UV radiation (UVR) exposure is the primary environmental risk factor for developing cutaneous malignant melanoma (CMM).

OBJECTIVE
To measure changes in sun behavior from the first until the third summer after the diagnosis of CMM using matched controls as a reference.

DESIGN, SETTING, AND PARTICIPANTS
Three-year follow-up, observational, case-control study performed from May 7 to September 22, 2009, April 17 to September 15, 2010, and May 6 to July 31, 2011, at a university hospital in Denmark of 21 patients with CMM and 21 controls matched to patients by sex, age, occupation, and constitutive skin type participated in the study. Exposure to UVR was assessed the first and second summers (n = 20) and the first and third summers (n = 22) after diagnosis. Data from 40 participants were analyzed.

MAIN OUTCOMES AND MEASURES
Exposure to UVR was assessed by personal electronic UVR dosimeters that measured time-related UVR in standard erythema dose (SED) and corresponding sun diaries (mean, 74 days per participant each participation year).

RESULTS
Patients’ daily UVR dose and UVR dose in connection with various behaviors increased during follow-up (quantified as an increase in daily UVR dose each year; all days: mean, 0.3 SED; 95% CI, 0.05-0.5 SED; days with body exposure: mean, 0.6 SED; 95% CI, 0.07-1.2 SED; holidays: mean, 1.2 SED; 95% CI, 0.3-2.1 SED; days abroad: 1.9 SED; 95% CI, 0.4-3.4 SED; and holidays with body exposure: mean, 2.3 SED; 95% CI, 1.1-3.4 SED). After the second year of follow-up, patients’ UVR dose was higher than that of controls, who maintained a stable UVR dose. No difference was found between groups in the number of days with body exposure or the number of days using sunscreen in the second and third years of follow-up.

CONCLUSIONS AND RELEVANCE
Our findings suggest that patients with CMM do not maintain a cautious sun behavior in connection with an increase in UVR exposure, especially on days with body exposure, when abroad, and on holidays.
doses and completed corresponding sun diaries that provided information about sun behavior, sunburn, and use of sun protection measures. Our objective was to measure changes in sun behavior from the first until the third summer after CMM diagnosis using matched controls as a reference.

Methods

Study Design
This is a prospective, observational, case-control study performed from May 7 to September 22, 2009, April 17 to September 15, 2010, and May 6 to July 31, 2011. All participants lived within 100 km of Bispebjerg Hospital, Copenhagen, Denmark. The study was approved by the Committees for Biomedical Research Ethics for the Capital Region in Denmark (H-C-2008-097), and requirements from the Declaration of Helsinki protocols were met. Participants gave written informed consent. In the present study, we used a group of patients with CMM and matched controls; in 2009 or 2010, all had participated in a previous study of sun behavior the first summer after CMM diagnosis.9 We invited the same patients and 1 matched control per patient to participate in a follow-up study in 2011 to investigate sun behavior the second and third summers after diagnosis.

Patients With CMM
Twenty-four patients completed the investigations in 2009 and 2010.9 Twenty patients had superficial spreading malignant melanoma and 4 patients had melanoma in situ. Twenty-three of these patients were invited to participate in the follow-up study in 2011. One patient could not be contacted. Twenty-one patients accepted the invitation. Patients did not receive any medical therapy for CMM during the study.

Controls
Controls were recruited from the Danish Central Population Registry and among employees at the hospital. One control was a friend of a patient, and 3 controls were friends of the authors. Controls matched the patients recently diagnosed as having CMM by sex, age (±8 years), constitutive skin type measured on the UVR-shielded buttocks, and occupation at the start of the study in 2009 and 2010 (mainly indoor work, mainly outdoor work, retired or unemployed, or on leave [eg, maternity leave]), with the exception of 1 patient working indoors, who had a matched control who was on maternity leave during most of the study period. Fifty-one controls completed the investigations in 2009 and 2010.9 Twenty-two of these controls were invited to participate in a follow-up study in 2011. Twenty patients had superficial spreading malignant melanoma and 4 patients had melanoma in situ. Twenty-one controls accepted the invitation.

Exclusion Criteria
Exclusion criteria for all participants were a history of polyomorphous light eruption, solar urticaria, and other UVR-related skin diseases; physical disability that required mobility aid; organ transplantations; and any cancer except CMM for patients and any cancer for controls.

Personal Electronic UVR Dosimeter
The personal electronic UVR dosimeters (SunSaver) measure time-stamped UVR doses in standard erythema dose (SED) every fifth second and store a mean of the measurements every 5 minutes. The dosimeter is mounted in a housing that also contains a digital watch so that it can be used as a wristwatch.15 The dosimeter and its calibration have previously been described in detail by our study group.9 The participants were instructed to wear the dosimeter on their wrist when they were outdoors at least between 7 AM and 7 PM.

Sun Exposure Diary
In a sun exposure diary, the participants were asked to answer “yes” or “no” to the following questions: (1) Did you wear the SunSaver today? (2) Were you off work/school or on holiday today? (3) Are you abroad today? If yes, write the country code; (4) Did you sunbathe today? (sitting or lying in the sun with upper body or shoulders exposed to get a tan); (5) Have you used a solarium today? (6) Have you exposed your shoulders or upper body outdoors today? (eg, while working or playing in the garden); (7) Have you applied a sunscreen today? If yes, write factor number and tick which areas you applied sunscreen to: head, arms, legs, trunk, shoulders/back; (8) Did you get red from the sun today? For further analysis, body exposure was defined as sunbathing, exposing the shoulders or upper body outdoors, or using a solarium.

Data Analyzed
Only data from May, June, and July in each of the years 2009, 2010, and 2011 were analyzed to obtain a comparable study period in each year. Only data from patients and controls participating in the follow-up study in 2011 were analyzed. One patient, who participated in 2009 and 2011, was excluded because of poor adherence in 2011. The matched control was also excluded, as well as data from their first participation year (2009). The UVR dosimeter measurements and sun diary data were analyzed from 40 (95%) of 42 participants. Each participant had dosimeter measurements and corresponding diary data for more than 35 days and at least 20 days in June or July of each participation year. If a participant had body exposure according to the diary but the UVR dosimeter read 0 SED, we considered this an error in filling in the diary. This error resulted in 14 days being eliminated (0.2% of total days analyzed). A total of 5912 days were analyzed.

Skin Type and Pigment Protection Factor
We measured skin type objectively as pigment protection factor (PPF) using reflectance spectroscopy (model 555, Optimize Scientific; Chromo-light) that quantifies melanin by diffuse reflectance measurements.16 The PPF equals the predicted number of SED that elicits just perceptible erythema (minimal erythema dose) and measures in the range of 1 to 25.17-19 Constitutive skin pigmentation (PPF on UVR-shielded buttocks) was allowed to vary no more than ±1.5 between a patient and matching control. We also registered self-reported skin type according to the Fitzpatrick classification scale.
**Statistical Analysis**

To analyze whether patients and controls changed their UVR exposure during the years of follow-up, we performed generalized estimating equations, considering the repeated measurements. Variables from the sun exposure diaries and UVR dosimeters were set as the dependent variable and year of follow-up (from the first to the third participation year) as the explanatory variable. This was done separately in patients and controls. To analyze whether associations between UVR exposure and year of follow-up in patients were significantly different from those of controls, we added an interaction term between CMM (yes/no) and year of follow-up to the model.

We used the Wilcoxon matched-pairs signed rank sum test to analyze possible differences between patients and matched controls in age and constitutive PPF, as well as differences in UVR exposure behavior (data from the UVR dosimeters and sun exposure diaries), in each of the 3 years of follow-up (Bonferroni-Holm adjusted P values). The χ² and Fisher exact tests were used to analyze differences between patients and controls in Fitzpatrick skin type. The statistical significance limit was P < .05.

We used SPSS statistical software, version 19.0 for Windows (SPSS Inc), for data analysis. Data are presented as mean (SD).

**Results**

We found no statistically significant difference between patients and controls in baseline characteristics (Table 1).

**Associations Between UVR Exposure and Year of Follow-up in Patients and Controls**

The number of days with dosimeter measurements and sun exposure diary information (at work, off work, on holiday, abroad, and with body exposure) (see the eTable in the Supplement) was not related to the year of follow-up among controls or patients, neither was the daily UVR dose received by controls during these behaviors (Table 2). The mean sun protection factor number as well as the number of days using sunscreen, with sunburn, with body exposure without using sunscreen (see eTable in the Supplement), and the number of days with sunscreen on head, arms, legs, trunk, and shoulders or back was unrelated to year of follow-up (data not shown for both). This applied to both patients and controls.

Patients’ daily UVR dose increased 25% from the first to the second summer (group 1) and 33% from the first to the third summer after diagnosis (group 2) (Table 2); the estimated increase

**Table 1. Baseline Characteristics of the Study Participants at the Start of the Study**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients (n=20)</th>
<th>Controls* (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men/women, No. (%)</td>
<td>7 (35)/13 (65)</td>
<td>7 (35)/13 (65)</td>
</tr>
<tr>
<td>Age at study entry, mean (SD), y</td>
<td>43 (13)</td>
<td>43 (13)</td>
</tr>
<tr>
<td>Fitzpatrick skin type, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>6 (30)</td>
<td>2 (10)</td>
</tr>
<tr>
<td>II</td>
<td>6 (30)</td>
<td>8 (40)</td>
</tr>
<tr>
<td>III</td>
<td>8 (40)</td>
<td>7 (35)</td>
</tr>
<tr>
<td>IV</td>
<td>0 (0)</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Constitutive PPF, mean (SD)</td>
<td>4.8 (1.2)</td>
<td>4.6 (0.9)</td>
</tr>
<tr>
<td>Living in a home with a garden, No. (%)</td>
<td>6 (30)</td>
<td>6 (30)</td>
</tr>
</tbody>
</table>

Abbreviation: PPF, pigment protection factor.

* Controls matched the patients by sex, age, constitutive skin type measured on the UVR-shielded buttocks, and occupation at the start of the study.

**Table 2. Measured UV Radiation Doses in SED at Various Points of Time and Situations**

<table>
<thead>
<tr>
<th>Variable</th>
<th>SED per Day, Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1 First Summer After Diagnosis (2010)</td>
</tr>
<tr>
<td>On days analyzed</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>0.8 (0.3)</td>
</tr>
<tr>
<td>Controls</td>
<td>1.4 (0.7)</td>
</tr>
<tr>
<td>On workdays</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>0.5 (0.4)</td>
</tr>
<tr>
<td>Controls</td>
<td>0.7(0.5)</td>
</tr>
<tr>
<td>On days off work</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>0.9 (0.6)</td>
</tr>
<tr>
<td>Controls</td>
<td>1.5 (0.8)</td>
</tr>
<tr>
<td>On holidaysa</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>1.4 (0.5)</td>
</tr>
<tr>
<td>Controls</td>
<td>2.7 (1.6)</td>
</tr>
<tr>
<td>On days abroad</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>1.2 (0.7)</td>
</tr>
<tr>
<td>Controls</td>
<td>3.5 (5.0)</td>
</tr>
<tr>
<td>On days with body exposurea</td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>2.1 (1.4)</td>
</tr>
<tr>
<td>Controls</td>
<td>3.4 (1.3)</td>
</tr>
</tbody>
</table>

Abbreviation: SED, standard erythema dose.

a Groups 1 and 2 each comprised 10 patients and 10 matched controls.
b Away from home during a holiday.

c Sunbathing, exposing the shoulders or upper body outdoors, or using a solarium.
A mated increase was 1.2 SED each year analyzing groups 1 and 3; the estimated increase was 0.6 SED each year analyzing groups 1 and 2 together (95% CI, 0.3-2.1 SED; \( P = .009 \)) (Figure 2 and Table 3). In addition, patients’ daily UVR dose on days abroad increased 100% from the first to the second summer (group 1) and 64% from the first to the third summer after diagnosis (group 2) (Table 2); the estimated increase was 1.9 SED each year analyzing groups 1 and 2 together (95% CI, 0.4-3.4 SED; \( P = .02 \)) (Figure 2 and Table 3). Finally, patients’ daily UVR dose on holidays with body exposure increased 83% from the first to the second summer (group 1) and by more than 300% from the first to the third summer after diagnosis (group 2) (data not shown); the estimated increase was 2.3 SED each year analyzing groups 1 and 2 together (95% CI, 1.1-3.4 SED; \( P < .001 \)) (Table 3). Patients’ daily UVR dose on workdays and days off work were unrelated to the year of follow-up.

### Differences in UVR Exposure Between Patients and Controls

Looking at all days, patients’ daily UVR dose increased during the follow-up period to a level that was above that of controls after the second year of follow-up, whereas controls maintained a stable UVR dose; the slopes of the regression lines were significantly different between patients and controls (estimated difference, 0.3; 95% CI, 0.01-0.6; \( P = .04 \)) (Figure 1). The same observation applied to the daily UVR dose on holidays (estimated difference, 1.3; 95% CI, 0.4-2.3; \( P = .008 \)) and on days abroad (estimated difference, 2.1; 95% CI, 0.3-3.9; \( P = .02 \)); both increased to a level above that of controls just after the first year of follow-up (Figure 2).

However, the only statistically significant differences between patients and controls in UVR exposure behavior, looking separately at the 3 years of follow-up, were that patients had fewer days with body exposure without using sunscreen (median, 1 vs 4; \( P = .003 \)) and more days applying sunscreen on the upper extremities (median, 9.5 vs 0; \( P = .01 \)) compared with controls in the first year of follow-up.

### Abbreviations

- SED, standard erythema dose
- UVR, UV radiation

### Table 3. Results of the Generalized Estimating Equations on the Associations Between UVR Exposure (Assessed by Sun Exposure Diaries and UVR Dosimeters) and Year of Follow-up for the Patient Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Increase in Daily UVR SED Each Year (95% CI)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>On all days</td>
<td>0.3 (0.05-0.5)</td>
<td>( .02 )</td>
</tr>
<tr>
<td>On holidays\textsuperscript{a}</td>
<td>1.2 (0.3-2.1)</td>
<td>( .009 )</td>
</tr>
<tr>
<td>On days abroad</td>
<td>1.9 (0.4-3.4)</td>
<td>( .02 )</td>
</tr>
<tr>
<td>On days with body exposure\textsuperscript{c}</td>
<td>0.6 (0.07-1.2)</td>
<td>( .03 )</td>
</tr>
<tr>
<td>On holidays with body exposure</td>
<td>2.3 (1.1-3.4)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: SED, standard erythema dose; UVR, UV radiation.

\textsuperscript{a} Variables from the sun exposure diaries and UVR dosimeters were set as the dependent variable and year of follow-up (from the first to the third participation year) as the explanatory variable. This was done separately in each of the 2 groups (patients and controls). Only relations found to be statistically significant are shown. Sun exposure diary data were unrelated to year of follow-up among patients or controls; neither were measured UVR doses among controls.

\textsuperscript{b} Away from home during a holiday.

\textsuperscript{c} Sunbathing, exposing the shoulders or upper body outdoors, or using a solarium.
Discussion

In a prospective, observational, case-control study, we used personal electronic UVR dosimeters and sun diaries to study sun behavior in patients with CMM. We found that patients increased their daily UVR dose on all days and their daily UVR dose on days with body exposure, on holidays, on holidays with body exposure, and on days abroad from the first to the third summer after diagnosis. This increase, except on days with body exposure, was significantly different from that of controls who were exposed to almost identical UVR doses during the follow-up period.

The primary strength of the study was the prospective design that allowed us to study changes in sun behavior within the same study population. We used controls matched to patients in age, sex, occupation, and constitutive skin type, which ensured that our findings were not affected by differences in these characteristics between patients and controls. The long observation period (mean, 74 days per participant) minimized the risk of participants’ sun behavior being affected by their participation in a study. We used objective methods—UVR dosimetry and sun diaries in which sun behavior was registered daily. Lastly, data from 95% of the participants were analyzed because of high adherence.

The primary limitation of our study was its rather small sample size, although this was partly compensated by the prospective design and long observation period. In addition, the quality of the data depended on the participants remembering to answer the questions in the diary every day and to wear the dosimeter. The diaries were scrutinized for errors after collection at the end of each participation month, and participants were contacted immediately to correct any possible mistakes. Furthermore, we went out to the participants at home or at work with a laptop once or twice during the study period to check the function of the dosimeter and show the participants their individual UVR dose curve to emphasize the importance of wearing the dosimeter. Lastly, we used the participants’ mean number of days and mean UVR doses on days in certain behaviors to assess the relationship to year of follow-up; participants therefore contributed with various numbers of days to the analyses.

Regarding sun protection, data from the sun exposure diaries revealed that the number of days with body exposure, using sunscreen, and with body exposure without using sunscreen was unrelated to time since diagnosis among patients. This corresponds with a questionnaire study by Mujumdar et al., who found that sun protection was stable among patients diagnosed as having CMM between 12 months and 6 years earlier. Only during the first summer after diagnosis did patients have fewer days with body exposure without using sunscreen and applied sunscreen on the upper extremities more often compared with matched controls. The number of days with body exposure was not significantly different between patients and controls in any of the 3 years of follow-up, indicating that patients over time do not protect themselves more while in the sun compared with controls.

A questionnaire survey from the Danish Cancer Society found that 42% of Danes were sunburned (red from the sun) during the summer of 2011. We found that 50% of controls and 60% of patients were sunburned at least once during the study period (mean in summer 2011, 74 days) (data not shown). The difference between the general population and controls in the present study may be explained by the use of daily records in our study, minimizing the errors of recall bias. The percentage of both controls and patients being sunburned is noteworthy because it has been found that the frequency of sunburn (also in adulthood) increases risk of CMM.

Patients’ daily UVR dose increased during the follow-up period in connection with an increase on days with body exposure during follow-up while on holidays (P = .009) (A) and on days abroad (P = .02) (B). The difference in the slopes of the regression lines between patients and controls was 1.3 (P = .008) while on holiday and 2.1 (P = .02) on days abroad.

Figure 2. Patients’ Daily UV Radiation Dose While on Holidays and on Days Abroad

Compared with controls, patients increased their daily standard erythema dose (SED) during follow-up while on holidays (P = .009) (A) and on days abroad (P = .02) (B). The difference in the slopes of the regression lines between patients and controls was 1.3 (P = .008) while on holiday and 2.1 (P = .02) on days abroad.
exposure, on holidays, and on days abroad. This development was different from that of controls, who maintained a stable UVR dose during the follow-up period. Moreover, patients spent 260 days abroad in total during the study period (mean, 7 days per person), whereas controls only spent 125 days abroad (mean, 3 days per person). Patients spent 137 of these days (52%) outside Northern Europe (Southern and Eastern Europe, Africa, Asia, and North and South America), whereas controls only spent 58 days (46%) outside Northern Europe. This is disturbing because CMM in general is believed to be caused by high intermittent UVR doses\(^1,2\) — a UVR exposure pattern that is associated with body exposure and holidays spent in sunny countries\(^3,23\) — and because risk of CMM among Danes is associated with vacations spent in sunny countries\(^2,4\)

In conclusion, data from the present study indicate that from the first until the third summer after diagnosis of CMM, patients increase their daily UVR dose in connection with an increase on days with body exposure, holidays, and days abroad, whereas controls maintain a stable UVR exposure dose. Over time, patients have unprotected body exposure to the same extent as controls, indicating that patients with CMM do not maintain the cautious sun behavior they exhibit just after CMM diagnosis.

**REFERENCES**