Objectives: To examine during what behaviors people apply sunscreen and to assess the relationship to UV exposure monitored by personal dosimetry and diaries.

Design: Open prospective observational study.

Setting: University hospital.

Participants: A convenience sample of 340 Danish volunteers: children, adolescents, indoor workers, sun worshippers, golfers, and gardeners (age range, 4-68 years).

Intervention: Subjects recorded sunscreen use and sun-exposure behavior in diaries and carried personal, electronic UV dosimeters, measuring time-stamped UV doses continuously, during a median of 119 days covering 346 sun-years (1 sun-year equals 1 subject participating during 1 summer season).

Main Outcome Measures: Associations between sunscreen use and age, sex, skin type, occupation, sunburn, UV exposure doses, and behavior; and adequate application density and sun protection factor required to prevent sunburn.

Results: There were great variations in sunscreen use, which was highly correlated with risk behavior (sunbathing or exposing the upper body) \((r=0.39; P<.001)\). Sunscreens were used on a median of 5 days per sun-year (range, 1 day for gardeners to 16 days for sun worshippers). Ten percent of females and 41% of males never used sunscreens. Females used sunscreens more but also had more unprotected risk behavior than males (8 days vs 4 days; \(P<.001\)). Sunscreen use was not correlated with age, and children had as much unprotected risk behavior as adults. Sunscreens were used on 86% of the days with risk behavior in southern Europe vs 20% in northern Europe \((P<.001)\). The UV doses were significantly higher on days with sunscreen \((P\leq.03)\) and on sunburn days \((P<.001)\). The median sun protection factor was 10.5. The sun-protecting effect corresponded to an application density of 0.5 mg/cm².

Conclusion: Days with sunscreen correlated not with days without risk behavior, but with days “sunbathing with the intention to tan,” indicating that sunscreens were used as tanning aids to avoid sunburn.

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See also pages 950 and 1025

We have conducted a prospective investigation of sunscreen use during a summer half-year. Diary information about sunscreen use, sun-exposure behavior, and incidence of sunburn were collected and corresponding UV doses were recorded continuously by personal dosimetry dur-
ing all activities in the whole period.\textsuperscript{11,12} The aim of this study was to analyze the association between sunscreen use and age, sex, skin type, occupation, sunburn, UV exposure doses, and behavior. In addition, we intended to determine the adequate application density and sun protection factor (SPF) required to prevent sunburn.

**METHODS**

**STUDY POPULATION**

This study was performed in Denmark (latitude, 56° north; longitude, 12° east) during 3 summer seasons: June 16 to October 31, 1999; April 5 to September 30, 2000; and April 6 to August 31, 2001. A convenience sample of 340 volunteers from the Copenhagen area took part in the study, 14 of whom participated in all 3 seasons and 39 in 2 of the seasons, resulting in 407 sun-years (1 sun-year equals 1 subject participating during 1 summer season).\textsuperscript{11,12} All subjects were of Scandinavian ancestry and had no history of skin disorders; 153 were male and 187 were female (mean age, 30 years; age range, 4-68 years).

The subjects were chosen to cover a wide age span. In addition, groups with expected UV radiation exposure levels were included. The age-related subject groups were as follows: 97 children (age, 4-15 years) from kindergarten, primary, and secondary schools; 30 adolescents (age, 16-19 years) from high school; and 89 indoor workers (age, 21-64 years), consisting of students, hospital employees, and employees of a computer company. The high-exposure groups consisted of 53 sun worshippers (age, 21-63 years) recruited through a women’s magazine, 24 golfers (age, 27-68 years), and 47 municipal gardeners and rangers (age, 21-60 years).

The inclusion criteria for a sun-year were more than 30 days with both UV dosimeter readings and corresponding diary data, of which 21 days or more had to be in June, July, or August. These criteria resulted in 346 sun-years with a median of 119 days (interquartile range [IQR], 93-132 days) for analysis and the exclusion of 61 sun-years from subjects considered nonresponders. However, 43 of the nonresponders had either diary data or UV data enough for inclusion (10 had both but not on corresponding days). The 37 nonresponders with only diary data did not differ significantly from the responders in sun-exposure behavior such as days off, days abroad, risk behavior, and number of sunburns. Likewise, the 16 nonresponders with UV data did not differ significantly from responders in mean UV dose or exposure hours per day. The remaining 18 nonresponders (4% of the total of 407 sun-years) had neither sufficient diary nor UV data for inclusion. Thirty-seven (61%) of the nonresponders were younger than 20 years, which may explain the more carelessness handling of the UV dosimeters in that group. The distribution of skin types for 345 of the 346 sun-years were as follows: I, 23; II, 83; III, 180; and IV, 56.\textsuperscript{13} The participants gave their written informed consent. The Scientific Ethical Committees for Copenhagen and Frederiksberg approved the study (KF11-007/99), which was conducted according to Declaration of Helsinki principles.

**AMBIENT UV RADIATION EXPOSURE**

Solar UV radiation was measured with a UV meter (UV-Biometer model 501; Solar Light Co Inc, Glenside, Pa) on the roof of a 7-floor building at our hospital. The measurements are expressed in standard erythema doses (SEDs), where 1 SED=100 J/m² normalized to 298 nm, and using the International Commission on Illumination erythema action spectrum.\textsuperscript{14-16}

**PERSONAL ELECTRONIC UV DOSIMETER, SUNSAVER**

The dosimeters we used were developed and assembled in our department and include a sensor and a data logger. The dosimeter is mounted in a housing together with a digital watch. A silicon carbide photodiode (JECF1-IDE; Laser Components, Olching, Germany), which is sensitive only in the range of 200 to 400 nm, was chosen as the sensor. The sensor has a built-in diffuser and cosine response with spectral response similar to the International Commission on Illumination erythema action spectrum.\textsuperscript{13} The data logger controls the sensor, which was set to measure every eighth second and to store the average of the last 75 measurements every 10 minutes, together with the time. Measurement range of the dosimeter is 0.1 to 23 SEDs per hour. The dosimeter is battery driven and can run for 145 days without maintenance, and the data can be transferred to a personal computer. In an earlier study, members of our group collected reliable UV data from wrist measurements and found a significant correlation between wrist and head UV doses, with the wrist receiving 50% of the UV dose received by the head.\textsuperscript{17,18} The subjects were instructed to replace their normal wristwatch with the dosimeter, to wear it continuously between 7 AM and 7 PM, and not to immerse it in water but to place it on a towel with the sensor facing upward during swimming (the dosimeter is not waterproof).\textsuperscript{11}

**DIARY**

The participants (or the parents of the 22 children younger than 10 years) were carefully instructed in how to complete the provided diary. They were to answer yes or no to the following questions: (1) Did you wear the SunSaver dosimeter today? (2) Are you off work/school or on holiday today? (3) Are you abroad today? If yes, write country code. (4) Did you sunbathe today (sitting or lying in the sun with the upper body or shoulders exposed to get a tan)? (5) Have you exposed your shoulders or upper body outdoors today? (6) Have you been at the beach or at the sea today? (7) Have you applied a sunscreen today? If yes, write the factor number. (8) Did you get sunburned today? If yes: Red? Red and sore? Red, sore, and blistered? On a minimal, moderate, or extensive area?

We considered a yes response to question 4 or 5 to indicate “risk behavior,” since a great part of the body would be sun exposed.

**STATISTICAL ANALYSIS**

We included 39,068 days (74% of total) in our analysis with both UV dosimeter measurements and diary information, of which 39,952 days were with sunscreen applied. All calculations are based on sun-years and each of the 346 sun-years was weighted equally, independent of the number of days a subject participated per sun-year.\textsuperscript{11} We used nonparametric statistical tests because most of the data were not normally distributed. The results are therefore reported as median (IQR). The Mann-Whitney test was used to compare unpaired continuous data between groups, and the Spearman rank correlation was used to investigate interactions between 2 continuous measurements. Wilcoxon paired rank sum tests were performed on paired continuous data, and χ² tests were used to investigate associations between categorical data. In each
RESULTS

DISTRIBUTION OF SUBJECTS USING SUNSCREENS

Table 1 shows the great variations in sunscreen use within the subgroups. In 25% of sun-years, the participants never used sunscreen (range, 9% in the children to 45% in the gardeners). On the other end of the spectrum, 4 subjects applied sunscreen more than 75% of the time during their study participation. During risk behavior, in only 6% of the sun-years did subjects apply sunscreen on all days, while in 26% they did not apply sunscreen at all. Of the 316 sun-years when subjects were engaged in risk behavior, the 242 sun-years when subjects used sunscreen had twice as many days with risk behavior (median, 16 days [IQR, 9-27 days] vs 8 days [IQR, 4-18 days]) as the 74 sun-years without sunscreen use (P<.001). The subjects used a median SPF of 10.2 (IQR, 8-15).

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Sun-Years</th>
<th>% of Sun-Years by No. of Sunscreen Use Days</th>
<th>% of Sun-Years With 0% to 100% Sunscreen Use on Risk Behavior Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0  &gt;0-5 &gt;5-10  &gt;10-20 &gt;20</td>
<td>0  1-24 25-49 50-74 75-99 100</td>
</tr>
<tr>
<td>Total</td>
<td>346</td>
<td>25  27  19  16  13</td>
<td>26  20 16 19 13 6</td>
</tr>
<tr>
<td>Children</td>
<td>68</td>
<td>9   34  24  22  12</td>
<td>12  22 25 25 12 4</td>
</tr>
<tr>
<td>Adolescents</td>
<td>22</td>
<td>18  18  36  14  14</td>
<td>14  24 24 29 10 0</td>
</tr>
<tr>
<td>Indoor workers</td>
<td>111</td>
<td>24  29  23  17  7</td>
<td>25  20 16 20 10 9</td>
</tr>
<tr>
<td>Sun worshippers</td>
<td>49</td>
<td>14  14  14  22  35</td>
<td>16  16 10 18 31 8</td>
</tr>
<tr>
<td>Golfers</td>
<td>31</td>
<td>39  35  6  16  3</td>
<td>50  20 7 13 7 3</td>
</tr>
<tr>
<td>Gardeners</td>
<td>65</td>
<td>45  26  11  6  12</td>
<td>46  18 9 11 9 7</td>
</tr>
</tbody>
</table>

*One sun-year equals 1 subject participating during 1 summer season and having both UV dosimeter and diary readings for more than 30 days, of which at least 21 days are in June, July, or August.
†Risk behavior was defined as sunbathing or exposing the upper body or shoulders.

DISTRIBUTION OF DAYS WITH SUNSCREEN AND RISK BEHAVIOR

Table 2 illustrates the variation in days with sunscreen applied and the connection to risk behavior among the individuals and the subgroups. For all subjects considered together, sunscreen was applied on a median of 5 days (IQR, 1-13 days). The range was 1 day (IQR, 0-7 days) for gardeners to 16 days (IQR, 4-40 days) for sun worshippers. There was no correlation between number of days with sunscreen and number of days without risk behavior, but there was a significant correlation between number of days with sunscreen and number of days with risk behavior (P<.001; r=0.39). The correlation be-

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Participation Days</th>
<th>No. of Days With Risk Behavior</th>
<th>% of Participation Days With Sunscreen</th>
<th>% of Risk Behavior Days With Sunscreen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>119 (93-132)</td>
<td>13 (6-23)</td>
<td>4.1 (0.6-12.2)</td>
<td>30 (11-67)</td>
</tr>
<tr>
<td>Children</td>
<td>108 (73-124)</td>
<td>15 (8-24)</td>
<td>6.1 (1.9-14.2)</td>
<td>39 (11-67)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>115 (94-133)</td>
<td>19 (10-30)</td>
<td>6.9 (1.2-13.3)</td>
<td>37 (9-61)</td>
</tr>
<tr>
<td>Indoor workers</td>
<td>123 (107-130)</td>
<td>11 (6-18)</td>
<td>3.8 (0.6-9.8)</td>
<td>31 (1-67)</td>
</tr>
<tr>
<td>Sun worshippers</td>
<td>138 (96-151)</td>
<td>23 (13-35)</td>
<td>12.1 (2.5-30.8)</td>
<td>60 (11-88)</td>
</tr>
<tr>
<td>Golfers</td>
<td>105 (77-118)</td>
<td>12 (4-21)</td>
<td>2.7 (0.0-8.6)</td>
<td>4 (0-49)</td>
</tr>
<tr>
<td>Gardeners</td>
<td>121 (101-135)</td>
<td>8 (2-18)</td>
<td>0.8 (0.0-5.3)</td>
<td>9 (0-50)</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range (25%-75%).
*Children and golfers significantly fewer than indoor workers, sun worshippers, and gardeners (P<.001).
†Children and adolescents significantly more than indoor workers and gardeners (P=.045).
‡Children significantly higher than indoor workers (P = .02), golfers (P = .008), and gardeners (P=.001).
§Indoor workers significantly fewer than sun worshippers (P = .4).
‖Indoor workers significantly more than gardeners (P = .03).
¶Sun worshippers significantly more than all other groups (P=.007) except adolescents (P = .2).
††Sun worshippers significantly higher than all other groups (P=.04) except adolescents (P = .09).
‡‡Sun worshippers higher than indoor workers (P = .0), golfers (P<.001), and gardeners (P<.001).
§§Golfers and gardeners significantly lower than all other groups (P=.047).
‖‖Gardeners significantly lower than all other groups (P=.01) except golfers (P = .42).

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tween number of sunscreen days and number of days with exposed shoulders only was $r = 0.35$, while the correlation was stronger with number of days sunbathing with the intention to tan ($r = 0.42$). Adolescents and sun worshippers had the strongest correlations ($r = 0.57$ and $r = 0.53$, respectively) between sunscreen use and intention to tan, whereas there were no significant correlations among golfers and gardeners.

**UV DOSES AND SUNSCREEN USE RELATED TO RISK BEHAVIOR**

Table 3 shows that the median UV dose received per sunscreen day was more than doubled on days with risk behavior compared with days without ($P < .02$). For all subjects considered together, 23% (IQR, 1%-50%) of the median cumulative measured UV dose was received on days with sunscreen use, while 65% (IQR, 32%-84%) of the median cumulative UV dose during risk behavior was measured on days with sunscreen use.

**SUNSCREEN AND GENDER**

Female subjects never applied sunscreen during 18 (10%) of their sun-years compared with 67 (41%) of the males. In addition, during the sun-years when sunscreen actually was used, females applied sunscreen on significantly more days than the males did (10 days [IQR, 4-18 days] vs 6 days [IQR, 3-13 days]; $P = .002$). Of days with risk behavior, females applied sunscreen on a median of 41% of the days (IQR, 13%-67%), males on only 11% of the days (IQR, 0%-60%) ($P < .001$). Yet, females had more risk behavior days without sunscreen applied than did males (8 days [IQR, 3-17 days] vs 4 days [IQR, 1-10 days]; $P < .001$). However, no significant differences were found between males and females in the cumulative UV dose measured in the study period or UV dose per day with risk behavior.

**AGE AND SUNSCREEN USE**

There was no significant correlation between age and number of days with sunscreen either in the total group or in the group of children and adolescents.

**SUNSCREEN USE AND SKIN TYPE**

There were no differences in number of days with risk behavior and sunscreen use among the skin types. Only subjects with skin type IV differed from the others by having significantly more days with risk behavior, more days without sunscreen, higher UV dose per day, and higher UV dose per day with sunscreen than subjects with skin types I to III ($P < .02$). The UV dose received per day with sunscreen applied was significantly lower for skin type I ($P < .03$) and significantly higher for skin type IV ($P < .02$) than for skin types II and III. Subjects with skin types I and II applied sunscreen with a higher SPF (SPF, 14; IQR, 10-17) than those with skin types III and IV (SPF, 9; IQR, 7-13) ($P < .05$).

**SUNSCREEN USE IN NORTHERN AND SOUTHERN EUROPE**

Table 4 shows the results for 93 subjects engaging in risk behavior in both northern Europe (mainly Denmark) and southern Europe (Mediterranean area). On days with risk behavior, the subjects applied sunscreen significantly more often in southern than in northern Europe (median, 86% vs 20% of the days; $P < .001$). In both northern and southern Europe, the UV dose per risk behavior day with sunscreen was greater than (in some

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Table 3. UV Doses (Expressed as SEDs) and Sunscreen Use Related to Risk Behavior

<table>
<thead>
<tr>
<th>Variable</th>
<th>SEDs/d</th>
<th>SEDs/Sunscreen Day With Risk Behavior</th>
<th>SEDs/Sunscreen Day Without Risk Behavior</th>
<th>% of SEDs With Sunscreen on All Days</th>
<th>% of SEDs With Sunscreen on Risk Behavior Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1.0 (0.6-1.4)</td>
<td>4.8 (2.9-8.1)</td>
<td>1.9 (0.9-3.6)</td>
<td>23 (1-50)</td>
<td>65 (32-84)</td>
</tr>
<tr>
<td>Children</td>
<td>0.9 (0.7-1.4)</td>
<td>4.0 (3.0-5.6)</td>
<td>1.6 (0.6-3.2)</td>
<td>34 (15-57)</td>
<td>71 (35-85)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>1.0 (0.7-1.9)</td>
<td>8.2 (6.4-11.4)</td>
<td>1.9 (0.4-3.0)</td>
<td>48 (7-58)</td>
<td>69 (47-79)</td>
</tr>
<tr>
<td>Indoor workers</td>
<td>0.7 (0.5-1.0)</td>
<td>4.5 (2.8-6.9)</td>
<td>2.3 (0.9-3.8)</td>
<td>23 (1-47)</td>
<td>61 (36-81)</td>
</tr>
<tr>
<td>Sun worshippers</td>
<td>1.0 (0.7-1.7)</td>
<td>4.5 (2.9-7.0)</td>
<td>1.0 (0.8-2.4)</td>
<td>45 (17-79)</td>
<td>78 (50-94)</td>
</tr>
<tr>
<td>Golfers</td>
<td>1.2 (1.0-2.0)</td>
<td>5.6 (3.0-6.8)</td>
<td>4.5 (2.1-5.2)</td>
<td>9 (0-29)</td>
<td>51 (24-76)</td>
</tr>
<tr>
<td>Gardeners</td>
<td>1.3 (1.0-1.7)</td>
<td>4.3 (1.9-7.7)</td>
<td>1.9 (1.6-2.8)</td>
<td>2 (0-19)</td>
<td>32 (19-80)</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range (25%-75%); SEDs, standard erythema doses.

- $P = .001$.
- Gardeners significantly lower than children ($P = .03$) and sun worshippers ($P = .04$).
- Children significantly higher than gardeners ($P = .03$).
- Sun worshippers higher than indoor workers ($P = .03$), golfers ($P = .03$), and gardeners ($P = .005$).
- Golfers significantly higher than all other groups ($P < .001$).
- Indoor workers significantly lower than children ($P < .001$) and sun worshippers ($P < .02$).
- Children significantly lower than sun worshippers, golfers, and gardeners ($P < .049$).
- Sun worshippers significantly lower than indoor workers ($P = .03$), golfers ($P = .03$), and gardeners ($P = .001$).
- Indoor workers significantly lower than children ($P < .001$) and sun worshippers ($P < .02$).
- Indoor workers significantly lower than all other subgroups ($P < .007$).
- Children significantly higher than sun worshippers ($P = .03$).
- Children significantly lower than sun worshippers, golfers, and gardeners ($P < .049$).
- Sun worshippers significantly lower than children ($P = .03$) and sun worshippers ($P < .02$).
- Children significantly lower than sun worshippers, golfers, and gardeners ($P < .049$).
- Children significantly higher than gardeners ($P = .03$).
- Children significantly lower than sun worshippers ($P = .03$).
groups more than double) that of days without sunscreen, except for gardeners. Gardeners had another UV exposure pattern, where the UV dose per day was independent of sunscreen use. We found a significant correlation between numbers of days with sunscreen use in northern vs southern Europe (P < .01, r = 0.41). There was a small, but significant, difference in SPF used in southern vs northern Europe (median SPF, 11 [IQR, 8-16] vs 9 [IQR, 6-15]; P < .001).

UV DOSES IN RELATION TO SUNSCREEN USE AND SUNBURN

On days off with risk behavior, the UV doses were significantly higher per sunburn day than per nonsunburn day in both the total group and the subgroups (P < .001) except among golfers (P = .25). Table 5 shows that individual subjects had a significantly higher UV dose on days with sunscreen use than on days without use (P ≤ .03). Ultraviolet doses to the skin through sunscreen, calculated by reducing the UV dose received on the UV dosimeter by the SPF filter effect, were still significantly higher than on days without sunscreen use (as expected). Since the subjects had a median of only 1 sunburn, the number of persons was too small for a paired test of sunburn days with and without sunscreen.

One group used time-stamped UV dosimeters placed near volunteers on the ground to obtain data on UV doses, sunscreen use, and sunburns, but only on sunbathing days.10 We chose continuous, time-stamped, personal measurements of UV doses during all kinds of subject activities and supplemented these with diary information. This approach allows identification of the times and behaviors during which sunscreens are used. In our convenience sample, the proportion of subjects younger than 20 years equaled that in the Danish population overall, while adults engaging in outdoor work, outdoor sport, and sun worship were overrepresented. We thus selected an adult population sample that might have a higher UV exposure than the average Danish population. We have daily reports about sunscreen use and SPF but not about skin area covered or amount of sunscreen applied.

We found great variation within and among the subgroups in sunscreen use, which was highly correlated with risk behavior. Although sun worshippers applied sunscreen on 60% of the days with risk behavior, they still had a median of 7 days (IQR, 2-17 days) without sunscreen applied. The number of unprotected days with risk behavior was not significantly different among the groups except gardeners, who had a median of only 4 unprotected risk days (IQR, 1-12 days) even though they applied sunscreen on only 9% of the days with risk behavior. The fact that sun worshippers and adolescents used sunscreen on more days could give the false impression that they were better protected during UV exposure, but gardeners with less sunscreen use had fewer unprotected days with risk behavior and fewer sunburns. Sun worshippers and gardeners received about the same cu-

### Table 4. Comparison of Days and UV Doses (Expressed as SEDs) Among Participants Who Had Risk Behavior Days in Both Northern and Southern Europe

<table>
<thead>
<tr>
<th>Variable</th>
<th>No.</th>
<th>% of Risk Behavior Days With Sunscreen</th>
<th>SEDs per Risk Behavior Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Northern Europe</td>
<td>Southern Europe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without Sunscreen</td>
<td>With Sunscreen</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>20 (0-61)</td>
<td>86† (50-100)</td>
</tr>
<tr>
<td>Children</td>
<td>19</td>
<td>11 (0-36)</td>
<td>80‡ (57-100)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>7</td>
<td>16 (11-31)</td>
<td>94§ (80-100)</td>
</tr>
<tr>
<td>Indoor workers</td>
<td>29</td>
<td>17 (0-54)</td>
<td>78‡ (50-100)</td>
</tr>
<tr>
<td>Sun worshippers</td>
<td>22</td>
<td>62‡‡ (24-78)</td>
<td>100† (78-100)</td>
</tr>
<tr>
<td>Gardeners</td>
<td>8</td>
<td>20 (0-59)</td>
<td>36†* (0-81)</td>
</tr>
<tr>
<td>Golfers</td>
<td>8</td>
<td>0 (0-36)</td>
<td>64†† (4-100)</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range (25%-75%); SEDs, standard erythema doses. *Risk behavior was defined as sunbathing or exposing the upper body or shoulders. †Significantly higher than in northern Europe (P = .03). ‡Significantly higher than on days without sunscreen in northern Europe (P = .03). ‡‡Significantly higher than on days without sunscreen in southern Europe (total, P < .001; children, P = .03; and golfers, P = .04). ††Indoor workers significantly lower than adolescents (P = .02) and gardeners (P = .046). §Sun worshippers significantly higher than the other groups (P = .01) except golfers (P = .07). #Sun worshippers significantly lower than adolescents (P = .01) and indoor workers (P = .02). **Golfers significantly lower than children (P = .03), adolescents (P = .01), and sun worshippers (P = .001). ††Gardeners significantly higher than the other groups (P = .05) except adolescents (P = .10). ‡‡Gardeners significantly higher than children, sun worshippers, and golfers (P = .04).
mulative UV dose during a summer season (138 SEDs vs 150 SEDs), but their exposure patterns were different. Sun worshippers received a median of 63%, but gardeners only 13%, of their UV dose during risk behavior with most of their body exposed. Sun worshippers received 9%, but gardeners 51%, of their UV dose on working days, with a smaller part of their body exposed.11

More than half of the subjects had risk behavior on all of the days with sunscreen, indicating that people apply sunscreen only during risk behavior. In a previous study,11 our group found that high UV doses were correlated with risk behavior and, further, that people usually get small UV doses on days without risk behavior. This information makes the practice of using sunscreen only during risk behavior seem very sensible. Among golfers and gardeners, a median of 40% of the days with sunscreen were without risk behavior; however, since they get a greater part of their UV doses without risk behavior, it seems sensible for this group to use sunscreen during any period of exposure. Independent of risk behavior as a part of a daily routine, 4 subjects applied sunscreen on more than 75% of their participation days.

Opposite to what people expect,20 children did not use more sunscreen than adults and had as many unprotected days with risk behavior. Females used more sunscreen than males did but had more risk behavior without sunscreen and more sunburns.11,12 Sunscreen use was independent of skin type, but subjects with skin type I received a significantly lower UV dose and subjects with skin type IV a significantly higher UV dose on days with sunscreen than did subjects with skin type II or III.

In northern Europe, only 14% of adults, 16% of children, and no adolescents used sunscreen on 75% or more of days with risk behavior. This is in contrast to a recent Danish retrospective interview study in which 48% of subjects claimed that they “always or almost always” used sunscreens and that 77% applied sunscreens on their children during risk behavior.20 When it came to holidays in southern Europe, most of our subjects were aware of the importance of sunscreen protection, as a median of 59% of those 20 years or older and 65% of those younger than 20 years used sunscreen on 75% or more of the days with risk behavior. In the interview study, 71% claimed always or almost always to use sunscreen on themselves, and 83% on their children, during risk behavior in sunny countries.20 It seems that people have a tendency to overestimate their sunscreen use in retrospective studies, especially with regard to children, probably because sunscreen use is thought to demonstrate social responsibility and good parental care.

It has been suggested that the use of sunscreen encourages people to stay out longer in the sun. One group10,21 has measured the connection between UV dose, exposure hours, and sunscreen with SPF 30 vs SPF 10 during sunbathing in southern Europe, without finding any significant differences between the 2 SPF groups. We found that subjects had significantly more sun exposure hours (median, 5.7 hours vs 4.1 hours) and double the UV dose on days with risk behavior and sunscreen use compared with days without sunscreen use. However, the much more frequent use of sunscreen during risk behavior, especially in southern Europe, indicates that people know they will be exposed to high UV doses and thus apply sunscreen as a tanning aid to avoid sunburn. This viewpoint is strengthened by the fact that we found no correlation between sunscreen use and days without risk behavior but a significant correlation with days exposing the shoulder, and the strongest correlation with days spent sunbathing with the intention to tan. Yet, in a study among 808 Danish beachgoers, sunscreen use was not found to influence mean exposure time (203 minutes) at the beach.19 It seems, therefore, that things other than sunscreen protection determine the duration of sun exposure.

Table 5. UV Doses (Expressed as SEDs) in Relation to Sunscreen Use and Sunburn on Days Off With Risk Behavior

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median (IQR) Without Sunscreen</th>
<th>Median (IQR) With Sunscreen</th>
<th>Median (IQR) To the Skin Through Sunscreen*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2.3 (1.4-3.7)</td>
<td>4.7† (2.9-7.7)</td>
<td>2.6† (1.6-4.3)</td>
</tr>
<tr>
<td>Children</td>
<td>1.7 (1.1-2.8)</td>
<td>4.8† (3.0-8.8)</td>
<td>2.6† (1.6-4.2)</td>
</tr>
<tr>
<td>Adolescents</td>
<td>2.6 (1.3-5.8)</td>
<td>8.4† (4.5-11.8)</td>
<td>4.4† (2.5-6.6)</td>
</tr>
<tr>
<td>Indoor workers</td>
<td>2.3 (1.4-3.2)</td>
<td>4.3† (2.5-5.5)</td>
<td>2.3† (1.3-3.2)</td>
</tr>
<tr>
<td>Sun worshippers</td>
<td>2.6 (1.5-3.9)</td>
<td>4.5† (2.6-7.0)</td>
<td>2.4 (1.5-4.6)</td>
</tr>
<tr>
<td>Golfers</td>
<td>2.8 (2.3-4.1)</td>
<td>5.6† (3.5-7.7)</td>
<td>3.4 (1.8-5.2)</td>
</tr>
<tr>
<td>Gardeners</td>
<td>2.5 (1.4-5.3)</td>
<td>5.6† (2.7-7.5)</td>
<td>3.0 (1.5-4.4)</td>
</tr>
</tbody>
</table>

Abbreviations: IQR, interquartile range (25%-75%); SEDs, standard erythema doses.

*The UV dose (SED) to the skin through sunscreen = UV dose corrected for effect of sunscreen if 0.5 mg/cm2 were applied = UV dose divided by fourth root of the sunscreen sun protection factor.19

†Significantly higher than on days without sunscreen applied (P < .03).
‡Significantly higher than on days without sunscreen applied (P < .02).
§Significantly higher than on days without sunscreen applied (P = .047).
#There were no significant differences between UV doses obtained on sunburn days without sunscreen applied and nonsunburn days with sunscreen applied except for sun worshippers (P = .03).
Subjects in this study more often applied sunscreen on sunburn days, and sunburns occurred twice as often on “days off” with risk behavior and sunscreen use than without sunscreen use (9.5% vs 4.8%). This indicates that sunburn occurred when persons knew they were going to have prolonged sun exposure with risk behavior, but the sunscreen application had been either inadequate or sloppy.17-26 Obtaining the SPF declared on the bottle presupposes that a layer of 2 mg/cm² is applied.27 The SPF effect on the skin is not only halved but falls as the square root when 1 mg/cm² is applied, and by the fourth root if only 0.5 mg/cm² is applied.23 Several studies have shown that people usually apply only 0.5 mg/cm², which implies that a declared SPF of 8, 16, or 32 yields an effective SPF on the skin of only 1.7, 2.0, or 2.8, respectively.21,22,24,28,29 We found that on days off with risk behavior and with sunscreen applied, the median UV dose on sunburn days was 7.9 SEDs compared with 2.3 SEDs on nonsunburn days without sunscreen. Calculation of the fourth root of the median declared SPF of 10.5 gives an effective SPF of 1.8 on the skin. Using the effective SPF on the skin for each individually declared SPF, we calculated the UV dose to the skin through sunscreen to be a median of 4.3 SEDs on sunburn days vs 2.6 SEDs on nonsunburn days (Table 5). Equal SEDs to the skin through sunscreen can thus be obtained with an effective SPF of less than 4.3/2.6 = 1.7. This would be sufficient to transfer the sub-jects from the sunburned to the nonsunburned group. Yet, sunscreen users who are exposed to high UV doses may need an effective SPF of at least 7.9/2.6 or 3.0. An effective SPF of 2 on the skin should be sufficient to prevent sunburn in an average person during an average day with risk behavior. This could be achieved by using a sunscreen with a declared SPF of 16 in a layer of 0.5 mg/cm². For very sun-sensitive persons or during long-lasting exposure to high UV doses, a sufficient cover could still be achieved by applying SPF 16 sunscreen in a layer of 1 or 2 mg/cm².30 It is not possible to completely compensate for too thin a sunscreen layer by simply increasing the SPF, highlighting the importance of adequate application density.31 Finally, these calculations consider only the minimum sunscreen use required to prevent sunburn, and more protection may be desirable during long outdoor activities or exposure to very high UV doses.

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