Minireview

Tanning Beds, Sunlamps, and Risk of Cutaneous Malignant Melanoma

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Abstract

Background: A number of studies have been conducted evaluating the risk of cutaneous malignant melanoma after exposure to sunlamps and/or sunbeds. The proportion of subjects in the individual studies who have reported exposure has, in general, been modest, and the resulting risk estimates for melanoma have been unstable with wide 95% confidence intervals (95% CI). The inconclusive results seen in individual studies have resulted in confusion as to the carcinogenicity of these devices.

Methods: We conducted a systematic review and meta-analysis of these studies. A review of the literature from Jan 1, 1984 to April 2004 using MEDLINE identified 12 case-control studies and 1 cohort study which quantitatively evaluated the use of sunlamps and/or sunbeds and subsequent melanoma. After applying exclusion/inclusion criteria, 9 case-control and 1 cohort study provided data for the analysis. Summary odds ratios (OR) and 95% CIs for sunlamp/sunbed use and subsequent melanoma were calculated using a random-effect model.

Results: Ten studies provided data for assessment of melanoma risk among subjects who reported “ever” being exposed compared with those “never” exposed. A positive association was found between exposure and risk (summary OR, 1.25; 95% CI, 1.05-1.49). Significant heterogeneity between studies was present. Evaluation of the metrics “first exposure as a young adult” (5 studies) and “longest duration or highest frequency of exposure” (6 studies) also yielded significantly elevated risk estimates (summary OR, 1.69; 95% CI, 1.32-2.18, and 1.61; 95% CI, 1.21-2.12, respectively, with no heterogeneity in either analysis).

Conclusions: Results indicate a significantly increased risk of cutaneous melanoma subsequent to sunbed/sunlamp exposure. (Cancer Epidemiol Biomarkers Prev 2005;14(3): 562–6)

Introduction

There is good experimental and epidemiologic evidence that UV radiation exposure (mainly from sunlight) is causally related to all forms of human skin cancer including cutaneous malignant melanoma (1). Melanoma incidence has most strongly and consistently been associated with reported “intermittent sun exposure” mostly accrued through recreational activities. A quantitative review of studies of sun exposure and melanoma found a positive association between intermittent exposure and risk of cutaneous malignant melanoma in 21 (statistically significant in 16) of 23 studies included in the analysis (2).

Because of its nature, exposure to artificial UV radiation through sunlamp and sunbed use is intermittent in character, there has been consistent concern over the past 15 years that use of such devices for recreational tanning may increase risk of melanoma (3). In addition, data from surveys conducted in Europe (4, 5) and North America (6) indicate that sunbeds are now being used by an increasing proportion of the population, particularly young people.

A series of epidemiologic investigations have attempted to determine the nature of this putative association. However, analysis of sunlamp/sunbed use has been hampered by small numbers of exposed subjects in individual studies. In order to evaluate the strength and consistency of association between use of these devices and melanoma, we have conducted a systematic review and meta-analysis.

Materials and Methods

To identify relevant studies of sunbeds/sunlamps and melanoma, we conducted a MEDLINE database search for the years 1984 to 2004, using the terms “melanoma (etiology, epidemiology) and sunbeds, sunlamps, and solarium” as keywords. We also selected all review articles in English on UV radiation, tanning devices, solaria, and melanoma, and scrutinized these to locate articles with data on sunlamp and sunbed use missed by the MEDLINE search. We did not attempt to locate unpublished data. We chose 1984 as the year of start of our search as that year saw the first publications from large-scale epidemiologic studies of melanoma and UV exposure with good control for phenotype confounders. The search yielded a total of 12 case-control studies reporting risk estimates for melanoma subsequent to sunbed/sunlamp use (7-18). In addition, one cohort study was found which reported on usage among Norwegian and Swedish women (19).

Selection of Studies. All case-control studies of cutaneous malignant melanoma that reported on use of sunlamps, sunbeds, or both were initially considered for the analysis. For inclusion, we required that numbers (or percentages) of exposed cases and controls were presented in the study, and odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated using a random-effect model. Ten studies provided data for assessment of melanoma risk among subjects who reported “ever” being exposed compared with those “never” exposed. A positive association was found between exposure and risk (summary OR, 1.25; 95% CI, 1.05-1.49). Significant heterogeneity between studies was present. Evaluation of the metrics “first exposure as a young adult” (5 studies) and “longest duration or highest frequency of exposure” (6 studies) also yielded significantly elevated risk estimates (summary OR, 1.69; 95% CI, 1.32-2.18, and 1.61; 95% CI, 1.21-2.12, respectively, with no heterogeneity in either analysis).

Conclusions: Results indicate a significantly increased risk of cutaneous melanoma subsequent to sunbed/sunlamp exposure. (Cancer Epidemiol Biomarkers Prev 2005;14(3): 562–6)
available, evaluating at least “ever” versus “never” use of these devices. Because of these requirements, two earlier studies were omitted; one due to missing CIs (7) and the other due to missing data on numbers of exposed cases and controls (8). A study by MacKie et al. (10) was also omitted because it was not possible from the information presented to determine accurately the proportions or numbers of cases and controls exposed. All other studies were included in the analysis.

In order to attempt to make the analysis reflect, as far as possible, recreational rather than medical use of sunlamps/sunbeds, we did not include studies of psoralen and UVA radiation therapy [e.g., that of Stern et al. (20)]. Where studies provided separate estimates of risk for medical and nonmedical use, the estimates for nonmedical use were used. Where separate estimates were not given, the overall ORs and CIs were used. Whenever possible, ORs adjusted for phenotype factors (hair, skin, eye color, prototype, number of nevi, etc.) and sun exposure were used in preference to crude or unadjusted values. The studies of Swerdlow et al. (13) and Osterlind et al. (9) present risk estimates as crude ORs unadjusted for phenotype factors. Swerdlow\(^5\) indicated the “ever versus never exposed” value was adjusted only for age, sex, and region of residence. In the case of the study by Walter et al. (14), risk estimates were calculated as crude and adjusted ORs, and because the two analyses gave “essentially the same effect” (p.236), the authors presented the unadjusted values. Thus, the Walter estimates can be expected to closely approximate adjusted values.

A number of the studies presented data which allowed us to evaluate whether initial exposure to sunbeds/sunlamps occurring earlier in life “as a young adult” conferred a different risk than if exposure began closer to the time of the study. A total of five studies contributed to this analysis and, with the exception of the study of Walter et al. (14), the estimates used were the adjusted values.

Finally, a number of studies attempted to determine whether a dose-response gradient with exposure was seen. We produced summary ORs comparing melanoma risk between subjects with the longest duration or highest frequency of exposure and subjects never exposed. Six studies provided data for this analysis.

Two of the authors (R.P.G. and T.K.L.) examined each of the studies independently to determine which risk estimate was the best indicator of “first exposure as a young adult” and which was the best for “longest duration or highest frequency of use,” and after a discussion concerning one study, agreed on the measures considered to be most appropriate.

Recalculation of summary ORs using values for total sunbed/sunlamp usage rather than use for tanning purposes might provide a more powerful approach to summarizing data on melanoma and sunlamp/sunbed use. However, because the studies had different overall aims, different metrics were used to record duration and/or frequency of sunlamp/sunbed use. With the exception of Westerdahl et al. (17), no study collected all the information (years of use, frequency of exposure per year, and duration of each exposure) needed to conduct a full quantitative assessment of the association. This made pooling of raw data infeasible.

Results

A total of 10 published articles (with 12 ORs) were used in assessing the relationship between ever versus never use of sunlamp/sunbed and melanoma (Table 1). The summary OR showed a modest elevated risk (OR, 1.25; 95% CI, 1.03-1.49). Positive associations were seen in 8 of 10 individual studies, although only 4 risk estimates were statistically significant. One of the studies (9) showed an inverse association. There was significant heterogeneity ($Q = 28.9; P = 0.0024$) likely due to the studies being conducted over a long period of time with different designs. Also, one study (9) showed results markedly different from the others. Recalculation excluding the Osterlind study substantially reduced but did not eliminate the heterogeneity, and had only a slight effect on the summary OR. Excluding both the Osterlind study and the Swerdlow study (not adjusted for phenotype factors) again had essentially no effect (OR, 1.24; 95% CI, 1.09-1.41). The cohort study of Vieiro et al. (19) used “never/rarely” as the index in assessing exposure. We included this measure in the analysis as combining these two groups as the index should give a conservative estimate of risk among users. Excluding the Vieiro et al. study made little difference to the summary OR (OR, 1.21; 95% CI, 1.02-1.44).

Five studies contributed data to the analysis of first exposure as a young adult (Table 2) which showed a positive association with subsequent melanoma (OR, 1.69; 95% CI, 1.32-2.18). Confidence intervals for this analysis were wider than those seen for the previous metric because the estimates contributing to the summary ORs were based on relatively small numbers of subjects. All five of the individual studies showed a positive association although only two were statistically significant. This group of estimates showed no evidence of heterogeneity ($Q = 3.81; P = 0.58$). Recalculation excluding the Swerdlow study (no control for phenotype factors) had only a slight effect on the summary measure (OR, 1.65; 95% CI, 1.28-2.13).

Data from six studies were entered into the analysis of longest duration or highest frequency of use (Table 3). A higher point estimate of risk was seen in this analysis (OR, 1.61; 95% CI, 1.21-2.12) than in the ever versus never analysis, although the CIs for the two estimates overlapped slightly. All six individual study estimates showed a positive association with melanoma. Again, this group of estimates showed no evidence of heterogeneity ($Q = 5.90; P = 0.55$), and recalculation excluding the Swerdlow study (no control for phenotype factors) had virtually no effect on the summary OR (OR, 1.57; 95% CI, 1.19-2.09).

Discussion

This meta-analysis is subject to a number of limitations. The estimates of risk for melanoma subsequent to using sunlamps/sunbeds are based on published data in a series of 10 articles over a period of 20 years. A pooled analysis of original observations taken in the 10 studies would have provided a more powerful approach to summarizing data on melanoma and sunlamp/sunbed use. However, because the studies had different overall aims, different metrics were used to record duration and/or frequency of sunlamp/sunbed use. With the exception of Westerdahl et al. (17), no study collected all the information (years of use, frequency of exposure per year, and duration of each exposure) needed to conduct a full quantitative assessment of the association. This made pooling of raw data infeasible.

Results of the analysis are, of course, dependent on the choice of measures selected from each study. The overall measure, ever versus never use, is fairly clear-cut, with the caveat that we selected wherever possible the risk estimate and CIs noted “for tanning purposes” rather than total use. Recalculation of summary ORs using values for total sunlamp/sunbed usage rather than use for tanning purposes indicated that our decision did not affect the conclusions reached. The measures used to assess first exposure as a young adult were subject to more judgment. The case-control studies defined a young adult in different ways, with first exposure ages ranging from “less than 25” to “less than 39 years.” For the women’s prospective cohort study (19), we

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\(^5\) Personal communication (April 30, 2004).
defined first exposure as a young adult to be women who used sunbeds for the first time at ages 10 to 19. As this cohort was comprised of women who were recruited in 1991 to 1992 at ages 30 to 50, early exposure would have occurred before 1980.

The longest duration or highest frequency of use analysis combined what we considered to be the best measure of cumulative sunbed/sunlamp exposure available within each study. The intention of this analysis was to compare risk estimates in subjects with maximal cumulative usage to that in

<table>
<thead>
<tr>
<th>Reference</th>
<th>Place and period</th>
<th>Cases</th>
<th>Controls</th>
<th>% Controls exposed</th>
<th>Metric</th>
<th>OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osterlind et al. (9)</td>
<td>East Denmark 1982-1985</td>
<td>474</td>
<td>926</td>
<td>18%</td>
<td>Ever used sunbeds</td>
<td>0.71 (0.5-1.0)</td>
</tr>
<tr>
<td>Swerdlow et al. (13)</td>
<td>UK (Scotland) 1979-1984</td>
<td>180</td>
<td>197</td>
<td>8.3%</td>
<td>Ever used UV lamps or sunbeds</td>
<td>2.9 (1.3-6.4)</td>
</tr>
<tr>
<td>Walter et al. (14)</td>
<td>Ontario Canada 1984-1986</td>
<td>583</td>
<td>608</td>
<td>Males 14%</td>
<td>Ever used sunbeds/sunlamps</td>
<td>Males 1.88 (1.20-2.98)</td>
</tr>
<tr>
<td>Females 21%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Females 1.45 (0.99-2.13)</td>
</tr>
<tr>
<td>Garbe et al. (11)</td>
<td>Germany 1984-1987</td>
<td>856</td>
<td>705</td>
<td>7%</td>
<td>Use of sunbeds-yes</td>
<td>1.5 (0.9-2.4)</td>
</tr>
<tr>
<td>Autier et al. (15)</td>
<td>Germany, Belgium, France 1991-1993</td>
<td>420</td>
<td>447</td>
<td>Males 14%</td>
<td>Ever exposed to sunlamps for tanning</td>
<td>Sunlamps 1.77 (1.00-3.23)</td>
</tr>
<tr>
<td>Females 17%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Females 0.95 (0.64-1.41)</td>
</tr>
<tr>
<td>Westerdahl et al. (16)</td>
<td>South Sweden 1988-1990</td>
<td>400</td>
<td>640</td>
<td>25%</td>
<td>Ever used sunbeds/sunlamps</td>
<td>All 1.16 (0.83-1.61)</td>
</tr>
<tr>
<td>Holly et al. (12)</td>
<td>San Francisco USA 1981-1986</td>
<td>452</td>
<td>930</td>
<td>38%</td>
<td>Ever use of sunlamp</td>
<td>0.94 (0.74-1.2)</td>
</tr>
<tr>
<td>Chen et al. (18)</td>
<td>Connecticut USA 1987-1989</td>
<td>624</td>
<td>512</td>
<td>Males 16%</td>
<td>Ever used sunlamp</td>
<td>1.13 (0.82-1.54)</td>
</tr>
<tr>
<td>Westerdahl et al. (17)</td>
<td>South Sweden 1995-1997</td>
<td>571</td>
<td>913</td>
<td>Females 22%</td>
<td>ever used sunbeds</td>
<td>1.2 (0.9-1.6)</td>
</tr>
<tr>
<td>Females 33%</td>
<td></td>
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</tr>
<tr>
<td>Veierod et al. (19)</td>
<td>Sweden and Norway; female cohort 1991-1999</td>
<td>—</td>
<td>Total cohort, 106,379 women</td>
<td>Females 57%</td>
<td>2% of total female cohort exposed</td>
<td>Exposed ≥1/mo, age 10-39</td>
</tr>
</tbody>
</table>

Summary OR
No. studies = 12 (10 investigations, 1 with sex-specific, and 1 with exposure-specific risk estimates) 1.25 (1.05-1.49)

NOTE: Abbreviation: NS, not stated.
*Odds ratio adjusted in the original study for age, sex, host factors, and in some studies, sun exposure.
†Odds ratio unadjusted.
‡Sunbed use only; no OR given for sunlamp use.
§Used for tanning purposes.
‖Study conducted among female subjects only.
*Comparison group is never/rarely.

<table>
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<th>Cases</th>
<th>Controls</th>
<th>% Controls exposed</th>
<th>Metric</th>
<th>OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swerdlow et al. (13)</td>
<td>UK (Scotland) 1979-1984</td>
<td>180</td>
<td>197</td>
<td>3%</td>
<td>Age at first exposure &lt;30 y</td>
<td>3.8 (0.9-16.5)</td>
</tr>
<tr>
<td>Walter et al. (14)</td>
<td>Ontario Canada 1984-1986</td>
<td>583</td>
<td>608</td>
<td>Males 7%</td>
<td>First use &lt;age 30</td>
<td>Males 2.13 (1.13-4.13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Females 12%</td>
<td></td>
<td>Females 1.55 (0.94-2.59)</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>M + F 1.75 (1.18-2.59)</td>
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<td></td>
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<td></td>
<td></td>
<td>1.35 (0.88-2.08)</td>
</tr>
<tr>
<td>Chen et al. (18)</td>
<td>Connecticut USA 1987-1989</td>
<td>624</td>
<td>512</td>
<td>8%</td>
<td>&lt;age 25 at first use of sunlamp</td>
<td>2.3 (1.2-4.2)</td>
</tr>
<tr>
<td>Westerdahl et al. (17)</td>
<td>South Sweden 1995-1997</td>
<td>571</td>
<td>913</td>
<td>9%</td>
<td>First exposure at age ≤35</td>
<td>Exposed ≥1/mo, age 10-19</td>
</tr>
<tr>
<td>Veierod et al. (19)</td>
<td>Sweden and Norway; female cohort 1991-1999</td>
<td>—</td>
<td>Total cohort, 106,379 women</td>
<td>2% of total female cohort</td>
<td>Exposed ≥1/mo, age 10-19</td>
<td>Exposed ≥1/mo, age 10-19</td>
</tr>
</tbody>
</table>

Summary OR
No. studies = 6 (5 studies, 1 with sex-separate risk estimates) 1.69 (1.32-2.18)

*Odds ratio adjusted in the original studies for age, sex, host factors, and in some studies, sun exposure.
†Odds ratio unadjusted.
subjects “ever exposed’’ and those “never exposed.” This would enable us to determine whether there was a suggestion of a gradient of risk from none to maximal use. Of course those subjects most heavily exposed will also be included in the ever exposed category, so the OR differences seen between the levels of exposure are not independent.

The published articles covered a time period of nearly 20 years. During this time the UV emissions of artificial tanning devices changed in character. Sunlamps used up to the late 1970s were usually used in the home setting (except for medical use) and emitted primarily UVB (sometimes with a small component of UVC). In the early 1980s, two major changes took place. Indoor tanning began to be done largely in commercial salons rather than at home, and salons began to use UVA lamps. Thus, the character of the exposure changed and because of this there is some question whether results from the early studies (9, 13, 14) can be legitimately combined with those of more recent studies. We suggest that combining the results of the studies is appropriate, as there is no convincing human data demonstrating that UVB is more or less strongly related to melanoma than UVA. In fact, there is some evidence that melanocytes exposed in vivo to either UVA or to UVB show similar levels of thymine dimer formation (23).

In addition, studies have shown that UVA as well as UVB impairs antioxidant function and promotes reactive oxygen species, events known to be involved in cutaneous carcinogenesis (24-27). Finally, the risk estimates from later studies, taken together, do not differ in character from those seen in the earlier investigations.

Finally, although we have used risk estimates adjusted for phenotype factors and, when possible, for sun exposure, it is unlikely that the studies have achieved complete control for these potential confounders. If individuals who use artificial tanning devices are more likely to sunbathe, as many suspect, then some of the elevated risk seen might be due to recreational sun tanning.

Our results, however, suggest that any exposure to artificial tanning devices modestly, but significantly, increases risk of cutaneous melanoma; however, caution is needed as it is possible that there is unpublished (or unanalyzed) data on sunbed or sunlamp use in existence from previously conducted etiologic studies of melanoma. The subgroup analysis of risk among those exposed “early in adult life” suggests a risk estimate slightly higher than that seen in the ever versus never analysis. We take this to indicate that risk increases with adequate lag time (>10 years) after commencement of exposure. However, as noted above, this lag time is potentially confounded by the change in tanning device emissions from UVB to UVA in the early 1980s. The latter interpretation, however, seems unlikely as risk estimates for exposure during the period when UVA was emitted by sunbeds (17) are similar to those seen during earlier periods.

Summary ORs for those with the longest duration or highest frequency of use suggest a higher risk of melanoma among those most heavily exposed than among those ever exposed. Confidence intervals of the two estimates overlap; however, this does give some indication that a dose-response effect might be found to be present if exposure data were more effectively captured.

If there is a causal relationship between sunlamp/sunbed exposure and melanoma, the public health question is asked: how important is the risk? It is not possible with the data available to answer this question with any certainty. However, a large number of epidemiologic studies have been conducted on the relationship between solar UV exposure and melanoma, and these have been summarized quantitatively by Nelemans et al. (28) and Elwood and Jopson (2). Combining the highest reported levels of “intermittent” exposure produced a summary OR for all studies of 1.71 (95% CI, 1.54-1.90) in the Elwood study, and 1.57 (95% CI, 1.29-1.91) for population-based studies in the Nelemans investigation. These values are similar to that seen for longest duration or highest frequency of use of sunlamps/sunbeds in the present study. Although caution is required due to the possibility of confounding by inadequate control for concurrent sun exposure, the results suggest that artificial UV may be a significant contributor to risk among those with substantial exposure.

In summary, although it is not possible to determine accurately how much sunbed/sunlamp use contributes to individual risk of cutaneous malignant melanoma, it is clear that any use of these devices elevates risk for cutaneous malignant melanoma. Furthermore, risk further increases with appropriate lag time, and frequency and duration of use seem likely to be positively related to the magnitude of the risk.

Table 3. Exposure to sunlamps and/or sunbeds and cutaneous malignant melanoma: case control and cohort studies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Place and Period</th>
<th>Cases</th>
<th>Controls</th>
<th>% Controls Exposed</th>
<th>Metric</th>
<th>OR* 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swerdlow et al. (13)</td>
<td>UK (Scotland) 1979-1984</td>
<td>180</td>
<td>197</td>
<td>2% Males 4%</td>
<td>Duration of use &gt;1 y Sunbed/sunlamp use ≥1/mo for ≥12 mo</td>
<td>3.4* (0.6-20.3)</td>
</tr>
<tr>
<td>Autier et al. (15)</td>
<td>Germany, Belgium, France 1991-1993</td>
<td>420</td>
<td>447</td>
<td>Prior to 1980 5%</td>
<td>≥10 h exposure for tanning before 1980 1980 or later 2%</td>
<td>1.8* (1.0-3.2)</td>
</tr>
<tr>
<td>Chen et al. (18)</td>
<td>Connecticut USA 1987-1989</td>
<td>624</td>
<td>512</td>
<td>8%</td>
<td>≥10 uses of sunlamp</td>
<td>1.15* (0.3-4.20)</td>
</tr>
<tr>
<td>Westerdahl et al. (17)</td>
<td>South Sweden 1995-1997</td>
<td>571</td>
<td>913</td>
<td>6%</td>
<td>&gt;250 sunbed uses</td>
<td>1.5 (0.3-3.2)</td>
</tr>
</tbody>
</table>

*Odds ratio adjusted in the original studies for age, sex, host factors, and in some studies, sun exposure.

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