

## RESEARCH

# Cutaneous melanoma attributable to sunbed use: systematic review and meta-analysis

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## Abstract

**Objective** To estimate the burden of melanoma resulting from sunbed use in western Europe.

**Design** Systematic review and meta-analysis.

**Data sources** PubMed, ISI Web of Science (Science Citation Index Expanded), Embase, Pascal, Cochrane Library, LILACS, and MedCarib, along with published surveys reporting prevalence of sunbed use at national level in Europe.

**Study selection** Observational studies reporting a measure of risk for skin cancer (cutaneous melanoma, squamous cell carcinoma, basal cell carcinoma) associated with ever use of sunbeds.

**Results** Based on 27 studies ever use of sunbeds was associated with a summary relative risk of 1.20 (95% confidence interval 1.08 to 1.34). Publication bias was not evident. Restricting the analysis to cohorts and population based studies, the summary relative risk was 1.25 (1.09 to 1.43). Calculations for dose-response showed a 1.8% (95% confidence interval 0% to 3.8%) increase in risk of melanoma for each additional session of sunbed use per year. Based on 13 informative studies, first use of sunbeds before age 35 years was associated with a summary relative risk of 1.87 (1.41 to 2.48), with no indication of heterogeneity between studies. By using prevalence data from surveys and data from GLOBOCAN 2008, in 2008 in the 15 original member countries of the European Community plus three countries that were members of the European Free Trade Association, an estimated 3438 cases of melanoma could be attributable to sunbed use, most (n=2341) occurring among women.

**Conclusions** Sunbed use is associated with a significant increase in risk of melanoma. This risk increases with number of sunbed sessions and with initial usage at a young age (<35 years). The cancerous damage associated with sunbed use is substantial and could be avoided by strict regulations.

## Introduction

Exposure to the sun is the most important environmental cause of skin cancer, with the wavelength for ultraviolet radiation associated with development of the disease.<sup>1</sup> The wavelengths

for ultraviolet radiation range between 100 nm and 400 nm and are broadly categorised into ultraviolet A light (315-400 nm), ultraviolet B (280-315 nm), and ultraviolet C (100-280 nm). All ultraviolet C and most ultraviolet B wavelengths are blocked by the stratospheric ozone layer. A fraction of ultraviolet B and all ultraviolet A reaches the Earth's surface.

In light skinned populations, the ultraviolet radiation delivered by sunbeds has become the main non-solar source of exposure to ultraviolet light. Indoor tanning has been widely practised in northern Europe and the United States since the 1980s,<sup>2</sup> and since 2000 this trend has gained popularity in sunnier countries, such as Australia.<sup>3 4</sup> Modern indoor tanning equipment mainly emits in the ultraviolet A range, but a fraction (<5%) of this spectrum is in the ultraviolet B range. This ultraviolet B fraction induces a deep, long lasting tan. Powerful ultraviolet tanning units may be 10-15 times stronger than the midday sunlight on the Mediterranean Sea, and repeated exposure to large amounts of ultraviolet A delivered to the skin in relatively short periods (typically 10-20 minutes) constitutes a new experience for humans.

Indoor tanning has a plethora of negative health effects, many of which are involved in cancerous processes.<sup>5</sup> The impact of this trend on incidence of skin cancer is of concern, mainly because of cutaneous malignant melanoma, a cancer of poor prognosis when diagnosed at an advanced stage.

Until recently ultraviolet B was usually considered the only carcinogenic fraction of the solar spectrum reaching the Earth's surface. In 2009, the International Agency for Research on Cancer classified the whole ultraviolet spectrum and indoor tanning devices as carcinogenic to humans (group 1).<sup>6</sup> The rationale for classifying ultraviolet A and sunbeds as group 1 carcinogens was based on congruent lines of evidence from basic and epidemiological research. Briefly, extensive laboratory data and animal experiments (on DNA mutations and repair, immune function, cell integrity, cell cycle regulation, and other critical biological functions) documented a role for ultraviolet A in skin carcinogenesis<sup>7-9</sup> and that the body's repair and

removal of damaged DNA was less effective when the damage was caused by ultraviolet A rather than by ultraviolet B.<sup>10</sup> Experiments in human volunteers showed that exposure to ultraviolet A and ultraviolet B can weaken the immune system through mechanisms that interact and overlap, increasing vulnerability to cancer as well as to other diseases.<sup>11</sup> Also, tanning lamps induce the types of DNA damage to the skin associated with photocarcinogenesis.<sup>11</sup> Lastly, the meta-analysis undertaken in 2005 found a significant 75% increase in risk of melanoma (from 40% to 228%) when indoor tanning started during adolescence or young adulthood.<sup>11 12</sup> Some evidence was also found that indoor tanning increased the risk of squamous cell carcinoma, especially when sunbed use started before the age of 20.

The meta-analysis by the International Agency for Research on Cancer in 2006 could not examine dose-responses, and additional epidemiological studies published since then have provided an opportunity for some aspects of the relation between sunbed use and melanoma to be explored in greater depth. Using meta-analysis we quantified the risk of melanoma associated with indoor tanning using artificial ultraviolet light, including dose-response and the estimated burden of melanoma and death associated with sunbed use in western Europe.

## Methods

To update the meta-analysis of 2006, we used the same methodological approach as previously described.<sup>11</sup> Briefly, MB searched the literature published up to May 2012 using the databases PubMed, ISI Web of Science (Science Citation Index Expanded), Embase, Pascal, Cochrane Library, LILACS, and MedCarib. We used the following keywords for diseases: “skin cancer”, “squamous cell carcinoma”, “SCC”, “basal cell carcinoma”, “BCC”, and “melanoma”. To define exposure, we used the following keywords: “sunbed”, “sunlamp”, “artificial UV”, “artificial light”, “solaria”, “solarium”, “indoor tanning”, “tanning bed”, “tanning parlour”, “tanning salon”, and “tanning booth”. No language restriction was applied. We reviewed the titles and abstracts to identify potentially eligible studies and carried out a manual search of studies identified from references cited in reviews on skin cancer.

From the initial search we selected case-control, cohort, and cross sectional studies published as original articles. Non-eligible trials included ecological studies, case reports, reviews, and editorials.

PA and SG reviewed the selected articles and SG and MB abstracted the data using a standardised data collection protocol. The minimal common information on use of indoor tanning appliances for all studies was “ever used.” For those studies that did not strictly assess ever users of indoor tanning appliances compared with never users,<sup>13 14</sup> we used the information closest to this category.

We also extracted the highest category of sunbed use reported in each study—that is, the greater duration (defined as “high use”) along with estimates of risk for the association with first use of sunbeds at a young age—before age 35 years.

## Statistical analysis

We transformed every measure of association, adjusted for the maximum number of confounding variables, and 95% confidence intervals, into logarithms of relative risk and calculated the corresponding variance.<sup>15</sup> When no estimates were reported, we used tabular data to calculate the crude estimates and 95% confidence intervals.

The meta-analysis was calculated from a random effect model as described previously<sup>16</sup>—that is, a mixed effects model with summary relative risk obtained from maximum likelihood estimation. We calculated confidence intervals assuming an underlying *t* distribution. Heterogeneity was assessed by Higgins and Thompson’s *I*<sup>2</sup> statistic.<sup>17</sup> The *I*<sup>2</sup> statistic ranges from zero to 100%, zero indicating that the relative risks of the different studies included in the meta-analysis are homogeneous—that is, that the relative risks are consistent with each other.

We used a two step procedure to obtain summary risk estimates for dose-response. Firstly, we fitted a linear model within each study to estimate the relative risk per session of sunbed use. When sufficient information was published (the number of participants in usage category), we fitted the model according to a previously proposed method.<sup>18</sup> This method provides the natural logarithm of the relative risk and an estimator of its standard error, taking into account that the estimates for separate categories depend on the same reference group. When the numbers of participants in each serum level category were not available from the publications, we calculated coefficients ignoring the correlation between the estimates of risk at the separate exposure levels. Secondly, we estimated the summary relative risk by pooling the study specific estimates with the mixed effects models.

All analyses were done with SAS Windows version 9.2. We used PROC MIXED in SAS to calculate the random effects models.

## Heterogeneity and sensitivity analyses

We carried out several sensitivity analyses to evaluate the stability of the pooled estimates. Firstly we examined the pooled relative risks for case-control and prospective (cohort and nested case-control) studies separately. Then we examined changes to the results after the exclusion of specific studies.

To investigate heterogeneity between the studies we carried out metaregressions and subgroup analyses. Heterogeneity was investigated by looking at factors that could influence the quality of the studies and that could be responsible for heterogeneity, such as the study design, adjustment for confounding factors, features of the population, and publication year. As an additional analysis for heterogeneity, we compared risk estimates according to the average latitude of countries or areas where studies were done.

To investigate whether publication bias may have affected the validity of the estimates, we constructed funnel plots of the regression of log relative risk on the sample size, weighted by the inverse of the pooled variance. We evaluated publication bias using the Macaskill test.<sup>19</sup>

## Sunbed use and burden of melanoma

To translate the estimation of risk in the current study to the burden in the general population, we provided a broad estimation of the burden of sunbed use in Europe. We gathered data on the prevalence of sunbed use from recent surveys carried out in Europe. As no survey was available for central European countries, we limited our estimation to the original 15 countries of the European Community (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Spain, Sweden, Portugal, the Netherlands, and the United Kingdom) plus the three countries that are part of the European Free Trade Association (Iceland, Norway, and Switzerland). For these 18 countries, we extracted data on the incidence of melanoma from GLOBOCAN 2008.<sup>20</sup>

We identified seven surveys carried out in the 18 countries from which we extracted prevalence of ever having used a sunbed during lifetime.<sup>21-27</sup> We also extracted the prevalence of sunbed use in the control group included in the Swedish cohort.<sup>14</sup> Data were available for Denmark, France, Germany, Iceland, Spain, Sweden, Switzerland, and the United Kingdom. These countries represent 70% of all melanoma cases occurring in the 18 countries studied. Prevalence for the other 10 countries was determined from estimates for neighbouring countries.

We estimated the attributable fraction with Levin's formula<sup>28</sup> by using prevalence of ever use of sunbeds from surveys and the summary relative risk for ever use of sunbeds.

## Results

Figure 1 describes the literature search process. Since the meta-analysis of 2006, eight additional studies were identified, one of which was the update of the Norwegian-Swedish cohort.<sup>29</sup> Thus in May 2012, 32 studies had investigated the relation between sunbed use and melanoma (table 1). All studies were based on the case-control design except three, which were cohort studies.<sup>14 50 59</sup> The Nurse's Health Study was based on a cohort design but the trial was a case-control study with retrospective assessment of sun exposure and sunbed use in samples of skin cancer cases and controls matched on year of birth.<sup>42</sup> One study was a survey among patients attending a dermatology clinic.<sup>53</sup> One third of patients participated in the survey. Sunbed use of patients with a diagnosis of cutaneous melanoma was compared with that of other patients. Although this study was not in the broadest sense a case-control design, it was included in the meta-analysis.

Four of the 32 studies<sup>13 14 30-59</sup> were excluded from the meta-analysis because they did not include estimates of the relative risk for cutaneous melanoma associated with sunbed use.<sup>34 44 46 40</sup> One study<sup>55</sup> was redundant as it was reanalysed and published in 1999.<sup>54</sup>

Studies used for meta-analysis totalled 11 428 cases of melanoma. The first study<sup>30</sup> was published in 1981 and the last<sup>59</sup> in 2012. Eighteen studies were carried out in European countries, seven in the United States and Canada, and two in Australia.

### Summary relative risks

Twenty seven studies presented positive estimates for ever use compared with never use of sunbeds (fig 2). Eight of these studies reported only crude relative risks and one adjusted for age and sex only. The summary relative risk was 1.20 (95% confidence interval 1.08 to 1.34), with heterogeneity ( $I^2=56%$ ). Evidence of publication bias was lacking ( $P=0.99$ , Macaskill test). An analysis restricted to the 18 cohort and population based case-control studies produced a slightly higher summary relative risk (1.25, 1.09 to 1.43). An analysis restricted to the 18 studies that adjusted for confounders related to sun exposure and sun sensitivity yielded a similar summary relative risk (1.29, 1.13 to 1.48).

When the cohort studies were excluded from the analysis the summary relative risk decreased slightly but remained statistically significant (1.20, 1.06 to 1.37).

Thirteen studies presented estimates relevant for the evaluation of first use of sunbeds in youth (before age 35) compared with never use (fig 3). All relative risks were adjusted for confounders related to sun exposure or sun sensitivity, except in one study.<sup>54</sup> The risk was almost doubled (relative risk 1.87), with no indication of heterogeneity ( $I^2=0$ ).

Four studies reported data on risk associated with the number of sunbed sessions per year. A summary relative risk derived from relative risks reported for each session was 1.018 (95% confidence interval 0.998 to 1.038), which indicated a 1.8% increase in risk of melanoma for each annual session. A significant 42% increased risk was found for high use of sunbeds (summary relative risk 1.42, 95% confidence interval 1.15 to 1.74; fig 4). Nine studies reported risks associated with time since first use, with first use distant in time (that is, more than five years before diagnosis) associated with a higher summary relative risk (1.49, 1.18 to 1.88;  $I^2=34%$ ) than first use more recently (1.18, 0.95 to 1.48;  $I^2=51%$ , table 2).

Risks for sunbed related melanoma were compared in populations living at different latitudes (fig 5). Relative risks associated with ever versus never use of sunbeds did not differ much with variations in latitude and there was no indication that risks would be higher in more sun sensitive populations such as those in the Nordic countries.

### Sensitivity analysis

The summary relative risk remained significant when all possible studies, including publications with missing estimates, were included and a relative risk of 1 (no effect) was imputed for the missing relative risks (1.20, 1.10 to 1.34).

### Squamous and basal cell carcinomas

Two studies<sup>42 59</sup> published since 2005 looked at the risk of non-melanoma skin cancer associated with sunbed use. Adding data from this study to that of the 2006 meta-analysis<sup>11</sup> yielded summary relative risks for ever versus never sunbed use of 2.23 (1.39 to 3.57) for squamous cell carcinoma (1242 cases in five studies)<sup>42 59-62</sup> and 1.09 (1.01 to 1.18) for basal cell carcinoma (6995 cases in six studies).<sup>42 59 61-64</sup>

### Impact on burden of melanoma in western Europe

Of 63 942 new cases of cutaneous melanoma diagnosed each year in the 15 countries that were members of the European Community and the three countries that were part of the European Free Trade Association, an estimated 3438 (5.4%) were related to sunbed use (table 3). Women represented most of this burden, with 2341 cases (6.9% of all melanoma cases in women) related to sunbed use; 1096 cases annually occurred in men (3.7% of all cases in men). Taking a melanoma incidence to mortality ratio of 3.7 for European men and 4.7 for European women,<sup>20</sup> in the 15 European Community countries, about 498 women and 296 men would die each year from a melanoma as a result of being exposed to indoor tanning using artificial ultraviolet light.

## Discussion

Overall, the summary of results of 27 observational studies published within the past 30 years shows that the risk of cutaneous melanoma is increased by 20% for those who were ever users of indoor tanning devices with artificial ultraviolet light. The risk of melanoma was doubled when use started before the age of 35 years. This latest estimate originates from studies in various populations and latitudes, which obtained consistent results with zero heterogeneity. Summary risk estimates calculated from population based case-control studies were close to those of cohort studies.

## Comparison with 2006 evaluation

The 2006 evaluation<sup>11</sup> did not find evidence for a dose-response relation between the level of sunbed use and risk of melanoma; however, a formal metaregression analysis could not be carried out because not enough data were published at that time. Since then, large studies have provided data consistent with a dose-response relation—for example, a study in Minnesota<sup>47</sup> found dose-responses for years during which sunbeds were used, cumulative time (hours) of sunbed use, and cumulative number of tanning sessions.

Table 2 summarises the results of the meta-analyses of 2006<sup>11</sup> and of this meta-analysis. From 2005 to 2011, most summary relative risks have increased. These changes support the hypothesis that earlier studies tended to underestimate risks associated with indoor tanning because this behavioural trend is relatively new and thus recent uses may not (yet) have influenced the incidence of melanoma.<sup>11 65</sup> From this logic it is possible that future epidemiological studies on sunbed use and skin cancer could show relative risks higher than those found to date.

## Risk of melanoma associated with sunbed use in different populations

We did not observe a significant difference in risk when taking latitude of residence into account. Most studies included in this meta-analysis were adjusted for phototype or a proxy for sun sensitivity. In this respect, the summary relative risks presented in this article are valid for all light skinned populations such as those in Europe, North America, and Australasia. The number of melanoma cases arising from sunbed use may, however, be higher than we estimated because it seems that sunbed users are more likely to have fair skin, have red or blond hair, have more freckles, and be phototype I/II (burn easily and tan minimally if at all when first exposed to the sun) than III/IV (burn moderately and tan easily or always when first exposed to the sun) than non-users.<sup>66</sup>

Sunbed users also have the tendency to adopt unhealthy lifestyles compared with non-users<sup>2</sup> and we could hypothesise that use of sunbeds may be a marker of populations more exposed to sun. However, several studies, such as the cohort study by Veierød et al<sup>14</sup> (see table 1), did adjust for a variable of sun exposure. The summary relative risk is then unlikely to reflect a more intense exposure to sun among sunbed users. Compelling evidence that use of sunbeds can be a cause of melanoma and not just a proxy for sun exposure arises from the investigation of a melanoma epidemic in Iceland, a country located between 64° and 66° N and where sunny days are uncommon.<sup>67</sup> After 1990, the incidence of melanoma increased sharply, mainly in young women, with preferential occurrence on the trunk. The incidence tended to decline after 2000, when public health authorities imposed greater control on sunbed installation and utilisation. Although that study was an ecological one, the exposure of Icelandic youngsters that took place after 1985 seemed to be the most likely reason for that epidemic.<sup>68</sup>

The results of this meta-analysis are in full agreement with the considerable amount of data pointing to childhood and adolescence as the key periods for initiation and development of melanoma in adulthood.<sup>69</sup> This evidence on the risks of skin cancer associated with exposure to ultraviolet light at young ages underlines the health threats documented by many recent surveys, which show substantial use by children and adolescents of tanning devices using artificial ultraviolet light in the United States and European countries,<sup>70-73</sup> with evidence for unabated

increasing use in the United States.<sup>74</sup> For instance, in Denmark, a survey completed in 2008 found that 2% of children aged 8 to 11 years and 13% aged 12 to 14 years had used a sunbed within the past 12 months.<sup>72</sup>

## Burden of melanoma associated with sunbed use in Europe

In Europe, 71% of melanoma cases in 2008 occurred in the 15 European Union countries and the three European Free Trade Association countries. We estimated that in these 18 countries each year, around 3438 new cases of melanoma and 794 related deaths would be related to sunbed use. This estimation is limited to western European countries because of a lack of information on sunbed use in central European countries. The number of deaths from melanoma associated with sunbed use was determined for the United Kingdom in 2003,<sup>75</sup> with an estimated 100 deaths (range 50-200) annually. Our calculation of attributable fractions would put the number of deaths for the United Kingdom at 99, a figure consistent with the earlier estimate. The estimation of deaths from melanoma should be treated with caution since some epidemiological data suggest that, on average, sunbed related melanoma could be of low malignant potential.<sup>75 76</sup> None the less, the burden of cancer attributable to sunbed use could further increase in the next 20 years because the recent, high usage levels observed in many countries have not yet achieved their full carcinogenic effect and because usage levels of teenagers and young adults remain high in many countries. This prediction is supported by the observation over 10-15 years of increases in the incidence of melanoma on the trunks of women from countries with widespread access to indoor tanning.<sup>67 77-80</sup> The incidence rates of trunk melanoma in women aged 20-49 years therefore could be a relevant indicator for monitoring activities to decrease the use of sunbeds.

## Indoor tanning industry and regulation

Melanoma and other skin cancers that are specifically associated with sunbed use are preventable diseases by avoiding exposure to these devices. Generally the sunbed industry has not self regulates effectively and has tended to disseminate non-evidence based information, which can deceive consumers.<sup>81-83</sup> Tanning salon operators simply following regulations is an illusory prevention method, as such regulations are unable to turn a carcinogenic agent into a healthy one. Instead, the sunbed industry has used the opportunity to claim that properly regulated indoor tanning is safe, and that it might even have health benefits.<sup>81</sup>

Discouraging sunbed use or requiring parental authorisation is not effective, partly because many parents of teenagers willing to use sunbeds are also sunbed users themselves.<sup>2 73</sup>

Prevention of the harmful effects associated with sunbed use must be based on tougher actions. Recommendations from the World Health Organization, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and the European Society of Skin Cancer Prevention (EUROSKIN) maintain that the highest regulatory priorities should be the restriction of sunbed use by people under 18 years of age and the banning of unsupervised indoor tanning facilities. Such restrictions have now been implemented in Australia and in several European countries (Austria, Belgium, France, Germany, Portugal, Scotland, and Spain). In the United States, until the recent ban by the state of California issued on 10 October 2011, no state had banned access to indoor tanning for adolescents aged less than 18 years.

If sunbed use by teenagers and young adults does not substantially decrease in the short term, then more radical actions should be envisioned, such as the nationwide prohibition of the public use of tanning devices, which was implemented by the Brazilian National Health Surveillance Agency<sup>84</sup> in November 2009.<sup>85</sup>

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Data sharing: The statistical analysis programs in SAS are available on request from the corresponding author ([mathieu.boniol@i-pri.org](mailto:mathieu.boniol@i-pri.org)).

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**What is already known on this topic**

Earlier studies suggested an increased risk of melanoma, in particular when sunbed use started before age 35  
No consistent dose-response relation was found

**What this study adds**

This study confirms a doubling of the risk of melanoma when first sunbed use is at a young age (<35 years)  
A dose-response relation exists between amount of sunbed use and risk of melanoma  
In Europe each year, 3438 new cases of melanoma would be due to sunbed use

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## Tables

**Table 1 | Characteristics of studies on sunbed use and melanoma considered for meta-analysis**

Studies	Country	No of cases	No of controls	Adjustments
Cohort or population based case-control studies:				
Adam et al 1981 <sup>30</sup>	UK	169	207	Crude
Gallagher et al 1986 <sup>40*</sup>	Canada	595	595	—
Holman et al 1986 <sup>45</sup>	Australia	511	511	Crude
Osterlind et al 1988 <sup>51</sup>	Denmark	474	926	Not clear
Zanetti et al 1988 <sup>58</sup>	Italy	208	416	Age, hair colour, skin reaction, sunburn in childhood, education level
Beitner et al 1990 <sup>34*</sup>	Sweden	523	505	—
Walter et al 1990 <sup>55*†</sup>	Canada	583	608	—
Westerdahl et al 1994 <sup>57</sup>	Sweden	400	640	Hair colour, nevi, skin type, sunburns
Holly et al 1995 <sup>43</sup>	USA	452	930	—
Chen et al 1998 <sup>35</sup>	USA	624	512	Age, sex, phenotype, recreational sun exposure
Walter et al 1999 <sup>54</sup>	Canada	583	608	Age, sex, and skin reaction
Westerdahl et al 2000 <sup>56</sup>	Sweden	571	913	Sunburns, hair colour, sunbathing
Han et al 2006 <sup>42</sup>	USA	200	804	
Clough-Gorr et al 2008 <sup>36</sup>	USA	423	678	Age, sex, family history, hair colour, sun exposure
Cust et al 2011 <sup>37</sup>	Australia	604	479	—
Lazovich et al 2010 <sup>47</sup>	USA	1167	1101	Age, sex, family history, hair colour, sun exposure
Veierød et al 2010 <sup>14</sup>	Norway, Sweden	412	106 366‡	Age, residence, hair colour, sunburns, annual "bathing" holiday
Elliott et al 2011 <sup>39</sup>	UK	959	513	Age, sex, educational level, family history of melanoma, sun sensitivity, and sun exposure
Nielsen et al 2011 <sup>50</sup>	Sweden	210	29 520‡	Crude
Zhang et al 2012 <sup>59</sup>	USA	349	73 494‡	Age, family history, hair colour, number of moles, sunburn tendency and history, outdoor sun exposure, ultraviolet index, state of residence at birth, age 15, and age 30
Other case-control studies:				
Klepp and Magnus 1979 <sup>46*</sup>	Norway	78	131	—
Holly et al 1987 <sup>44*</sup>	USA	121	139	—
Swerdlow et al 1988 <sup>52</sup>	UK	180	120	Crude
Mackie et al 1989 <sup>48</sup>	UK	280	180	Nevi, skin type, sunburn, freckles, tropical residence
Dunn-Lane et al 1993 <sup>38</sup>	UK	100	100	Crude
Garbe et al 1993 <sup>41</sup>	Germany	280	280	Nevi, hair type, and phototype§
Autier et al 1994 <sup>31</sup>	Multicentre	420	447	Crude
Naldi et al 2000 <sup>49</sup>	Italy	542	538	Age, sex, skin, hair, eye, nevi, freckles, sunburns, number of holidays in sunny climates
Kaskel et al 2001 <sup>13</sup>	Germany	271	271	Crude
Bataille et al 2004 <sup>33</sup>	UK	413	416	Sex and age
Bataille et al 2005 <sup>32</sup>	Belgium, France, Netherlands, Sweden, UK	597	622	Sex, age, and skin phototype§
Ting et al 2007 <sup>53</sup>	USA	29	307	Not clear

\*Not included in main meta-analysis as no estimate of risk was reported.

†1990 study was reanalysed in 1999. Present meta-analysis uses relative risk adjusted for potential confounders presented in 1999 publication.

‡Cohort size.

Table 1 (continued)

Studies	Country	No of cases	No of controls	Adjustments
§Sensitivity to sunlight.				

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Table 2| Summary relative risks found by meta-analyses on sunbed use and cutaneous melanoma

Sunbed use	No of studies in 2005 meta-analysis*		No of studies in present meta-analysis		I <sup>2</sup> (%)
	No of studies in 2005 meta-analysis*	Summary relative risk (95% CI)	No of studies in present meta-analysis	Summary relative risk (95% CI)	
Ever use	19	1.15 (1.00 to 1.31)	27	1.20 (1.08 to 1.34)	56
Ever use†	10	1.17 (0.96 to 1.42)	18	1.25 (1.09 to 1.43)	60
First use in youth (<35 years)	7	1.75 (1.35 to 2.26)	13	1.87 (1.41 to 2.48)	0
High use	NR	NR	14	1.42 (1.15 to 1.74)	—
First use recently	5	1.10 (0.76 to 1.60)	9	1.18 (0.95 to 1.48)	51
First use distant in time‡	5	1.49 (0.93 to 2.38)	9	1.49 (1.18 to 1.88)	34

NR=not reported.

\*International Agency for Research on Cancer, 2006.

†Cohort or population based case-control studies only.

‡More than five years before diagnosis.

Table 3| Estimation of number of melanoma cases attributed to sunbed use in Europe

Population	Attributable fraction (%) <sup>*</sup>		Incidence case caused by ever use of sunbeds		
	Men	Women	Men	Women	Total
Austria†	6.5	10.6	34	52	86
Belgium†	6.5	10.6	41	102	143
Denmark	8.1	13.0	52	106	157
Finland‡	5.8	9.4	29	43	72
France	1.4	3.8	47	157	203
Germany	6.5	10.6	500	904	1404
Greece§	0.4	1.3	1	3	3
Iceland	3.9	6.1	1	1	2
Ireland	1.6	5.8	5	25	30
Italy§	0.4	1.3	15	52	67
Luxembourg†	6.5	10.6	2	4	6
Norway‡	5.8	9.4	38	57	95
Portugal§	0.4	1.3	1	7	8
Spain	0.4	1.3	6	26	32
Sweden	5.8	9.4	71	113	184
Switzerland	5.1	8.7	54	101	155
Netherlands†	6.5	10.6	114	231	345
United Kingdom	1.6	5.8	87	357	444
Total			1096	2341	3438

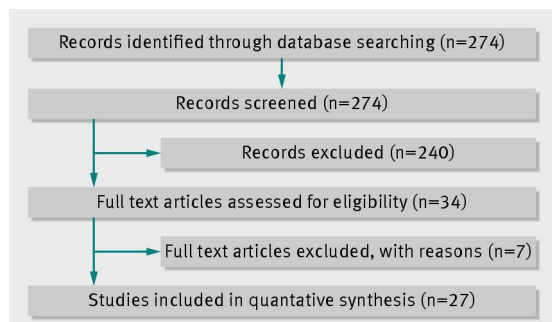
<sup>\*</sup>Calculated from relative risk determined in present meta-analysis and various surveys on prevalence of sunbed use in population.

†Prevalence data for Germany were used for Austria, Luxembourg, Belgium, and Netherlands.

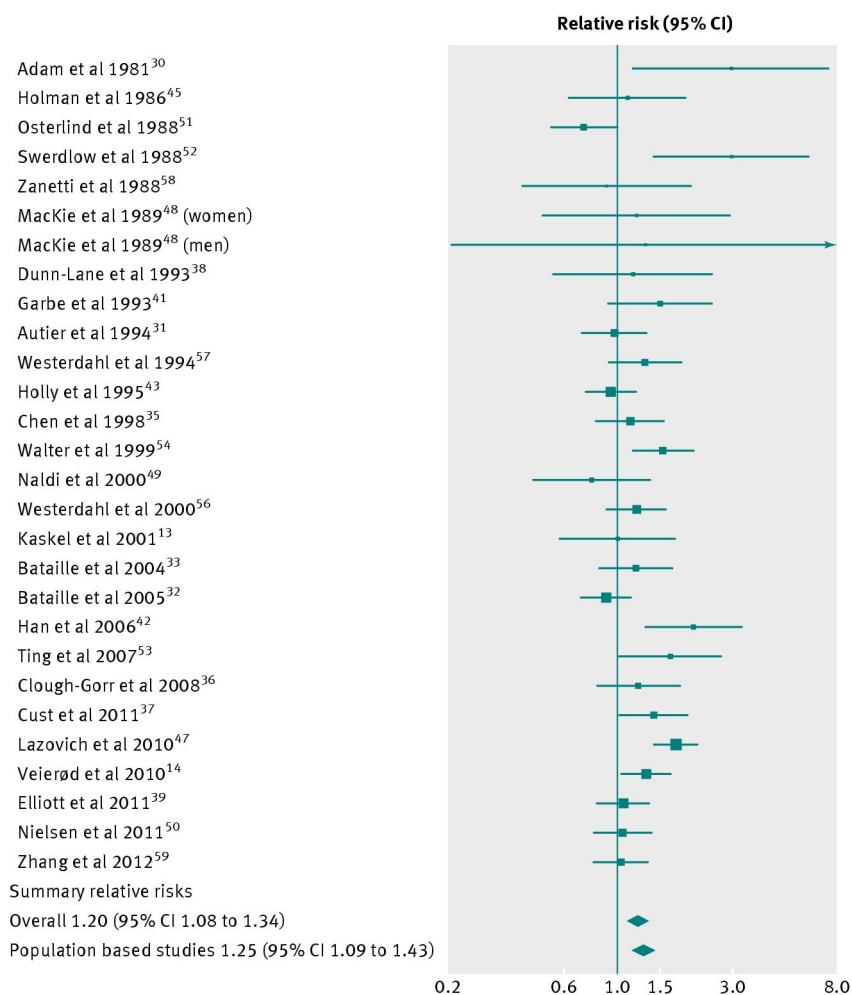
‡Prevalence data for Sweden were used for Finland and Norway. As no data were reported for men, we applied the male:female ratio from Germany survey to Sweden prevalence data.

§Prevalence data for Spain were used for Greece, Italy, and Portugal.

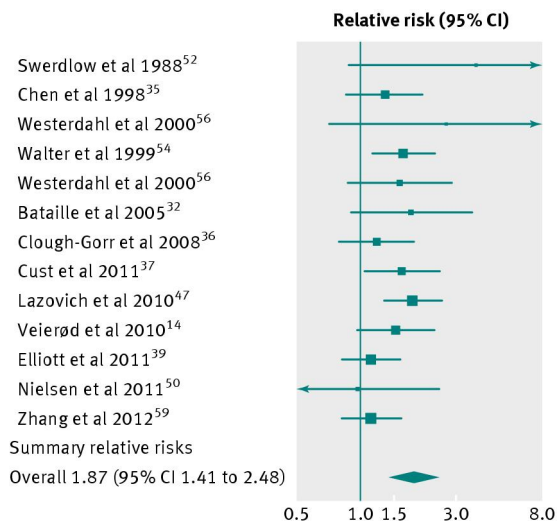
## Figures



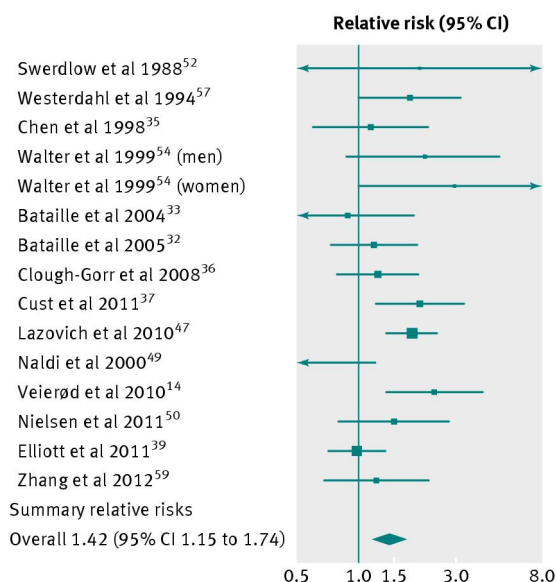
**Fig 1** Flow of studies on sunbed use and risk of cutaneous melanoma



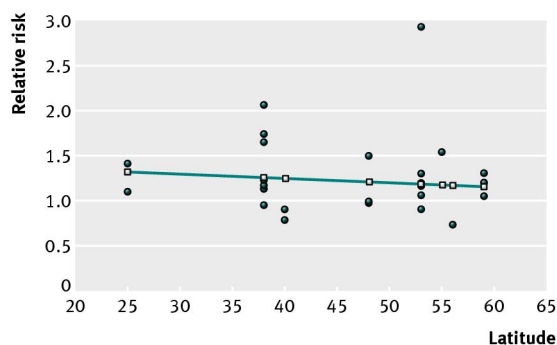
**Fig 2** Forest plot of risk for melanoma associated with ever use of sunbeds. Heterogeneity  $I^2=57%$  for all studies combined



**Fig 3** Forest plot of risk for melanoma associated with ever use of sunbeds when first use was before age 35 years. No heterogeneity ( $I^2=0$ )



**Fig 4** Forest plot of risk for melanoma associated with high use of sunbeds. Heterogeneity  $I^2=47\%$



**Fig 5** Risk for melanoma associated with ever use of sunbeds as a function of latitude