International Prevalence of Indoor Tanning
A Systematic Review and Meta-analysis

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IMPORTANCE Indoor tanning is a known carcinogen, but the scope of exposure to this hazard is not known.

OBJECTIVE To summarize the international prevalence of exposure to indoor tanning.

DATA SOURCES Studies were identified through systematic searches of PubMed (1966 to present), Scopus (1823 to present), and Web of Science (1898 to present) databases, last performed on March 16, 2013. We also hand searched reference lists to identify records missed by database searches and publicly available data not yet published in the scientific literature.

STUDY SELECTION Records reporting a prevalence of indoor tanning were eligible for inclusion. We excluded case-control studies, reports with insufficient study information, and reports of groups recruited using factors related to indoor tanning. Two independent investigators performed searches and study selection. Our search yielded 1976 unique records. After exclusions, 161 records were assessed for eligibility in full text, and 88 were included.

DATA EXTRACTION AND SYNTHESIS Two independent investigators extracted data on characteristics of study participants, inclusion/exclusion criteria, data collection format, outcomes, and statistical methods. Random-effects meta-analyses were used to summarize the prevalence of indoor tanning in different age categories. We calculated the population proportional attributable risk of indoor tanning in the United States, Europe, and Australia for nonmelanoma skin cancer (NMSC) and melanoma.

MAIN OUTCOMES AND MEASURES Ever and past-year exposure to indoor tanning.

RESULTS The summary prevalence of ever exposure was 35.7% (95% CI, 27.5%-44.0%) for adults, 55.0% (33.0%-77.1%) for university students, and 19.3% (14.7%-24.0%) for adolescents. The summary prevalence of past-year exposure was 14.0% (95% CI, 11.5%-16.5%) for adults, 43.1% (21.7%-64.5%) for university students, and 18.3% (12.6%-24.0%) for adolescents. These results included data from 406,696 participants. The population proportional attributable risk were 3.0% to 21.8% for NMSC and 2.6% to 9.4% for melanoma, corresponding to more than 450,000 NMSC cases and more than 10,000 melanoma cases each year attributable to indoor tanning in the United States, Europe, and Australia.

CONCLUSIONS AND RELEVANCE Exposure to indoor tanning is common in Western countries, especially among young persons. Given the large number of skin cancer cases attributable to indoor tanning, these findings highlight a major public health issue.
Indoor tanning is a World Health Organization group 1 carcinogen associated with malignant melanoma and nonmelanoma skin cancer (NMSC). Prior studies have estimated that indoor tanning accounts for more than 3400 cases of melanoma each year in Europe and more than 170,000 cases of NMSC each year in the United States. The risk of all types of skin cancer is highest in those exposed at young ages, suggesting a susceptibility period in early life. Despite the mounting evidence of harms of indoor tanning, data on the scope of this problem, with which to guide public health efforts, are missing.

The goal of this study was to summarize the international prevalence of exposure to indoor tanning. In addition to estimating the overall prevalence of indoor tanning, we were specifically interested in the prevalence among young adults and adolescents, groups that may be most susceptible to skin cancer from this exposure.

Methods

We carried out this review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines.

Data Sources and Literature Search

We defined indoor tanning as the use of a UV emission device to produce a cosmetic tan. The terminology used is diverse. In this analysis, we considered the following terms and their variations to be synonymous with indoor tanning: indoor tanning, sunbed, sunlamp, tanning bed, tanning booth, solarium, artificial tanning, artificial UV tanning, and nonsolar UV tanning.

We identified studies through searches of the electronic databases PubMed (1966 to present), Scopus (1823 to present), and Web of Science (1898 to present), with no language restrictions. The last search was performed on March 16, 2013. We also reviewed identified articles and relevant reviews to locate published articles missed by the database searches and to locate publicly available data not yet published in the scientific literature. The specific search strategies used are detailed in the eMethods in the Supplement.

Study Selection

Two of us (M.R.W. and D.N.) independently assessed the eligibility of studies, using the title and abstract for initial screening, followed by review of the full text or its equivalent. Any disagreements were settled by consensus including a third investigator (E.L.). Studies in languages other than English were assessed for eligibility after translation.

Any record that reported a prevalence of exposure to indoor tanning was eligible for inclusion. We excluded records with no indoor tanning prevalence data available, records that did not report original data (editorials or reviews), records with no full text available (conference proceedings), records that did not report the number of participants, and case reports. To obtain prevalence estimates representative of the general population, we excluded studies of groups recruited based on factors that could be related to indoor tanning (studies of indoor tanners, skin cancer screening participants, dermatology clinic patients, and patients with skin cancer). Case-control studies were also excluded for generalizability reasons because even the results from control groups are from populations specifically matched to groups of patients with disease, which may not be representative of a general population. For records reporting the same original data, we included the record reporting the most extensive relevant results, followed by the record with the earliest publication date.

Data Extraction

We used a data extraction sheet, which was developed on the basis of the Cochrane Consumers and Communication Review Group’s data extraction template (http://ccrg.cochrane.org/author-resources). We extracted the following data items from each record: characteristics of study participants (including age, sex, ethnicity, and geographic location), inclusion/exclusion criteria, data collection format (eg, interview or questionnaire), prevalence outcomes (including all prevalence measures, as well as those available by sex or age group), and statistical methods.

Data Synthesis and Statistical Analysis

Primary Analyses

For the primary meta-analyses, we included records that reported the prevalence of ever exposure to indoor tanning (eg, participants were asked, “Have you ever used an indoor ultraviolet tanning device to produce a cosmetic tan?”) or the prevalence of past-year exposure to indoor tanning (eg, participants were asked, “Have you used indoor tanning in the past 12 months?”). Records that did not report one of these exposure measures were excluded from primary analyses. Also excluded were records that assessed specific occupational groups. Primary analyses were performed separately for 3 geographic regions (United States and Canada, Northern and Western Europe, and Australia), as well as for all these regions combined.

Based on the age groups reported by the included studies, analyses were separated into 3 participant categories: (1) adults (aged ≥18 years), (2) university students (college, university, undergraduate, or graduate students), and (3) adolescents (≤19 years old). If a record reported a prevalence that included more than 1 participant category, we separated the results into those for adolescent, university student, or adult subsets and analyzed these separately wherever possible. If separating the results was not possible, we included them in the participant category that matched the majority of the study population. When sex-specific prevalences were available, our analyses were also stratified by sex. For records that reported data from several different time points, each time of data collection was considered to be an individual data point.

We used Stata, version 12, statistical software to perform random-effects model meta-analyses, yielding summary prevalences and 95% CIs. All statistical tests were 2 sided. Because very few studies reported standard errors or 95% CIs,
we calculated the standard error for each study, assuming prevalence to be a Bernoulli random variable, \( p \), with variance equal to \( p(1-p) \). In a few cases of very low prevalence in which the previous calculation yielded a negative lower 95% CI, we used an exact 95% CI calculation as the input into the analysis. To investigate variability (heterogeneity) in study outcomes, we used a \( \chi^2 \) test for heterogeneity and an \( I^2 \) statistic.

Small study effects and publication bias across studies were assessed by using funnel plots, which were reviewed visually, and using Begg’s rank correlation and Egger’s weighted linear regression tests for formal testing.

### Sensitivity Analyses

We performed several sensitivity analyses to assess how our primary analyses estimates varied when we included records that did not meet our inclusion criteria for the primary analyses or that excluded studies with the potential to bias our summary estimates. Specifically, 4 separate sensitivity analyses were performed that (1) included records with exposure measures that did not fit our categories of ever exposure or past-year exposure; (2) included records of specific occupational groups that are not representative of the general population: pilots and flight attendants, outdoor workers, and health care workers; (3) excluded records reporting combined data for mixed participant categories; and (4) excluded records of potentially lower methodologic quality, which did not report clear sampling methods, used convenience sampling, or had sample sizes less than 500 (details in eTable 1 and eTable 2 in the Supplement).

### Trends Over Time

To address the possibility of changes in indoor tanning exposure over time, we separately examined past-year prevalence from records in the most recent 5 years of available data (2007-2012). Past-year prevalence was used instead of ever prevalence because it has greater potential to reflect changing exposure patterns over time. We also performed meta-regressions to evaluate the effect of the year of data collection on past-year indoor tanning exposure. If years of data collection were not reported, we used the year of publication. We used the median year if a range of data collection years was reported.

### Population Proportional Attributable Risk

We calculated population proportional attributable risk as 
\[
(\text{prevalence of exposure} \times \frac{\text{RR} - 1}{\text{1 + prevalence of exposure} \times \text{RR} - 1})
\]
where RR is relative risk based on summary relative risks for NMSC and melanoma reported in 2 rigorous meta-analyses published in the last year, which together encompassed 38 studies with 20,756 skin cancer cases. To calculate the 95% CIs for the population proportional attribut-
Results

Our search yielded 755 results on PubMed, 1565 on Scopus, and 1102 on Web of Science. After duplicates were removed, there were 1959 unique results. A hand search through reference lists, review articles, and publicly available data yielded 8 additional publications and 9 additional publicly available studies. We screened the 1976 unique records by titles and abstracts. After exclusions, 161 records were assessed for eligibility in full text or its equivalent, and 88 records met inclusion criteria and were included (Figure 1). Three records were available only in German30,34,39 and 1 was available only in French32; these were assessed for eligibility after translation.

The 88 records included in this review were published between 1992 and 2013, reported data from 1986 to 2012 from 16 Western countries, and included 491,492 participants (eTable 1 in the Supplement). The 88 included records contributed 115 individual data points. Seven studies used exposure measures other than ever or past-year exposure, and 6 assessed specific occupational groups (1 study overlapping). These 12 studies were excluded from primary analyses and used only in sensitivity analyses (see the Supplement). Seventy-six records with 406,696 total participants were included in the primary analyses. Thirty-four of these records reported prevalence in adults, 15 reported prevalence in university students, and 34 reported prevalence in adolescents.

The overall summary prevalence of ever exposure to indoor tanning was 35.7% (95% CI, 27.5%-44.0%) for adults, 55.0% (33.0%-77.1%) for university students, and 19.3% (14.7%-24.0%) for adolescents (Figures 2, 3, and 4).23-66 The summary prevalence of exposure to indoor tanning in the past year was 14.0% (95% CI, 11.5%-16.5%) for adults, 43.1% (21.7%-64.5%) for university students, and 18.3% (12.6%-24.0%) for adolescents (Figures 5, 6, and 7).* Analyses stratified by sex...
showed a higher prevalence of indoor tanning among women compared with men in each category (Table 1). Analyses of adults and adolescents stratified by geographic region showed highest summary prevalences in Northern and Western Europe, followed closely by the United States and Canada, with Australia consistently having the lowest. Analyses of university students were based entirely on data from the United States (Figures 2-7).23–90

Heterogeneity across studies was significant ($P < .001$), and $I^2$ statistics were greater than 99% in adult, university student, and adolescent analyses. The potential for bias due to small-study effects was also observed: funnel plots appeared somewhat asymmetrical, and the results were significant ($P < .05$) for Begg’s rank correlation and/or Egger’s weighted linear regression tests in all analyses except that of ever exposure in university students.
Past-year exposure in adults. Plots show point prevalence (squares), 95% CIs (horizontal lines), summary prevalence and 95% CIs for each region and overall (diamonds, the width of which represents the 95% CIs), and summary prevalence estimate (dotted line). Records are listed by date of publication and then by date of data collection. (See eTable 1 in the Supplement for full citations and descriptions.) CDC indicates Centers for Disease Control and Prevention; CER, Centre for Epidemiology and Research; NCI, National Cancer Institute; NSW, New South Wales.

Sensitivity Analyses
The 4 sensitivity analyses (described in the Methods section) yielded results consistent with our main findings (eTable 2 in the Supplement). Overall, all sensitivity analyses prevalence estimates were within an absolute 6% of the primary analyses estimates.

Trends Over Time
Estimates of past-year exposure to indoor tanning prevalence collected in the most recent 5 years of available data were higher than estimates including all time periods. A meta-analysis of the most recent estimates (2007-2012) of past-year exposure to indoor tanning yielded past-year prevalences of 18.2% (95% CI, 12.2%-24.1%) in adults, 45.2% (9.4%-81.0%) in university students, and 22.0% (17.2%-26.8%) in adolescents. These are absolute increases of 3.4% in adults, 2.1% in university students, and 1.7% in adolescents from the results of the primary analyses. Meta-regressions examining the effect of the year of data collection on prevalence of indoor tanning exposure in the past year yielded no statistically significant associations between prevalence and year of data collection (P = .44 in adults, P = .95 in university students, and P = .58 in adolescents) (eFigure in the Supplement).

Population Proportional Attributable Risk
We applied our summary ever-exposure prevalence estimates for adults in the United States (35.4%), Northern and Western Europe (41.6%), and Australia (10.7%) to calculate the population proportional attributable risks for basal cell skin cancer.

<table>
<thead>
<tr>
<th>Source and Year of Publication</th>
<th>No. of Participants</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States and Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhains et al,1999</td>
<td>1003</td>
<td>0.11 (0.09-0.13)</td>
</tr>
<tr>
<td>NCI (unpublished),2005</td>
<td>5523</td>
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<td>0.33 (0.29-0.37)</td>
</tr>
<tr>
<td>NCI (unpublished),2007</td>
<td>7424</td>
<td>0.09 (0.08-0.09)</td>
</tr>
<tr>
<td>Heckman et al,2008</td>
<td>29394</td>
<td>0.13 (0.13-0.14)</td>
</tr>
<tr>
<td>Boilek-Berquist et al,2009</td>
<td>184</td>
<td>0.35 (0.28-0.42)</td>
</tr>
<tr>
<td>Genuis et al,2009</td>
<td>1411</td>
<td>0.09 (0.08-0.11)</td>
</tr>
<tr>
<td>Bandi et al,2010</td>
<td>1187</td>
<td>0.09 (0.07-0.10)</td>
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<td>Bandi et al,2010</td>
<td>1931</td>
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<tr>
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<td>25233</td>
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<td>Subtotal (I^2 = 99.3%, P &lt; .001)</td>
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<td>0.13 (0.11-0.16)</td>
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<tr>
<td>Northern and Western Europe</td>
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<tr>
<td>Schneider et al,2009</td>
<td>500</td>
<td>0.21 (0.17-0.25)</td>
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<tr>
<td>Galán et al,2011</td>
<td>2007</td>
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<td>Kester et al,2011</td>
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<td>Kester et al,2011</td>
<td>3746</td>
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<tr>
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<tr>
<td>Subtotal (I^2 = 99.6%, P &lt; .001)</td>
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<td>0.21 (0.13-0.30)</td>
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<td>Australia</td>
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<tr>
<td>CER, NSW (unpublished),2005</td>
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<td>Lawler et al,2006</td>
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<tr>
<td>Francis et al,2010</td>
<td>5085</td>
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<td>Subtotal (I^2 = 91.8%, P &lt; .001)</td>
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<td>0.02 (0.01-0.02)</td>
</tr>
<tr>
<td>Overall (I^2 = 99.8%, P &lt; .001)</td>
<td></td>
<td>0.14 (0.11-0.17)</td>
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<table>
<thead>
<tr>
<th>Source and Year of Publication</th>
<th>No. of Participants</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td></td>
<td></td>
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<tr>
<td>Hillhouse et al,1999</td>
<td>254</td>
<td>0.39 (0.33-0.45)</td>
</tr>
<tr>
<td>Knight et al,2002</td>
<td>489</td>
<td>0.47 (0.43-0.51)</td>
</tr>
<tr>
<td>Danoff-Burg and Mosher,2006</td>
<td>164</td>
<td>0.35 (0.28-0.42)</td>
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<tr>
<td>Stapleton et al,2008</td>
<td>174</td>
<td>0.43 (0.36-0.50)</td>
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<tr>
<td>Dennis et al,2009</td>
<td>162</td>
<td>0.81 (0.77-0.89)</td>
</tr>
<tr>
<td>Mosher and Danoff-Burg,2010</td>
<td>421</td>
<td>0.48 (0.43-0.52)</td>
</tr>
<tr>
<td>Fogel and Krausz,2013</td>
<td>576</td>
<td>0.07 (0.05-0.09)</td>
</tr>
<tr>
<td>Overall (I^2 = 99.1%, P &lt; .001)</td>
<td></td>
<td>0.43 (0.22-0.63)</td>
</tr>
</tbody>
</table>
carcinoma, squamous cell carcinoma, and melanoma (Table 2). The population proportional attributable risk for the 3 regions ranged from 3.0% to 10.8% for basal cell carcinoma, from 6.7% to 21.8% for squamous cell carcinoma, and from 2.6% to 9.4% for melanoma, corresponding to 419,245 cases of skin cancer in the United States, 26,484 in Northern and Western Europe, and 18,441 in Australia. Overall, we estimate 452,796 cases of basal and squamous cell carcinoma (NMSC) and 11,374 cases of melanoma each year attributable to indoor tanning.

Discussion

In this systematic review and meta-analysis of more than 490,000 participants and 88 studies from 16 countries, we...
found a high prevalence of indoor tanning exposure. Specifically, 35% of adults had been exposed to indoor tanning, with 14% within the past year. Exposures to indoor tanning were highest for university students: 55% had been exposed to indoor tanning, with 43% within the past year. Approximately 19% of adolescents had been exposed to indoor tanning, with 18% within the past year. Ever and past-year indoor tanning exposure was higher for women than men, as has been reported elsewhere.101

To our knowledge, this is the first summary of the international prevalence of indoor tanning exposure. Prior reviews have focused on high-risk groups,103,104 correlates,103,104 and motivations44 for indoor tanning but have not addressed the absolute prevalence of this exposure. Because the risk of melanoma and NMSC is highest in those exposed to indoor tanning in early life,105,106 our finding that the majority of university students and approximately 1 in 5 adolescents have been exposed is concerning. It is possible that skin cancer rates in this highly susceptible group will be even higher in the coming decades as this younger generation ages.
In addition to providing context, we believe that the comparison between indoor tanning and smoking is worth considering from a public health standpoint. Both indoor tanning and smoking are voluntary, modifiable behaviors with minimal to no health benefits. Both are also significant problems among young persons. We believe that we should learn from the public health efforts geared toward reducing smoking and apply these lessons to reducing indoor tanning. Approaches that have been successful for tobacco prevention should be implemented and tailored to reduce indoor tanning exposure, including advertising bans, taxation, restriction on use by adolescents, and broader policies that facilitate public education and changing social norm. Indoor tanning restrictions for minors have increased during the past decade, although many regions included in this review still have no such restrictions.107

Our study had several limitations. Most of the included data come from Western countries and are not representative of indoor tanning exposure worldwide. Many of the included studies are made up primarily of whites or excluded nonwhite participants. However, skin cancer and indoor tanning are issues affecting mostly Western white populations, making our results most relevant to those at risk. All the data available for university students came from the United States, which may limit the international generalizability of this particular subset. Furthermore, some of the included studies used convenience sampling and had small study sizes. Our sensitivity analyses that excluded these studies had results that were consistent with our primary results, however. Moreover, the included studies span a broad period from the 1980s to the present, and data summarized from such a span of years may not be representative of current exposure. Finally, our study is limited by heterogeneity and evidence of small-study effects and publication bias. We used random-effects methods to account for heterogeneity. Results of detailed sensitivity analyses that addressed study quality and heterogeneity were consistent with our primary results.

Conclusions

Our findings suggest that exposure to indoor tanning is common in Western countries, especially among young persons. This is especially concerning because the risk of melanoma and NMSC is highest in those exposed to indoor tanning in early life. Indoor tanning is a major public health problem, accounting for nearly half a million new cancer diagnoses each year. It is time to open the debate about and pursue additional research into appropriate and effective policy and prevention strategies with the potential to significantly reduce skin cancer risks.


