Increases in Melanoma Among Adolescent Girls and Young Women in California

Trends by Socioeconomic Status and UV Radiation Exposure

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Objective: During the past 3 decades in the United States, melanoma incidence among non-Hispanic white girls and women aged 15 to 39 years has more than doubled. To better understand which specific subpopulations of girls and women experienced this increase and thereby to target public health interventions, we assessed the relationship between melanoma incidence and small-area level measures of socioeconomic status (SES) and UV radiation (UV-R) exposure.


Setting: State of California.

Participants: A total of 3800 non-Hispanic white girls and women aged 15 to 39 years, in whom 3842 melanomas were diagnosed.

Main Outcome Measures: Incidence rates per 100 000 person-years and rate ratios according to SES quintiles and UV-R exposure tertiles.

Results: Whereas melanoma rates increased over time for all SES categories, only changes among the highest 3 categories achieved statistical significance. UV radiation was significantly and positively associated with melanoma incidence only among adolescent girls and young women in the 2 highest quintiles ranked by SES, which suggests that SES is not a proxy for UV-R exposure. Those living in neighborhoods with the highest SES and UV-R categories had 80.0% higher rates of melanoma than those in neighborhoods in the lowest categories (rate ratio, 1.80; 95% confidence interval, 1.13-3.01).

Conclusions: Understanding the ways that SES and UV-R exposure work together to influence melanoma incidence is important for planning effective prevention and educational efforts. Interventions should target adolescent girls and young women living in high SES and high UV-R neighborhoods because they have experienced a significantly greater increase in disease burden.

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MELANOMA IS THE MOST lethal form of skin cancer and represents a substantial cause of productive years of life lost to cancer, especially when occurring in young persons. Among non-Hispanic white girls and women aged 15 to 39 years in the United States, age-adjusted incidence rates of cutaneous melanoma among adolescents have more than doubled (from 5.5 to 13.9 cases per 100 000 person-years) during a 3-decade period (1973-2004), with a 2.7% (95% confidence interval [CI], 2.1-3.4) increase annually since 1992. Rates among young men of the same age plateaued after 1980 (annual percentage change, 0.4; 95% CI, −0.2 to 0.9).1 Increases among women were comparable for late-stage and localized tumors, suggesting that heightened surveillance does not entirely explain the incidence changes, which would theoretically manifest as increased diagnoses of thinner cutaneous melanomas.1

Current understanding of melanoma etiology implicates 2 general and probably synergistic causes: UV radiation (UV-R) exposure2,3 and genetic susceptibility.4-7 UV radiation exposure from artificial (ie, history of frequent tanning-bed use) and naturally occurring (ie, history of repeated sunburn and various measures of total time spent outdoors) sources correlates with melanoma risk.6,11 Socioeconomic status (SES) is another...
strong predictor of melanoma incidence at the population level, with the highest rates occurring among persons with higher SES. This association may reflect a variety of risk factors, including knowledge regarding melanoma prevention, access to physician skin screening, and/or social norms regarding recreational activities that increase UV-R exposure. Artificial and naturally occurring UV-R exposure may be linked to SES because affluence tends to affect leisure and vacation time, travel to regions where UV-R differs from that of the home area, and sunbathing attitudes and practices. It remains unclear whether SES affects melanoma rates independently of or as a proxy for UV-R exposure.

Incidence of melanoma is consistently and significantly higher among fair-skinned populations, with more than 90% of all US cases occurring among non-Hispanic whites (hereafter referred to as whites). A recent study found overall increases in melanoma rates among white girls and women aged 15 to 39 years but did not assess SES or other specific population characteristics associated with the increase. We took advantage of the availability of small-area measures of SES and UV-R to investigate their association with melanoma incidence among non-Hispanic white adolescent girls and young women in California, where some of the highest levels of ambient UV-R exposure in the US occur and where tanning-parlor density is of an intermediate level, currently ranging from 2.3 to 13.8 facilities per 100,000 population (mean [SD] nationwide density, 11.8 [6.0]). Disentangling associations between area-level SES and UV-R exposure helps to identify subpopulations that may benefit most from public health interventions.

**METHODS**

We obtained data regarding all 3,842 incident cases of malignant melanoma (International Classification of Disease for Oncology, 3rd Edition) diagnosed among 3,800 white girls and women aged 15 to 39 years from January 1, 1988, through December 31, 1992, and January 1, 1998, through December 31, 2002, from the California Cancer Registry (CCR), which serves as the population-based cancer registry for the state. Melanoma is a reportable disease by law, and case reporting to CCR is estimated at 99%. Pericensal periods were selected based on the availability of appropriate census tract denominators necessary to calculate neighborhood SES rates. Demographic and tumor information for each newly diagnosed melanoma was abstracted directly from medical records and death certificates. Hispanic surname lists were used to aid assignment of patient Hispanic ethnicity. Population denominator estimates were based on US Census data for census tracts of residence, as described herein. This analysis was approved by the institutional review board of the Cancer Prevention Institute of California.

**RESIDENTIAL SES INDEX**

Most US cancer registries do not collect individual-level patient SES characteristics. However, CCR routinely geocodes the patient residential address at time of diagnosis to a US census tract and calculates neighborhood SES rates. For this study, we linked to census information regarding neighborhood SES. We used an SES index developed by Yost et al that uses principal component analysis to incorporate information regarding 7 census indicator variables integrating 3 key domains of SES (educational level, income, and occupation): average educational attainment, median annual household income, percentage living below the federal poverty level, percentage of blue-collar workers, percentage of workforce older than 16 years and unemployed, median monthly rent, and median house value. This SES measure has been demonstrated to show meaningful variation in California melanoma incidence. Individuals for whom census tract group by residence at diagnosis was unknown (incident cases, 260 [6.7%]) were randomly allocated to a tract within the same county. These individuals did not differ significantly from patients with known tract group by distributions of neighborhood SES or UV-R (as seen herein). Standardized scores assigned to each census tract were categorized into quintiles, each representing 20% of the total population (1=lowest and 5=highest) because finer categorizations did not provide adequate sample size. Because census tract-level population denominators are available from the US Census Bureau for decennial census years only, we examined SES-specific trends for the 5-year pericensal periods 1988 to 1992 and 1998 to 2002, as has been performed previously.

**RESIDENTIAL UV-R EXPOSURE INDEX**

We calculated UV-R exposure based on residential census tract at diagnosis of melanoma, using previously described methods. Briefly, we derived 1-km² ground surface level UV-R values using spatial smoothing techniques for data from 215 UV-R measurement stations throughout the United States (13 of which are spread throughout California, with most in highly populated areas of the state), adjusted for local climate and terrain features. The resulting surface of ground level UV-R for California was intersected with the census tract polygons for all census tracts in California to provide a measure of potential residential average annual UV-R exposure (measured in average annual watt-hours per meter squared [Wh/m²]). This objective measurement approach for UV-R exposure has been previously validated and shown to correlate highly with melanoma risk. UV radiation indices were categorized into tertiles (1=low [3908-4949], 2=intermediate [4950-3603], and 3=high [5064-5723]).

**STATISTICAL ANALYSIS**

We used SEER*Stat version 6.5.1 (National Cancer Institute, Bethesda, Maryland) to calculate incidence rates per 100,000 person-years for the 2 available time periods, 1988 to 1992 and 1998 to 2002; rate ratios; and corresponding 95% confidence intervals (CIs). All rates were age adjusted to the year 2000 US standard. Tests of statistical significance assumed a 2-sided P value of <.05. Rate ratios were calculated for comparison across categories and trends were charted on a semilogarithmic scale to aid visual assessment of slope differences.

**RESULTS**

During the periods for which small-area population data to calculate SES were available from the US Census (1988 to 1992 and 1998 to 2002), 3,842 cases of malignant melanoma diagnosed in white girls and women aged 15 to 39 years were reported to the CCR. Characteristics of these patients are shown in Table 1. Most tumors were thin (≤2 mm) and occurred among women aged 30 years and older, although all 5-year age groups demonstrated statistically significant increases between 1988 to 1992 and...
1998 to 2002. The incidence of thin and thick tumors increased between the 2 periods, whereas the incidence of tumors with unknown/other thickness decreased. The proportion of cases within each SES quintile was similar over time. Regardless of the year of diagnosis, adolescent girls and young women in the highest SES quintile were nearly 6-fold more likely to be diagnosed with malignant melanoma than those in the lowest quintile.

**INCIDENCE TRENDS BY SES**

**Figure 1** and **Table 2** show changes in melanoma incidence from 1988 to 1992 and from 1998 to 2002 according to quintile of area-level SES. Increasing SES quintiles positively correlated with higher relative and absolute risks of developing melanoma. Whereas rates of melanoma increased over time in all groups, these changes were only statistically significant among adolescent girls and young women in the highest 3 SES quintiles (P < .001 for each).

**INCIDENCE TRENDS BY UV-R LEVEL**

Because SES correlates with UV-R exposure in California, we determined the joint influence of area-level SES and UV-R on the 1998 to 2002 incidence rates, the period with the most reliable UV-R data. Higher tertiles of ambient UV-R exposure were associated with incidence increases only among adolescent girls and young women in the highest 2 SES quintiles (**Figure 2**). Little variation in rates according to UV-R existed for those in the lowest 3 SES quintiles. **Table 3** shows that girls and women in the highest SES and UV-R categories had significantly increased rates of melanoma compared with those in the lowest categories for each of those variables. Girls and women from the highest SES, highest UV-R neighborhoods experienced 73.0% greater incidence relative to those from neighborhoods with the lowest SES and highest UV-R (rate ratio, 1.73; 95% CI, 1.36-2.19) and 80% greater incidence relative to those from neighborhoods with the lowest SES and the lowest UV-R (1.80; 1.13-3.01). In addition, the rate ratio for intermediate UV-R–exposed girls and women living in neighborhoods with the highest vs the lowest SES was 2.82 (95% CI, 1.72-4.92). Ratios for all other categories of SES and UV-R did not significantly differ.
Melanoma occurrence is rising disproportionately among adolescent girls and young women, and the public health response to this problem requires a detailed understanding of which population subgroups have experienced the greatest incidence growth. This analysis, using the largest available US population-based cancer data resource with information regarding small-area neighborhood SES and UV-R indices, found significant and substantial increases in melanoma from 1988 to 1992 and from 1998 to 2002 among white girls and women aged 15 to 39 years in the highest 3 quintiles classified by SES. The fact that UV-R exposure was a meaningful determinant of melanoma incidence only among girls and women in the highest 2 SES quintiles suggests that SES is not a proxy for ambient UV-R exposure. Instead, we identified girls and women living in neighborhoods with the highest SES and UV-R categorization as the population with the greatest and most rapidly increasing incidence rates. Hence, screening recommendations should target this group and include strategies to limit ambient sun exposure and SES-related behavioral risk factors.

Socioeconomic gradients in melanoma incidence among girls and women aged 15 to 39 years are not well studied, to our knowledge. A single study from Washington State examining age-specific trends between 1974 and 1985 found no significant association between melanoma rates and census tract-based SES among girls and women aged 10 to 29 and 30 to 49 years. Our results are consistent with individual-level data regarding US men and women aged 25 years and older from a linkage between Surveillance, Epidemiology, and End Results data and those from the National Longitudinal Mortality Study, which reported significantly lower incidence rates of melanoma among individuals with lower compared with higher levels of education and income (defined as those with < a high school education vs those with ≥ college diploma: rate ratio, 0.55; 95% CI, 0.36-0.82; and those earning <$12,500 annually vs those earning ≥$50,000 annually: 0.59; 0.36-0.95) .

Since increases in ambient UV-R were associated with increases in melanoma incidence only among adolescent girls and young women in more affluent areas, overall variations in melanoma incidence cannot be explained simply by the collocation of high SES and high UV-R neighborhoods. If residence-based exposure were chiefly responsible for the increases, there would be no gradient among girls and women in the highest UV-R tertiles (index range, 5064-5723) regardless of SES. Rather, we observed that within this high UV-R group, girls and women living in higher SES neighborhoods were diagnosed with melanoma 70.0% more often than those living in lower SES neighborhoods. Socioeconomic differentials in melanoma have previously been suggested to relate to differences in sun-exposure behaviors. Affluent women have been reported to have more leisure time, during which they may pursue outdoor activities such as gardening, playing sports, or walking; they may travel more frequently to high-altitude or low-latitude vacation destinations in which UV-R exposure is greater, or they may actively participate in natural and/or artificial tanning practices.

It is unlikely that our findings are the result of changes in data quality and/or improved surveillance or screening. The increasing incidence trends observed across all SES groups, including the lowest, imply changes inde-
dependent of access to care. To understand the effect of surveillance on our results, we analyzed data by SES and melanoma thickness because heightened screening should theoretically cause disproportionate increases in early-stage, thinner tumors. Rates rose significantly for thinner (≤2-mm) and thicker (>2-mm) melanomas (data not shown), in accordance with prior reports.1,26 Purdue et al3 demonstrated nationwide increases in thinner and thicker tumors among the same demographic female population as that described in this study. Moreover, the incidence changes consistently according to SES quintile with 6.3-fold and 11.0-fold increases for thinner and thicker melanomas among the highest vs lowest quintile (data not shown). It is possible that the melanoma rates calculated here underestimate the true rates because of underreporting of melanomas to cancer registries, especially those diagnosed by private physicians. Although underreporting27-30 and delayed reporting30 have been documented, some of us have previously shown that physician reporting of melanoma does not differ according to neighborhood SES.30

Our study provided several important benefits for examining population-level patterns of melanoma occurrence in adolescent girls and young women. We took advantage of the largest available US population-level database covering all of California and offering well-developed small-area SES and UV-R indices. Furthermore, California’s income distribution is generally representative of that of the US as a whole,41 and although the state does not receive the most cumulative UV-R, the pattern and range of exposures, including days in which the risk of overexposure to UV-R from the sun is low (UV index [UV-I] <2), moderate (UV-I=3-4), high (UV-I=6-7), very high (UV-I=8-10), and extreme (UV-I=11),42 captures the pattern and range for the country overall, so our results may be generalizable to a broader segment of the US population.

Despite these strengths, our analysis had several important limitations. First, whereas we restricted our study to non-Hispanic white adolescent girls and young women, it is possible that a small proportion of individuals from other racial/ethnic backgrounds who had cancer were misclassified as being white. The CCR classified 4.0% of self-reported Hispanic patients as non-Hispanic whites.43 Second, US cancer registries, including the CCR, do not collect individual-level SES information, which could have supplemented area-level data to better separate individual from contextual effects. Inferences regarding individuals based solely on area-level data may introduce inaccuracy (the ecologic fallacy). Nevertheless, since the United States does not use any comprehensive, linked health-tracking databases, distinguishing the independent effects of different risk factors necessarily requires detailed assessment of population-based data by patient demographic characteristics. Prior studies44-48 suggest that area-level patterns are generally consistent with, but underestimate, individual-level effects. Census tract measures were the smallest, most homogeneous geographic designation for which cancer, UV-R, and SES information was available. Third, our UV-R measure assigned exposure according to the ambient UV-R of each residential census tract at time of diagnosis and did not account for cumulative lifetime or, perhaps more importantly, early childhood and adolescent UV-R exposure. Future research should track individual-level rates according to SES and UV-R.

Melanoma is generally successfully treated when diagnosed early and, thus, it should be amenable to early detection via skin screening. Whereas the American Cancer Society recommends routine physician and self-examination,49 the 2009 US Preventive Services Task Force50 did not advocate screening by primary care providers at that time because of insufficient evidence showing that the benefits outweigh the harms associated with this practice. Identification of high-risk groups who would most benefit from screening may reconcile these recommendations and contribute to more specific guidelines with greater public health effect.

Our data support further melanoma education and prevention efforts targeting white adolescent girls and young women living in high SES, high UV-R areas. It is notable that this group has been somewhat resistant to education in Australia51 but that primary prevention efforts in that country have, in fact, slowed incidence rate increases among young adolescent girls and young women.52 Successful interventions that may be amenable for use in the United States include: (1) widespread campaigns encouraging the avoidance of midday sunlight, participation in outdoor sports only during the early morning and late afternoon, and use of UV-protective clothing and hats; (2) building shade structures in areas of high sun exposure, such as beaches, bus stops, and open-air shopping malls; (3) promotion of water-

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**Table 3. Melanoma Incidence Rates Among Non-Hispanic White Girls and Women Aged 15 to 39 Years Overall and Stratified by SES Quintiles and UV-R Exposure Tertiles, January 1, 1998, to December 31, 2002**

<table>
<thead>
<tr>
<th>SES Variable</th>
<th>1: Low</th>
<th>2: Intermediate</th>
<th>3: High</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Low</td>
<td>11.6 (7.2-17.7)</td>
<td>7.4 (4.3-11.9)</td>
<td>12.4 (5.8-29.9)</td>
<td>11.0 (8.0-13.4)</td>
</tr>
<tr>
<td>2: Low-Intermediate</td>
<td>12.7 (10.0-15.9)</td>
<td>9.7 (7.5-12.5)</td>
<td>12.4 (10.2-15.0)</td>
<td>11.6 (10.2-13.1)</td>
</tr>
<tr>
<td>3: Intermediate</td>
<td>10.7 (8.6-13.2)</td>
<td>15.8 (13.4-18.5)</td>
<td>11.5 (9.6-13.7)</td>
<td>12.7 (11.4-14.0)</td>
</tr>
<tr>
<td>4: High-Intermediate</td>
<td>13.4 (11.4-15.7)</td>
<td>16.7 (14.5-19.2)</td>
<td>19.6 (16.9-22.7)</td>
<td>16.1 (14.8-17.5)</td>
</tr>
<tr>
<td>5: High</td>
<td>12.1 (10.3-14.0)</td>
<td>20.8 (18.2-23.6)</td>
<td>20.8 (17.4-24.8)</td>
<td>16.8 (15.4-18.2)</td>
</tr>
<tr>
<td>Overall</td>
<td>12.2 (11.2-13.3)</td>
<td>16.1 (14.9-17.4)</td>
<td>15.2 (14.0-16.5)</td>
<td>14.4 (13.7-15.1)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; SES, socioeconomic status; UV-R, UV radiation.

*All rates age-adjusted to the year 2000 US standard (California Cancer Registry).*

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resistant, broad-spectrum, high-SPF [sun protection factor]—containing sunscreen as an adjunct to other protection methods, and (4) legislature banning individuals younger than 18 years from using tanning beds. Australian secondary prevention programs have been even more successful at disseminating skin-protection information. Using this model, “pop–up” clinics set up at schools and local gathering places in neighborhoods with the highest SES and ambient UV-R exposure could distribute educational information, teach the American Association of Dermatology’s “ABCDE” mnemonic for assessing the clinical warning signs of melanoma, and conduct free skin screenings.

The issue of whether the recent rise in melanoma among adolescent girls and young women is linked to increased tanning practices during the past few decades requires prompt attention. Future research should seek to understand if increases in tanning-bed use directly explain these trends because this activity is easier to regulate than other behaviors, such as outdoor tanning practices. Health education to limit the social desirability of tanning could build on the success of similar efforts to curb smoking initiation among young persons. To limit the recent increase in melanoma among girls and women, multidisciplinary prevention efforts should target those living in high SES and high UV-R neighborhoods for whom melanoma rates were 80.0% greater than in other areas.

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