Sunscreen Sales, Socio-Economic Factors, and Melanoma Incidence in Northern Europe: A Population-Based Ecological Study

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Abstract
In this ecological study, we drew upon recently published melanoma prevalence data, and compared them with historical market data and published socio-economic data to test for an association between historical sunscreen sales (1997-1999) and recent melanoma incidences (2008 and 2012) in 24 countries in Northern Europe. We also explored associations between current melanoma incidences and historical data on the following socio-demographic indicators: income, urbanization, and population aging. Melanoma incidences were higher in high-income countries where sales of sunscreen were also higher. Our results show that, at the population level, income was significantly associated with melanoma incidences, $\beta = 0.0003$, t(19) = 3.104, $p < .006$, and that increased sunscreen sales has not prevented higher income populations from being at higher risk of melanoma.

Keywords
public health, health communication, melanoma, disposable income, sunscreen

Introduction
The overall global incidence of cutaneous malignant melanoma has been sharply growing over the past 50 years, with the highest rates outside of Australia and New Zealand being seen in a number of Northern European countries (Erdmann et al., 2013). Recent 10-year follow-up evidence from a randomized controlled trial suggests that melanoma may be prevented by using sunscreen, provided it is used optimally (i.e., applied every morning and reapplied after heavy sweating, bathing, or long sun exposure; Green, Williams, Logan, & Strutton, 2011). Despite Green et al.’s (2011) study providing strong evidence for the effectiveness of sunscreen under trial conditions (Robinson & Bigby, 2011), historical evidence from the late 1990s has shown that, in practice, many people do not apply sunscreen optimally (Robinson & Rademaker, 1998; Wartha Wright, Wright, & Wagner, 2001). Epidemiological evidence from case–control studies is inconclusive, with some studies suggesting that sunscreen can reduce the risk of melanoma and non-melanoma skin cancers, and others suggesting that using sunscreen might actually increase the risk of melanoma by encouraging greater sunbathing time and thus ultraviolet (UV) exposure (Autier, 2001; Burnett & Wang, 2011; LeBoit, Burg, Weedon, & Sarasin, 2006; Planta, 2011; Weinstock, 2001). A meta-analysis by Dennis, Beane Freeman, and VanBeek (2003) identified seven case–control studies that reported a decreased risk of melanoma and nine studies that reported an increased risk of melanoma, although combined odds ratios of these studies failed to show either a significantly protective or harmful association between sunscreen use and melanoma. One of the main limitations of such case–control studies is that they are based on sunscreen use questionnaires, which use broad and sometimes subjective categories to measure the frequency of sunscreen use (e.g., “often”,”rarely”,”always,” Wolf et al., 1998) and are subject to recall bias. Although sales do not directly equate to use (as not all product bought is necessarily used), market data can be considered a useful means of estimating use (in volume) because sales data are not subject to recall bias. To date, there have been no cross-national, population-based ecological studies exploring the association between melanoma prevalence and sunscreen sales data.

UV exposure is the only established exogenous causal factor for melanoma (Westerdahl, Ingvar, Masback, & Olsson, 2000), and UV radiation has been shown to have a strong negative association with latitude (Elwood et al., 1974). Epidemiologists have also explored whether

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socio-demographic variables, like income, aging, and urbanization, are also risk factors for melanoma. A number of studies at the local or national level suggest that risk of melanoma is higher among higher income populations within a country (Bentham & Aase, 1996; Haider, Mamdani, & Shear, 2007; Kerkpatrick, Lee, & White, 1990; Singh et al., 2011; van der Aa, de Vries, Hoekstra, Coebergh, & Siesling, 2011). Perez-Gomez et al. (2008) found that the relative risk of melanoma generally increased with urbanization (i.e., those living in larger towns were at higher risk of melanoma). In addition, increasing age is a risk factor for melanoma, whereby incidence starts to increase throughout adulthood and the highest age-specific incidence is in the older age groups (Marks, 2001). There are to our knowledge no substantial cross-national studies exploring the relationships between melanoma prevalence and income, urbanization, and aging at the population level.

In this ecological study, we drew upon recently published melanoma prevalence data, and compared these data with historical market data and published socio-economic data to test for an association between historical sunscreen sales and recent melanoma incidence in 24 countries in Northern Europe. We also explored associations between current melanoma incidence and historical data on the following socio-demographic indicators: income, urbanization, and population aging.

Our hypothesis is based on best-available evidence, as provided by Green et al.’s (2011) findings, that if applied consistently and optimally, sunscreen can effectively reduce the risk of melanoma among those at risk (Robinson & Bigby, 2011). Thus, we hypothesized that, after adjusting for income, urbanization, and aging and after controlling for latitude, higher historical sunscreen sales would be associated with lower recent melanoma incidence. Causality of course cannot be inferred from an ecological study, only a significant association. However, the presence of such an association could serve as a basis for further research into whether and why sunscreen has not been applied consistently and optimally across populations in line with recommended guidelines.

**Method**

Comparable melanoma incidences for 2008 and 2012 (per 100,000 of the population) were retrieved from GLOBOCAN—a publically available database produced by the International Agency for Research on Cancer’s (IARC, 2014). A full description of the methodology can be found on the IARC website (IARC, 2014). According to IARC (2014), the methods of estimation are country-specific and depend on the quality and amount of the information available for each country. However, of the 24 countries in this sample, 21 were classified as “high quality regional or national data” (17 of which had coverage greater than 50% of a country’s population; IARC, 2014). The IARC database provides the general incidence of melanoma, and did not provide information on melanoma incidence according to bodily sites nor according to type (i.e., invasive vs. in situ). Separate incidences for melanoma in men and women were available, as well as combined-sex melanoma incidences. Mean incidences were calculated using data for 2008 and 2012 (Table 1).

Industry data on sunscreen sales (in volume per capita) were obtained from the Euromonitor Passport Global Market Information Database, 2012 Edition (Euromonitor International, 2012).1 Earliest available data were from 1997. This study uses mean sunscreen sales per capita between 1997 and 1999 (Table 1). It was felt that data from 1997 to 1999 were sufficient to explore its relationship with melanoma rates in 2008 and 2012. Existing research often assumes a minimum 10-year latency period (Liu & Soong, 1999 were sufficient to explore its relationship with melanoma rates in 2008 and 2012. Existing research often assumes a minimum 10-year latency period (Liu & Soong, 1999). Therefore, we assume a minimum 10-year latency period for the purpose of this study.1

To explore and adjust for the effect of potential confounding factors, we included three socio-demographic variables in our analyses. Data on income (gross domestic product [GDP] per capita, expressed in constant 2011 international dollars purchasing power parity for comparability), urbanization (the percentage of the population living in urban areas), and population aging (the percentage of the population older than 65 years) were taken from the World Bank World Development Indicators Database (2014 edition; World Bank, 2014). For sunscreen sales, income, urbanization, and population aging, all data were historical, expressed as an average of 3 years from 1997 to 1999 (Table 1).

The model controlled for latitude as a proxy for domestic/everyday UV exposure. Variations in the intensity of UV exposure are known to be related to melanoma incidences (Crombie, 1979), and a country’s UV Index is closely correlated with its latitude. Only countries with latitudes of 45°N and above were used.2 This is consistent with previous studies that have classified latitudes above 45°N as “high latitudes” (Chang et al., 2009). This allowed us to broadly control for a country’s general UV exposure.3 Also, in all countries, the vast majority of the population was Caucasian.4

Research has shown how, indoor tanning (in which sunscreen is generally not applied) can also significantly increase the risk of melanoma (Boniol, Autier, Boyle, & Gandini, 2012), thereby making it a target for regulation across Europe (Williams, 2012). Differences in sunbed use between countries may also have contributed to the observed differences in the incidence of melanoma between countries. We were unfortunately unable to find any comparable and consistent data on indoor tanning (sunbed) use for all 24 countries in this sample, despite extensive searching. A meta-analysis by Boniol et al. (2012) provided an estimated fraction of melanoma cases attributed to sunbed use in Europe for 12 countries included in this study.
Statistical Analysis

Statistical analyses were conducted in SPSS/PASW Statistics Version 18 (SPSS, Inc., 2014). The $t$ tests were used to explore differences between male and female melanoma incidences and also between melanoma incidences in Western Europe and Central and Eastern Europe. Linear regressions were used to explore bivariate relationships between melanoma incidences and the independent variables—historical sunscreen sales, income, urbanization, population aging, and latitude. Only those variables that were significantly associated, or nearly significantly associated (95% confidence interval [CI]), with melanoma incidences were selected for the final multivariate regression model.

Results

Bivariate Analyses

A paired-samples $t$ test revealed that melanoma incidences were higher in 2012 (10.92 ± 5.27) than they were in 2008 (9.89 ± 5.27), $t(22) = -5.182$, $p < .001$. Independent-samples $t$ tests showed that there was no statistically significant difference in melanoma rates between males and females ($p > .05$). We chose to use only combined-sex melanoma incidence data in our subsequent analyses. Independent-samples $t$ tests did, however, reveal that melanoma incidences in countries in Western Europe were significantly higher than in countries in Central and Eastern Europe, $t(22) = 4.78$, $p < .001$.

Bivariate regression analysis showed that there was a statistically significant relationship between mean sunscreen sales (1997-1999) and mean melanoma incidences (2008, 2012), $\beta = 0.183$, $t(22) = 5.207$, $p < .001$. However, contrary to our hypothesis, higher sunscreen sales were associated with higher melanoma incidences. Melanoma incidences were also significantly associated with income, $\beta = 0.0003$, $t(22) = 7.406$, $p < .001$; urbanization, $\beta = 0.196$, $t(22) = 1.953$, $p = 0.064$; and aging, $\beta = 1.377$, $t(22) = 5.207$, $p = 0.043$. Melanoma incidences were generally higher in countries with higher income, greater urbanization and a larger proportion of the population aged 65 and older. Thus, these variables were included in the final regression model.

As noted above, by selecting only those European countries with average latitude above 45°N, the potential effect of
domestic/everyday UV exposure had already been accounted for (not including lower latitude/high-UV countries).

However, an additional analysis was performed to see whether variances in average latitude above 45°N were associated with melanoma incidences. A linear regression showed that there was no significant association between the latitude and melanoma incidences in the countries selected in this study ($p > .05$). Thus, latitude was not included as a variable in the final regression model.

Linear regression analysis also showed that there was no significant relationship between the estimated fraction of melanoma cases attributed to sunbed use and melanoma incidences ($p > .05$), although it is important to note the small sample size ($n = 12$). The absence of complete data and of significance in the subset meant that sunbed use was not included in the multivariate regression model.

**Multivariate Regression Analysis**

Although our final multivariate regression model (Table 2) was statistically significant, $F(4, 19) = 11.93, p < .001$, sunscreen sales, urbanization and population aging no longer significantly predicted melanoma incidence. Income remained significantly positively associated with melanoma incidence, $\beta = 0.0003$, $t(19) = 3.104, p < .001$. When organized hierarchically, income significantly increased the model’s predictive capacity, accounting for 14.9% of the total model’s predictive capacity of 65.5%. Adjusted $R^2$ were used to account for the relatively small sample size.

**Discussion**

 Regional- and national-level studies have shown that the risk of melanoma is higher among higher income populations within a country (Bentham & Aase, 1996; Haider et al., 2007; Kerkpatrick et al., 1990; Singh et al., 2011; van der Aa et al., 2011). This is to our knowledge the first multi-national comparative study to explore show the relationship between mean disposable income and melanoma rates. After adjusting for sunscreen sales, urbanization and population aging, income was strongly associated with melanoma incidence, with high-income countries having higher melanoma incidences. In higher income countries, people have more money to spend on activities that might entail intermittent high UV exposure, such as vacationing in lower latitude countries, a known risk factor (Elwood, 1992). Like most commodities, sunscreen is generally more affordable in countries with higher disposable income per capita, which helps to explain why sales were higher in higher income countries.

Although the association between sunscreen sales and melanoma incidences lost significance in our final model, we nonetheless observed that melanoma incidences were generally higher in countries with higher historical sunscreen sales. This is an important observation that adds to existing knowledge on the relationship between sunscreen use and melanoma risk. Best-available evidence suggests that sunscreen, when applied optimally, can be effective at the individual level (Green et al., 2011). However, our findings suggest that in practice, sunscreen as a public health measure has not historically succeeded in protecting against increased risk of melanoma at the ecological or population level. Sunscreen sales are a proxy for the amount of time spent in high-UV areas. However, our findings may also relate to previous research which has found that the availability of sunscreen may actually have increased population-wide UV exposure, because of the false sense of protection it confers when used improperly (Weinstock, 2001). There is a distinction to be made between how successfully sunscreen has been marketed in high-income countries (as revealed by high per capita sales), and the relative lack of success that these countries have had in the prevention of melanoma (as revealed by high melanoma incidences). Our findings can be understood in relation to historical evidence, which suggests that during the late 1990s, even though some sunscreens were chemically effective when applied optimally (Green et al., 2011), in practice, they were not being applied correctly by sunbathers during periods of high UV exposure (Robinson & Rademaker, 1998; Wartha Wright et al., 2001). In short, our results show that increased sunscreen sales did not mitigate against the increased risk that high-income populations experience as a result of income-related activities like vacations to lower latitude countries.

**Limitations**

To reiterate, one of the well-known limitations of ecological studies is that they can only show an association between variables and cannot prove causation. Using population-level data offered the potential for ecological fallacies. Our data were not able to speak to individual-level behaviors. Per capita data divide the total volume of sunscreen purchased in a country by the total population. For instance, per capita data are unable to tell us whether a small proportion of the population are buying large volumes of sunscreen, or whether a large proportion of the population are buying small volumes of sunscreen. Also, data as to who is buying sunscreen and how it is being used are not included in this study. As such, it does not tell us the extent to which men are using
sunscreen relative to women, and younger people are using sunscreen relative to older people, although this is found elsewhere in the literature (Thieden, Philipsen, Sandby-Møller, & Wulf, 2005).

Another limitation of this study is that it was not able to adjust for differences in indoor tanning (sunbed) use between countries. As discussed above, we did not find a significant association between the estimated fraction of melanoma cases attributed to sunbed use and melanoma incidences for 12 countries included in this study. However, these data pertained to a limited number of countries \( (n = 12) \) and we were unfortunately unable to find any comparable and consistent cross-national data on indoor tanning (sunbed) use, despite extensive searching. Recent data from the “Euromelanoma” (van der Leest et al., 2011) project suggests that sunbed use varies between countries, with approximately 25% of those screened in Belgium reported having used sunbeds compared with less than 10% of those screened in the Ukraine. Although insufficient for the purposes of this article, the growing Euromelanoma project may provide valuable and comparable data on sunbed use across European countries, which could be used for future studies exploring these trends at the population level.

It is also worth noting that most of the existing literature on melanoma and sunscreen use concerns studies conducted before 1990, when sunscreens with little UVA protection were available. More recent sunscreens have started to include ingredients (e.g., avobenzone) that offer some UVA protection. With UVA being linked to melanoma development (Wang et al., 2001) and with newer sunscreens offering UVA protection, future ecological studies might show a different relationship between sunscreen use and melanoma rates.

One other consideration is the role of public awareness campaigns. Again, comparable and quantifiable data on melanoma prevention campaigns were not available across all the countries in our sample. As with sunbed use, the “Euromelanoma” campaign offers potential for future cross-national studies to explore associations between recent large-scale prevention initiatives (e.g., disseminating information about skin cancer and offering skin examinations to the general public on “Melanoma Day”; van der Leest et al., 2011).

**Conclusion**

Melanoma incidences were higher in high-income countries where sales of sunscreen were higher. In short, our results show that, at the population level, income was significantly associated with melanoma incidences, and that increased sunscreen sales has not prevented higher income populations from being at higher risk of melanoma. From a public health perspective, our results correspond with existing advice that sunscreen should be applied according to optimal recommendations (i.e., one teaspoon should be applied to per body part, prior to sun exposure and should be reapplied regularly and after activities such as swimming) and alternative methods of sun protection should be considered (e.g., wearing clothes and wide-brimmed hats; Robinson & Bigby, 2011).

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**Notes**

1. More details about Euromonitor’s data collection methodology can be found online at http://www.euromonitor.com/research-methodology
2. Latitudes were taken from the CIA Factbook (https://www.cia.gov/library/publications/the-world-factbook/).
3. Latitude varies across individual countries (i.e., the difference in latitude in much difference there is between the north and south of the country). However, the average latitudes given serve broadly as an ecological control for latitude (and thus as a proxy for a country’s general national ultraviolet [UV] exposure).
4. Southern European populations (at lower latitudes) have darker skin types that are less sensitive to UV radiation; thus, making comparisons across populations of different skin types would be more difficult.

**References**


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