Sun exposure and risk of melanoma

Susan A Oliveria¹, Mona Saraiya², Alan C Geller³, Maureen K Heneghan¹
and Cynthia Jorgensen²

¹Memorial Sloan-Kettering Cancer Center
²Centers for Disease Control and Prevention
³Boston University School of Medicine & Boston University School of Public Health

Corresponding author:
Susan A Oliveria
Dermatology Service
Memorial Sloan-Kettering Cancer Center
160 East 53rd Street, 2nd Floor
New York, NY 10022
USA

Telephone: 001 212 610 0767
Fax: 001 212 308 0530
Email: oliveri@mskcc.org

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Abstract

As skin cancer education programs directed to children and adolescents continue to expand, an epidemiologic basis for these programs is necessary to target efforts and plan for further evaluation. Here, we summarize the epidemiologic evidence on sun exposure during childhood and adolescence and melanoma risk. A literature review was conducted using MEDLINE® database (1966 – December 2004) to identify articles relating to sun exposure and melanoma. The review was restricted to studies that included sun exposure information on subjects 18 years of age or younger. Migrant studies generally indicate an increased melanoma risk in individuals who spent childhood in sunny geographic locations, and decreasing melanoma risk with older age at arrival. Individuals who resided in geographic locations close to the equator or close to the coast during childhood and/or adolescence have an elevated melanoma risk compared to those who lived at higher latitudes or never lived near the coast. The intermittent exposure hypothesis remains controversial; some studies indicate that children and adolescents who received intermittent sun exposure during vacation, recreation, or occupation are at increased melanoma risk as adults, but more recent studies suggest intermittent exposure to have a protective effect. The majority of sunburn studies suggest a positive association between early age sunburn and subsequent risk of melanoma. Future research efforts should focus on (1) clarifying the relationship between sun exposure and melanoma, (2) conducting prospective studies, (3) assessing sun exposure during different time periods of life using a reliable and quantitative method, (4) obtaining information on protective measures, and (5) examining the interrelationships between ability to tan, propensity to burn, skin type, history of sunburns, timing and pattern of sun exposure, number of nevi, and other host factors in the child and adolescent populations.
**Introduction**

Despite the decreasing incidence and mortality for many types of cancer, the incidence rate for melanoma skin cancer has been rising in the United States since 1973.[1][2] Melanoma is the most fatal of skin cancers accounting for 79% of all skin cancer deaths.[3] The number of new melanomas that will be diagnosed in 2005 is estimated to be about 59,580 and it is predicted that there will be about 7,770 deaths due to melanoma.[2] While melanoma is thought to be rare in individuals under the age of 20, recent evidence has also indicated a rapidly rising incidence of melanoma in children and teenagers[4][5][6][7], and epidemiologic studies have revealed a strong association between sun exposure during critical periods of early life and subsequent risk of melanoma during adulthood.[8][9][10][11][12][13][14][15][16]

Although the effects of sun exposure during early life are thought to be important, there remains controversy about the age period when most of an individual’s exposure occurs. Some studies have shown that most exposure occurs during childhood and adolescence.[17][18] Children spend an estimated 2.5-3.0 hours outdoors each day[19][20][21] and may receive three times more annual ultraviolet-B rays than adults because they have a greater opportunity for midday sun exposure during the summer months.[17] [22][23] Conversely, other studies have found that children receive the same amount of ultraviolet doses as adults because the recent technological revolution of the 1990s and advent of various electronic games and computers gave children and adolescents more incentive to stay indoors during the day.[24][25] In either case, health behaviors and habits that are established in childhood, including unprotected sun exposure, may be sustained into adulthood.[18] [22] [26][27][28][29][30][31][32][33][34] As skin cancer education programs directed to children and adolescents continue to expand, an epidemiologic basis for these programs is necessary to target efforts and plan for further evaluation. The purpose of this review is to summarize the epidemiologic evidence on sun exposure during childhood and adolescence and risk of melanoma to more effectively target public health programs.

**Methods**

**Literature Search**

We conducted a computerized literature search of the MEDLINE® database of the National Library of Medicine for the time period 1966 – December 2004 and limited the scope of our search to those studies published in English. We conducted our search using the following MeSH headings: adolescent, child, melanoma, skin neoplasms, sunburn, sunlight, and ultraviolet rays. We further reviewed the reference lists of relevant book chapters and obtained printed materials from recent scientific meetings addressing this topic.

The review was restricted to studies that included sun exposure information on subjects 18 years of age or younger. Studies identified for inclusion were based on the following criteria: (1) assessed associations between sun exposure and melanoma; and/or (2)
assessed associations between surrogate measures of sun exposure (such as place of birth; duration of residence; sunburn history; and time spent on vacation, recreation, and outdoor activities) and melanoma. In some instances, relevant results were presented for age groups in the range of 15-25 years; we critiqued these studies and included them in our review.

We classified studies into three groups based on the existing literature and the common use of these surrogate measures: (1) migration and geographic residence; (2) sun exposure including intermittent exposure; and (3) sunburn.

Results

Migration and Geographic Residence Studies

Migrant studies are commonly used to examine sun exposure and melanoma risk by comparing incidence in populations who have migrated between different geographical areas. Migrant studies provide compelling evidence of childhood and adolescence being critical times for future melanoma development, that is, an increased risk for individuals who spent childhood in sunny geographic locations.[35][36][37][38][39][40][41][42][43][44] In a case control study (511 cases and 511 controls) by Holman and Armstrong,[35] age at arrival and duration of residence in Australia was studied. Earlier age at arrival was a predictor of melanoma risk with little residual effect of duration of residence.[35] Specifically, migrants arriving before age 10 years appeared to have a risk similar to that of native-born Australians, whereas the estimated incidence in those arriving after age 15 years was around one-quarter of the native-born rate, with arrival at later ages giving no additional advantage.[35] In another analysis using these data, English and Armstrong[43] identified people at high risk of cutaneous melanoma. Age ≥ 10 years old at arrival in Australia was associated with a reduced risk of melanoma (OR = 0.38; 95% CI 0.24-0.61) compared to age at arrival < 10 years old. Similarly, in a case control study (412 cases and 445 controls) involving patients from Germany, Belgium and France, age (< 10 years old) at arrival in a sunny location of residence (ie. either the Mediterranean, subtropics or tropics) conferred a 4-fold increased risk of developing melanoma.[38]

In a review by Whiteman and Whiteman,[14] migrant studies were classified based on three criteria: (1) place of birth; (2) age at migration; and (3) duration of residence. Place of birth studies showed that melanoma rates among migrants born in areas of low insolation (ie. Northern Europe) migrating to areas of high insolation (ie. Israel and Australia) were lower than natives born at the high insolation area.[39] [42] [44] [46][47][48][49][50][51][52] Two studies reported an opposite effect, that is, higher melanoma risk among low-insolation born migrants (ie. Europe) migrating to high insolation areas (ie. Hawaii, Israel) than among natives of the high insolation country.[53][54] Age at migration studies showed decreasing melanoma risk with older age at arrival when individuals migrated to a place close to the equator.[35] [39] [44] Lastly, although choice of reference group varied, all ten duration of residence studies
reported increased melanoma risk with longer duration of residence in the adopted country.[35][36] [38][39] [42] [44] [47][48] [54][55]

In addition to migrant studies, location of residence studies provide further evidence that sun exposure in childhood and adolescence is closely associated with melanoma risk. Weinstock et al.[41] conducted a nested case control analysis involving 130 cases and 300 controls from the Nurses’ Health Study cohort and observed an increased risk of melanoma in women whose residence during the ages 15-20 years was more equatorial in latitude. On the other hand, these data also showed that latitude of residence after 30 years of age was not significantly related to melanoma risk. In another study of 474 cases and 926 controls, those who lived near the coast before the age of 15 years had an increased risk of melanoma compared to those who never lived near the coast (OR = 1.6; 95% CI 1.0-2.6).[56]

**Sun Exposure**

**Intermittent Exposure Hypothesis**

Epidemiologic studies suggest, based on the “intermittent exposure hypothesis,” that periodic versus long continued heavy sun exposure is the most important in melanoma causation.[10] [57][58][59][60][61] Elwood[57] has defined intermittent sun exposure as that usually received during recreational and vacation activities. It has been put forth that chronic or “regular” sun exposure may actually reduce the risk of melanoma.[51] [60][61][62][63] However, in epidemiological studies the intermittent exposure hypothesis has caused much controversy. For example, the ten duration of residence studies[35][36] [38][39] [42] [44] [47][48] [54][55] reported an increased melanoma risk with longer duration of residence in the adopted country suggesting that chronic sun exposure may be an important factor in melanoma development. While duration of residence studies are crude measures of sun exposure, they are easy to classify and there is evidence that they can be a reasonable proxy for sun exposure when comparing populations.[14] [64] Thus, past studies have indicated that intermittent sun exposure is associated with increased risk for melanoma, and more recent studies have reported factors associated with high levels of sun exposure, such as elastosis,[65] [66] sunburns, and intermittent sun exposure, may increase survival from melanoma.[67]

Different biological events may result from acute, intense sun exposure as opposed to high-dose chronic sun exposure. An intermittent pattern of exposure causes DNA damage to melanocytes which eventually may lead to the development of melanoma.[13] In the model proposed by Gilchrest et al.,[13] when melanocytes are damaged by intermittent intense ultraviolet radiation in the presence of both low melanin content (which has a photoprotective role in the skin) and low basal DNA repair capacity, they are likely to survive. This low DNA repair capacity in conjunction with the retention of “damaged” cells may increase the risk of melanoma. Cells may be at their highest vulnerability for genomic damage from intermittent sun exposures during childhood and adolescence.[13]
Sun Exposure during Vacation, Recreation, and Occupation

Sun exposure during vacation, recreation, or occupation may reflect intense intermittent exposure. Several studies (n=11) have looked at time spent in sunny vacations, specific types of recreational activities, or occupation during childhood or adolescence and risk of melanoma [36] [45] [52] [60][61][62] [68][69][70][71][72] (See Table 1). There is conflicting evidence, while some studies have determined that intermittent sun exposure during this critical time period leads to an increased melanoma risk, others have not. The exceptions are: (1) a German case-control study of 271 matched pairs which determined outdoor activities in childhood have a protective effect with an odds ratio of 0.3 (95% CI 0.1-1.1);[72] (2) an Australian case-control study of 507 matched pairs that showed when recreational sun exposure was expressed as a proportion of total outdoor exposure, the association between melanoma and intermittent exposure was not supported;[45] (3) a U.S. case-control study of 130 cases and 300 controls which determined among sun-resistant women (women who tend to tan readily instead of burn when exposed to sun), ages 15-20 years, high frequency of swimsuit use appeared to be protective against melanoma risk with an odds ratio of 0.3 (95% CI 0.1-1.0);[69] (4) a U.S. case-control study of 256 cases and 273 controls in which deep/moderate tanners appeared to be protected from melanoma with increasing sun exposure at ages 2-10 years (0.30 95% CI 0.17-0.55) and at ages 11-20 years (0.31 95% CI 0.16-0.59);[62] and (5) a Canadian case-control study of 583 cases and 608 controls that showed melanoma risk was significantly reduced in those who were positive for the indicators of sun exposure based on days of outdoor activity at ages 10-12 years 0.67 (95% CI 0.52-0.85).[61]

Although there is an abundance of epidemiologic studies relating to the intermittent exposure hypothesis, such studies have been hampered by the lack of a precise definition which can be operationalized. Epidemiologic studies to date have focused on sunburn history as a surrogate measure of intermittent exposure during childhood and adolescence. Sunburn is the result of overexposure to the sun without adequate sun protection and thus can be considered a measure of intermittent and/or intense sun exposure to unadapted or unadaptable skin.

Sunburn

Epidemiologic studies support an age relationship between sunburn and melanoma. To date, there have been seventeen case control studies addressing the association between sunburn during childhood and melanoma [56] [68] [70] [72][73][74][75][76][77][78][79][80][81][82][83][84][85] (See Table 2). It should be noted that the definition of sunburn varies across studies ranging from the presence of any sunburn, to sunburns that are painful and or blistering. Elwood and Jopson[10] presented an analysis of nine of these studies[56] [70] [73][74][75][76][77][78][79] with summary odds ratio estimates. The overall summary odds ratio based on nine of the published studies and a total of 2,732 cases was 1.95 (95% CI 1.66-2.31). All of the studies reported an increased risk of melanoma with history of sunburn during childhood with the odds ratios for individual studies ranging from 1.2-6.5. The lower bound of the majority of the confidence intervals presented for each study (6 of 9) was at or above the null value of 1.0, indicating the range of the true increased risk associated with sunburn
history. Summary estimates were calculated for seven studies excluding the two studies that were outliers based on tests of heterogeneity. The summary odds ratio was 1.62 (95% CI 1.35-1.95) based on 2,010 cases.

Twelve case control studies have addressed the association between sunburn during adolescence and melanoma[41] [45] [56] [60] [68] [76][77][81] [84][85][86] (See Table 2). In the Elwood and Jopson[10] review, seven of these studies[45] [56] [70] [74][75] [78][79] [87] were included in a pooled analysis. The odds ratios from individual studies range from 0.7 - 2.4; the overall summary odds ratio based on these studies (age range for sun exposure approximately 12 - 20 years) with a total of 1,826 cases was 1.73 (95% CI 1.44-2.07). Five of the seven studies reported an increased risk of melanoma with history of sunburn during adolescence. Summary estimates were calculated by Elwood and Jopson[10] for these five studies excluding the two studies that were classified as outliers. The summary odds ratio was 1.95 (95% CI 1.60-2.36) based on 1,723 cases. The lower bound of the majority of the confidence intervals presented for the studies (5 of 7) was at or above the null value of 1.0, indicating the possible range of the true increased risk associated with sunburn history.

Despite the strong evidence of sunburns during childhood and adolescence being a critical time period for the future development of melanoma, a handful of studies have not provided evidence of this “critical period.”[82, 83, 88] In a case-control study of 413 cases and 416 controls by Bataille et al.[82], sunburns before the age of 15 years were not associated with melanoma after adjustments for age, gender, and skin. Some studies have also suggested that sun exposure during adulthood is just as influential as sun exposure during childhood and adolescence.[83, 88] Pfahlberg et al.,[88] in a case-control study of 603 melanoma cases and 627 population controls from 11 participating centers in seven European countries, determined that the magnitude of melanoma risk is equally significant with an increasing number of sunburns during both childhood (OR = 2.0, 95% CI 1.2-3.5) and adulthood (OR = 2.1, 95% CI 1.4-3.3).

In a study by Autier et al.,[11] the joint effects of sun exposure during childhood and adulthood on melanoma risk were investigated. The findings suggest that adults who had intense childhood sun exposure are at the highest risk of melanoma (OR = 4.5, 95% CI 1.6-12.5, comparing high childhood and high adulthood sun exposure to low childhood and low adulthood sun exposure). However, the effects of sun exposures during childhood and adulthood were found to be not simply additive, and there was evidence to support a multiplicative interaction between sun exposures during these time periods. Therefore, high childhood sun exposure only led to significant melanoma risk if there was substantial sun exposure during adult life. This study showed that sun exposure during childhood and adulthood are interdependent in terms of melanoma risk.

In Whiteman’s review, ten case-control studies that reported melanoma risks associated with personal sun exposure during two or more age periods found no consistent findings.[35][36] [38] [56] [62] [74] [77][78][79] [86] Three case-control studies reported higher melanoma risk associated with childhood sun exposure,[41] [70] [75] while one study reported higher risk associated with adulthood sun exposure.[77] Five
case-control studies reported similar melanoma risk regardless of sun exposure age.[38] [56] [74] [79] [86]

Whiteman and Green[89] also conducted a review of the literature and calculated pooled estimates of melanoma risk associated with sunburn history. Sixteen case control studies were initially identified for inclusion; however, only two studies had comparable definitions of sunburn to pool the results. The overall risk of melanoma in those who reported ever having a sunburn was 2.0 (95% CI 1.6-2.6); numerous episodes of severe sunburn were associated with a 3.7-fold increased risk of melanoma. Analyses were also done to examine the relationship between childhood sunburn and risk of melanoma; however, only three studies met the inclusion criteria used by Whiteman and Green[89] for these analyses.[56] [70] [75] Because the odds ratios were heterogenous based on statistical testing, the authors did not attempt to pool the data and concluded that these studies do not support a positive relationship between childhood sunburn and increased risk of melanoma. The odds ratios from these three individual studies ranged from 2.1-8.9.

**Discussion**

We reviewed the literature on sun exposure during childhood and adolescence and risk of melanoma skin cancer during adulthood. Migrant studies generally indicate an increased melanoma risk in individuals who spent childhood in sunny geographic locations, and decreasing melanoma risk with older age at arrival to a sunny location. Individuals who resided in geographic locations close to the equator and close to the coast during childhood and/or adolescence have an elevated melanoma risk compared to those who lived at higher latitudes and never lived near the coast during the same age period. Studies on intermittent sun exposure during vacation, recreation, or occupation are variable. To date, the majority of sunburn studies suggest a positive association between early age sunburn and subsequent risk of melanoma.

There was significant variation in the methodologies used for the assessment of sun exposure in the studies and there was potential for bias from misclassification in almost all of the studies. It is quite difficult to measure sun exposure accurately. Sun exposure has been quantified in a variety of ways including: cumulative amount of exposure, type of exposure (e.g. recreational), pattern of exposure (chronic versus intermittent), and frequency of sunburn. Various approaches have been utilized to define and measure these exposures. Epidemiologic studies commonly use questionnaires to obtain information on exposures of interest when studying large groups of people in free living populations. This approach has been widely adopted for the study of sun exposures and skin cancer, although inherently there is the potential for both differential and nondifferential misclassification.[87] [90] Differential misclassification, resulting from recall bias may have affected the results in these studies if diseased cases over- or underreported sun exposure history as compared to nondiseased controls. Furthermore, the association between sun exposure during childhood and adolescence and melanoma may be underestimated due to the random misclassification of early life exposures. This
may explain the inconsistent results between studies, as well as the relatively weak observed associations.

Several studies have reported on the reliability or reproducibility of sun exposure measures. Most studies have shown that retrospective assessment of sun exposure in adults is not indicative of the actual amounts and patterns of exposure, nor are the results reproducible. In a few studies, however, habitual sun exposure in adolescents was identified as a stable behavior that is reported with an acceptable degree of validity and reliability, while sun exposure in adults has been reported with high levels of validity and fair to good reliability.

Prospective studies assessing sun exposure during different time periods of life (childhood, adolescence, young adulthood) using a reliable and quantitative method for determining ultraviolet exposure are important. Work has been done to establish standards for determining ultraviolet radiation exposure, which suggests the need for further research. To understand the etiology of skin cancer, especially melanoma, and the effect of sun exposure during different time periods of life, detailed and valid exposure information must be obtained on age at first sunburn, age at last sunburn, and number of sunburns. Information should also be obtained for protective measures, such as sunscreen use and wearing of protective clothing, to allow for adjustment in the analyses.

In studies of sun exposure and melanoma, estimates of effect will be influenced by adjustment or lack of adjustment for sun sensitivity and any related “genetic susceptibility”. There is variability in individual response to ultraviolet radiation exposure which has been characterized by phenotypic measures, hair, eye and skin color, skin type, freckling, propensity to burn versus tan, and number of nevi. Some studies, although not all, suggest an increased risk associated with individuals who burn easily and tan poorly and are thus inherently susceptible to the effects of the sun. Studies assessing the effect of sun exposure on risk of melanoma may be confounded (negatively) by lack of adjustment for sun sensitivity and there may be an interaction between exposure and susceptibility. Furthermore, pigmented traits, eye, hair and skin color are highly correlated with each other as well as with the ability to tan. Controlling for skin type when studying sunburn and melanoma has the potential to obscure an association because skin type is a determinant of sunburn and highly correlated with sunburn. Studies should focus on examining the interrelationships between ability to tan, propensity to burn, skin type, history of sunburns, timing and pattern of sun exposure, number of nevi, and other host factors.

As skin cancer education programs directed to children and adolescents continue to expand, an epidemiologic basis for these programs is necessary to target efforts and plan for further evaluation. There is the possibility that negative studies susceptible to publication bias may have been underrepresented in our review. Future research studies may help to clarify the relationship between sun exposure during this time period of life and risk of melanoma during adulthood. Future research efforts should focus on (1) clarifying the relationship between sun exposure and melanoma, (2) conducting prospective studies, (3) assessing sun exposure during different time periods of life using
a reliable and quantitative method, (4) obtaining information on protective measures, and (5) examining the interrelationships between ability to tan, propensity to burn, skin type, history of sunburns, timing and pattern of sun exposure, number of nevi, and other host factors in the child and adolescent populations.

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**What is already known on this topic**

- While melanoma is thought to be rare in individuals under the age of 20 years, recent evidence has indicated a rapidly rising incidence of melanoma in children and teenagers
- Epidemiologic studies have revealed a strong association between sun exposure during critical periods of early life and subsequent risk of melanoma during adulthood
- Although the effects of sun exposure during early life are thought to be important, there remains controversy about the age period when most of an individual’s exposure occurs

**What this study adds**

- A comprehensive summary of epidemiologic research on sun exposure during childhood and adolescence and future melanoma risk
- A critical review of previous studies and their methodology
- Public health recommendations for skin cancer education programs
References


Table 1 - Summary of results from studies on recreation, vacation, and/or occupation sun exposure during childhood and adolescence and melanoma skin cancer.

<table>
<thead>
<tr>
<th>First author, (reference), Year, location</th>
<th>Study design</th>
<th>Assessment of sun exposure and comparison</th>
<th>Critical age periods investigated</th>
<th>RR/OR (95% CI)</th>
<th>Adjusted RR/OR (95% CI)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECREATION, VACATION, AND/OR OCCUPATION</td>
<td></td>
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</tr>
<tr>
<td>Paffenbarger[52], 1978, USA</td>
<td>Retrospective cohort 45/180</td>
<td>Outdoor employment (yes v. no)</td>
<td>Prior to College</td>
<td>3.9 (N/A)</td>
<td>N/A</td>
<td>Purpose of study to generate hypotheses.</td>
</tr>
<tr>
<td>Lew[68], 1983, USA</td>
<td>Case control 111/107</td>
<td>Length of vacation in sunny places (≥ 30 days v. &lt; 28 days)</td>
<td>Childhood</td>
<td>2.5 (1.1-5.8)</td>
<td>N/A</td>
<td>No adjustment for confounders.</td>
</tr>
<tr>
<td>Green[36], 1986, Australia</td>
<td>Case control 153/154</td>
<td>Total hours of sun exposure (≥ 5000 v. &lt; 500)</td>
<td>Childhood Adolescence (ages 10-19 yrs)</td>
<td>1.8 (N/A)</td>
<td>4.4 (1.8-184.5)</td>
<td>Adjusted for age and nevi.</td>
</tr>
<tr>
<td>Holman[45], 1986, Australia</td>
<td>Case control 507/507</td>
<td>Outdoor exposure proportion (≥ 60% v. &lt; 29%)</td>
<td>Childhood Adolescence (ages 10-24 yrs)</td>
<td>N/A</td>
<td>1.57 (0.87-2.83)</td>
<td>Limited to SSM; adjusted for acute, chronic skin reaction, hair color, origin, and age at arrival.</td>
</tr>
<tr>
<td>Weinstock[69], 1991, USA</td>
<td>Nested case control 130/300</td>
<td>Swimsuit use outdoors (most v. least)</td>
<td>Adolescence (ages 15-20 yrs)</td>
<td>N/A</td>
<td>3.5 (1.3-9.3) (sun-sensitive)</td>
<td>Adjusted for age, sun sensitivity, and latitude of residence.</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Exposure</td>
<td>Age Group</td>
<td>OR (CI)</td>
<td>Adjustment</td>
<td>Notes</td>
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<tr>
<td>Zanetti[70], 1992, Italy</td>
<td>Case control 260/416</td>
<td>Beach holidays (1-59 weeks v. zero)</td>
<td>Childhood Adolescence</td>
<td>N/A</td>
<td>2.8 (1.6-4.6)</td>
<td>Adjusted for sex and age.</td>
</tr>
<tr>
<td>Nelemans[60], 1993, Netherlands</td>
<td>Case control 141/183</td>
<td>Sunbathing (yes v. no)</td>
<td>Adolescence (ages 15-25 yrs)</td>
<td>N/A</td>
<td>3.00 (1.43-6.30)</td>
<td>Adjusted for age, sex, education, tendency to burn, hair color, and, freckling. Effect modification apparent –increased risk in sun sensitive individuals.</td>
</tr>
<tr>
<td>Nelemans[60], 1993, Netherlands</td>
<td>Case control 141/183</td>
<td>Water sports (yes v. no)</td>
<td>Adolescence (ages 15-25 yrs)</td>
<td>N/A</td>
<td>2.20 (0.75-6.49)</td>
<td>Adjusted for age, sex, education, tendency to burn, hair color, and, freckling. Effect modification apparent –increased risk in sun sensitive individuals.</td>
</tr>
<tr>
<td>Nelemans[60], 1993, Netherlands</td>
<td>Case control 141/183</td>
<td>Vacations in sunny countries (yes v. no)</td>
<td>Adolescence (ages 15-25 yrs)</td>
<td>N/A</td>
<td>2.44 (1.09-5.42)</td>
<td>Adjusted for age, sex, education, tendency to burn, hair color, and, freckling. Effect modification apparent –increased risk in sun sensitive individuals.</td>
</tr>
<tr>
<td>Study Reference</td>
<td>Study Design</td>
<td>Exposure</td>
<td>Age Group</td>
<td>OR (95% CI)</td>
<td>Comment</td>
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<tr>
<td>White[62], 1994, USA</td>
<td>Case control 256/273</td>
<td>Sun exposure index (based on days of sun exposure and amount of clothing worn for protection) high v. low</td>
<td>Childhood (ages 2-10 yrs) Adolescence (ages 11-20 yrs)</td>
<td>N/A</td>
<td>0.30 (0.17-0.55) (childhood) 0.31 (0.16-0.59) (adolescence) Limited to “deep/moderate tanners”; adjusted for age, sex, and education; dose response effect.</td>
<td></td>
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<tr>
<td>Nelemans[71], 1994, Netherlands</td>
<td>Case control 128/168</td>
<td>Swimming pools v. none Open waters v. none</td>
<td>Childhood</td>
<td>3.11 (1.66-5.75) (swimming pools) 2.24 (1.11-4.52) (open waters)</td>
<td>2.20 (1.05-4.62) (swimming pools) 2.41 (1.04-5.58) (open waters) Adjusted for age, gender, education, hair color, freckling, tendency to burn, and sunlight exposure.</td>
<td></td>
</tr>
<tr>
<td>Walter[61], 1999, Canada</td>
<td>Case control 583/608</td>
<td>Days of outdoor activity (&gt; 100 v. ≥ 100)</td>
<td>Adolescence (ages 10-20 yrs)</td>
<td>0.67 (0.53-0.85)</td>
<td>0.67 (0.52-0.85) Adjusted for age, gender, and skin reaction to sun.</td>
<td></td>
</tr>
<tr>
<td>Walter[61], 1999, Canada</td>
<td>Case control 583/608</td>
<td>Beach vacations (yes v. no)</td>
<td>Age 12 yrs Age 18 yrs</td>
<td>1.63 (1.29-2.07) 1.26 (0.98-1.63)</td>
<td>1.67 (1.31-2.12) 1.29 (1.00-1.67) Adjusted for age, gender, and skin reaction to sun.</td>
<td></td>
</tr>
<tr>
<td>Kaskel[72], 2001, Germany</td>
<td>Case control 271/271</td>
<td>Outdoor activities (at least one of walking, playing soccer, cycling, athletics, or</td>
<td>Childhood (age ≤12 yrs)</td>
<td>N/A</td>
<td>0.3 (0.1-1.1) Adjusted for age, gender and residence</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 - Summary of results from studies on sunburn during childhood and adolescence and melanoma skin cancer.

<table>
<thead>
<tr>
<th>First author, (reference), Year, location</th>
<th>Study design No. cases/controls</th>
<th>Assessment of sun exposure</th>
<th>Critical age periods investigated</th>
<th>RR/OR (95% CI)</th>
<th>Adjusted RR/OR (95% CI)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SUNBURN</strong></td>
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<tr>
<td>Lew[68], 1983, USA</td>
<td>Case control 111/107</td>
<td>Painful sunburns (childhood) Blistering sunburns (adolescence) (yes v. no)</td>
<td>Childhood Adolescence</td>
<td>N/A</td>
<td>2.8 (1.3-6.3) (childhood) 2.05 (1.18-3.56) (adolescence)</td>
<td>No adjustment for confounders; painful sunburn during childhood assessed in good tanners.</td>
</tr>
<tr>
<td>Elwood[74], 1984, Canada</td>
<td>Case control 595/595</td>
<td>Episodes of severe Sunburn (severe/frequent v. rare/mild)</td>
<td>Childhood</td>
<td>1.9 (N/A)</td>
<td>1.3 (0.9-1.8)</td>
<td>Adjusted for hair, skin/eye color, freckles, sun reaction, and ethnicity.</td>
</tr>
<tr>
<td>Holman[73], 1986, Australia</td>
<td>Case control 507/507</td>
<td>≥ 5 Painful sunburns v. none</td>
<td>Childhood (age &lt;10 yrs) Adolescence (ages 15-24 yrs)</td>
<td>N/A</td>
<td>1.11 (0.51-2.41) (childhood) 0.98 (0.53-1.82) (adolescence)</td>
<td>Limited to superficial spreading melanoma; adjusted for acute, chronic skin reaction, hair color, country of origin, and age at arrival.</td>
</tr>
<tr>
<td>Cristofolini[86], 1987, Italy</td>
<td>Case control 103/205</td>
<td>Severe sunburn (yes v. no)</td>
<td>Adolescence or early adult life</td>
<td>N/A</td>
<td>0.70 (0.41-1.19)</td>
<td>Adjustment for age and sex only.</td>
</tr>
<tr>
<td>Østerlind[56], 1988, Denmark</td>
<td>Case control 474/926</td>
<td>≥ 5 Painful (severe) sunburns v. never</td>
<td>Childhood (age &lt;15 yrs) Adolescence</td>
<td>3.7 (2.3-6.1) (childhood) 2.4 (1.6-3.6)</td>
<td>2.7 (1.6-4.8) (childhood) 1.9 (1.2-3.1)</td>
<td>Adjusted for sex, number of nevi, freckles, and hair</td>
</tr>
<tr>
<td>Study</td>
<td>Study Design</td>
<td>Sunburn Exposed</td>
<td>Sunburn Unexposed</td>
<td>Sunburn Experienced</td>
<td>Odds Ratio (95% CI)</td>
<td>Adjusted for Confounders</td>
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</table>
| Weinstock[41], 1989, USA | Nested case control 130/300 | ≥ 5 Blistering sunburns v. 0 | Adolescence (ages 15-20 yrs) | 1.9 (1.1-3.4) | N/A | No adjustment for confounders.
| Elwood[75], 1990, UK | Case control 195/195 | Severe sunburn (ever v. never) | Childhood (ages 8-12 yrs) | N/A | 2.4 (0.8-7.3) | Adjusted for nevi, freckling, social class, hair color, and tendency to burn.
| Zanetti[70], 1992, Italy | Case control 260/416 | Sunburn (often) v. never | Severe sunburn v. never | Childhood | 12.0 (4.6-31.0) | N/A | Adjusted for sex, age, and type of skin reaction; dose response effect.
| Nelemans[60], 1993, Netherlands | Case control 141/183 | History of sunburn (yes v. no) | Adolescence (ages 15-25 yrs) | N/A | 3.90 (1.82-8.33) (indoor worker) 1.90 (0.89-4.06) (outdoor worker) | Adjusted for age, sex, education, tendency to burn, hair color, and, freckling. Effect modification apparent –increased risk in sun sensitive individuals.
| Autier[76], 1994, Belgium, | Case control 420/447 | ≥ 5 Painful sunburns | Childhood (ages 5-14 yrs) | 1.75 (1.09-3.01) | 1.49(0.97-2.32) | Adjusted for hair/eye color,
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>Case Control</th>
<th>Age Groups</th>
<th>Childhood (age &lt; 20 yrs)</th>
<th>Adolescence (age &gt; 14 yrs)</th>
<th>No. of Sunburns</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>France, Germany</td>
<td>Case control</td>
<td>513/498</td>
<td>Childhood</td>
<td>1.86 (1.19-2.46)</td>
<td>1.21 (1.19-2.46)</td>
<td>N/A</td>
<td>Number of sunburns higher in cases.</td>
</tr>
<tr>
<td>Garbe[84], 1994, Germany</td>
<td>Case control</td>
<td>400/640</td>
<td>Adolescence</td>
<td>1.0 (0.5-2.1)</td>
<td>1.6 (1.0-2.6)</td>
<td>N/A</td>
<td>Adjusted for nevi and hair color.</td>
</tr>
<tr>
<td>Westerdahl[77], 1994, Sweden</td>
<td>Case control</td>
<td>452/930</td>
<td>Childhood</td>
<td>3.3 (2.3-4.7)</td>
<td>2.4 (1.6-3.5)</td>
<td>N/A</td>
<td>Adjusted for sunscreen use, skin reaction to sun, hair color, nevi, complexion, ethnicity, history of skin cancer, and age; dose response apparent; effect modification by ability to tan.</td>
</tr>
<tr>
<td>Holly[78], Cress, 1995, USA</td>
<td>Case control</td>
<td>105/138</td>
<td>Childhood</td>
<td>2.4 (1.1-5.52)</td>
<td>2.5 (1.5-8.4)</td>
<td>N/A</td>
<td>Adjusted for age, skin color and type; dose response apparent.</td>
</tr>
<tr>
<td>Reference</td>
<td>Study Design</td>
<td>Outcome Measures</td>
<td>Age Group</td>
<td>Odds Ratio (95% CI)</td>
<td>Adjustment</td>
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<tr>
<td>Pfahlberg[83], 2001, Europe</td>
<td>Case control 603/627</td>
<td>≥ 6 sunburns v. none &lt;6 sunburns</td>
<td>Childhood (≤ age 15 yrs)</td>
<td>N/A</td>
<td>2.0 (1.2-3.5) Adjusted for location, ethnic origin, age and sex.</td>
<td></td>
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<tr>
<td>Kaskel[72], 2001, Germany</td>
<td>Case control 271/271</td>
<td>Sunburn ever v. never</td>
<td>Childhood (≤12 yrs)</td>
<td>5.7 (3.2-10.1)</td>
<td>1.9 (0.9-4.2) Adjusted for age, gender and residence.</td>
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<tr>
<td>Siskind[80], 2002, Australia</td>
<td>Case control 1263/3111</td>
<td>Hours in summer sun on weekdays, weekends and holidays.</td>
<td>Childhood (ages 5-12 yrs)</td>
<td>N/A</td>
<td>1.2 (1.1-1.3) Adjusted for skin color, hair color, propensity to burn, nevus density and age</td>
<td></td>
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<tr>
<td>Kennedy[85], 2003, Netherlands</td>
<td>Case control 580/386</td>
<td>Painful sunburn</td>
<td>Childhood/Adolescence (ages 0-19 yrs)</td>
<td>N/A</td>
<td>1.4 (0.9-2.1) Adjustment for age, sex and skin type</td>
<td></td>
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<tr>
<td>Soloman[81], 2004, USA</td>
<td>Case control 386/727</td>
<td>No. of sunburns (3+ v. none)</td>
<td>Female Childhood (ages 2-10 yrs)</td>
<td>N/A</td>
<td>3.4 (2.2-5.4) 3.3 (2.0-5.3) 1.8 (1.2-2.8) 2.3 (1.4-3.5) Adjustment for age, sex, income, tendency to burn, and sunburns during ages 2-10.</td>
<td></td>
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</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Outcome</td>
<td>Age Group</td>
<td>Odds Ratio (95% CI)</td>
<td>Adjustment</td>
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<tr>
<td>Bataille[82], 2004, UK</td>
<td>Case control 413/416</td>
<td>Severity of sunburns (ever v. never)</td>
<td>Childhood (&lt; age 15 yrs)</td>
<td>1.6 (1.1-2.3)</td>
<td>1.3 (0.9-2.0)</td>
<td>Adjusted for age, gender and skin type.</td>
<td></td>
</tr>
</tbody>
</table>
Sun exposure and risk of melanoma

Susan A Oliveria, Mona Saraiya, Alan C Geller, Maureen K Heneghan and Cynthia Jorgensen

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