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Tanning bed use and melanoma: Establishing risk and improving prevention interventions☆

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ABSTRACT

Purpose. Exposure to ultraviolet radiation (UVR) from indoor tanning devices is thought to cause melanoma and other negative health consequences. Despite these findings, the practice of indoor tanning in the United States remains prevalent. In this paper we aim to present a clear discussion of the relationship between indoor tanning and melanoma risk, and to identify potential strategies for effective melanoma prevention by addressing indoor tanning device use.

Basic procedures. We reviewed relevant literature on the risks of indoor tanning, current indoor tanning legislation, and trends in indoor tanning and melanoma incidence. Study was conducted at the University of Southern California, Los Angeles, CA between the years of 2014 and 2015.

Main findings. Our findings reaffirm the relationship between indoor tanning and melanoma risk, and suggest a widespread public misunderstanding of the negative effects of indoor tanning.

Principal conclusions. This review argues for an aggressive initiative to reduce indoor tanning in the United States, to design prevention efforts tailored towards specific high risk groups, and the need to better inform the public of the risks of indoor tanning.

Contents

Introduction

Since entering the United States in the 1970s, indoor tanning devices now support a $3 billion a year industry (Tanning Salons in the US, 2015). Despite an encouraging small decrease in indoor tanning behaviors noted between 2010 and 2013, a 2013 study from the National Health Interview Survey estimates that 7.8 million women and 1.9 million men in the United States tan indoors each year (Guy et al., 2015). Additional

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reports confirm similar findings (*J. Am. Acad. Dermatol.*, 1985). The high incidence of indoor tanning in the United States remains concerning in the setting of strong evidence in support of an association between the use of indoor tanning beds and melanoma risk (Group IAfRoCW, 2007) (El Ghissassi et al., 2009).

In 2009, as a response to data highlighting the risks associated with indoor tanning, the World Health Organization International Agency for Research on Cancer (IARC) classified ultraviolet light emitted from tanning beds as carcinogenic, and placed artificial sources of ultraviolet radiation alongside tobacco and asbestos in the highest category of carcinogen (El Ghissassi et al., 2009). The Society of Behavioral Medicine issued a position statement calling for a ban on indoor tanning in minors in 2014, and the American Academies of Dermatology and Pediatrics also released recent reports in support of a total ban on indoor tanning in individuals under the age of 18 (Pagoto et al., 2014).

Despite these and other efforts to reduce indoor tanning, melanoma incidence is rising in the United States and worldwide, over and above the effects of screening (Purdue et al., 2008; Garbe and Leiter, 2009). It is the goal of this paper to explore current evidence supporting the relationship between indoor tanning and melanoma risk, and to promote novel efforts to reduce melanoma incidence by identifying and targeting the populations most at risk of negative consequences from tanning indoors.

Methods

References for this review were collected via a "PubMed" search from years 1970 to 2015, English language only, and the review of the literature cited in selected papers. Search terms used included "indoor tanning", "tanning bed(s)", "sunbed(s)", "artificial tanning", "UV tanning", "ultraviolet light tanning", and "melanoma(s)". No restrictions were made regarding study design or type of paper. Review of the literature noted the critical pieces of information that went into (1) establishing the health risks of tanning; (2) efforts to prevent tanning; and (3) shortcomings of those efforts to date.

Results and discussion

The health risks of UV radiation obtained from indoor tanning

A common misconception among indoor tanners is that artificial UVR produces a "safer" tan than outdoor sunlight (CDC, 2014). This belief is contradicted by scientific evidence, and must be addressed in order to effectively reduce the burden of indoor tanning on health outcomes worldwide. Exposure to UVR from indoor tanning devices has been shown to cause DNA damage in skin cells, and is associated with an increased risk of developing melanoma, and squamous and basal cell carcinomas (Whitmore et al., 2001; The International Agency for Research on Cancer Working Group on Artificial Ultraviolet I SC, 2006; Karagas et al., 2002). Indoor tanning has also been associated with accelerated skin aging, ocular melanoma, immune suppression, and skin burns (Whitmore et al., 2001; Piepkorn, 2000; Vajdic et al., 2004; Walters and Kelley, 1987; Clingen et al., 2001; Cokkinides et al., 2009). Due to variation in the intensity and UV wavelength emitted by indoor tanning devices, consistent regulation of their use is paramount.

Indoor tanning devices exert their effect through the emission of both UVA and UVB radiation. While UVB is associated with direct DNA damage through cyclobutane pyrimidine dimer formation and the production of DNA damaging photoproducts, UVA exposure is associated with indirect DNA damage through the production of reactive oxygen species (Matsumura and Ananthaswamy, 2004; Walter et al., 1999; Autier et al., 1994; Bataille et al., 2004; Petersen et al., 2000). Solar UVR reaching the earth's surface is composed of roughly 95% UVA and 5% UVB radiation (El Ghissassi et al., 2009). UVB radiation induces burning of the skin at a much lower dose than UVA, which requires emissions 500 to 1000 times that of UVB to evoke a response (Gies et al., 1986; Parrish et al., 1982; Ying et al., 1974; Kaidbey and Kligman, 1979). Although UVB produces a delayed erythema (sunburn) or tan more efficiently than UVA, UVA alone is sufficient to cause a reaction (Parrish et al., 1982; *Praeger*, 1986). Indoor tanning devices can emit UVR in amounts 10 to 15 times higher than the sun at its most direct exposure (The International Agency for Research on Cancer Working Group on Artificial Ultraviolet I SC, 2006). In the 1990s UVB-exclusive high intensity tanning devices were developed, as well as high pressure UVA-only devices. Lazovich et al. examined the individual effect of these devices on melanoma risk (Lazovich et al., 2010). The authors found users of high intensity devices, high pressure devices, and traditional sunlamps to have an increased likelihood of developing melanoma compared to respondents who had never tanned indoors. Lazovich et al. could not identify one type of tanning equipment as more associated with melanoma than another, replicating the findings of previous research on risk according to indoor tanning device type (Bataille et al., 2004; Veierod et al., 2003; Clough-Gorr et al., 2008; Chen et al., 1998).

To address the association between indoor tanning and melanoma incidence, Lazovich et al. examined cases of invasive cutaneous melanoma diagnosed in individuals between the ages of 25 and 59 in Minnesota from 2004 to 2007 (Lazovich et al., 2010). The authors concluded that the use of UVB and UVA indoor tanning devices conferred an elevated risk of melanoma that increased with use by years, hours, and sessions. Risks were seen across all device types, and regardless of the age of at which the individual first tanned. The likelihood of melanoma having ever tanned indoors was 1.74 (95% CI 1.42, 2.14), while the adjusted odds ratio ranged from 2.5 to 3.0 in the category of greatest use (more than 50 h, more than 100 session, 10 or more years). When taking anatomic site of melanoma into account, by gender the dose response pattern remained significant for both men and women for truncal melanomas, among men with head and neck melanomas, and women with melanoma of the upper or lower limbs. It was also noted that melanoma cases were more likely to have been burned when indoor tanning and reported a greater number of painful sunburns than controls.

While Lazovich et al. adjusted for outdoor sun exposure, Vogel et al. assessed melanoma risk in the absence of sunburn from outdoor UVR. Vogel reported that melanoma patients who had never experienced sunburn were four times as likely to have tanned indoors than melanoma patients who had never tanned indoors, including those who reported zero lifetime sunburns (odds ratio, 3.87; $P = 0.002$) (Vogel et al., 2014). In patients with a history of sunburn, melanoma patients reported a greater number of years and sessions of indoor tanning, and having started tanning indoors at an earlier age than controls (Vogel et al., 2014).

A 2005 meta analysis reported an odds ratio of 1.25 (1.05–1.49) of having a melanoma if having ever used an indoor tanning bed (Gallagher et al., 2005). The risk was reported to increase to 1.69 (1.32–2.18) if the first exposure was as a young adult (Lazovich et al., 2010). These results were replicated by the International Agency for Research on Cancer, and supported by a 2005 meta analysis finding a 75% increase in risk of melanoma when indoor tanning began during adolescence or early adulthood (The International Agency for Research on Cancer Working Group on Artificial Ultraviolet I SC, 2006; Boniol et al., 2012). Sunbed use in adolescence was also noted to confer an additional risk of melanoma development by Cust et al. 2011, who reported the risk of melanoma attributed to sunbed use before age 35 as 75% (Cust et al., 2011).

A review of 27 observational studies associating use of sunbeds with skin cancers (BCC, SCC, and cutaneous melanoma) across western Europe found a summary relative risk of 1.20 (1.08–1.34) (Boniol et al., 2012). When examining only cohort and population based studies, the summary relative risk was found to be 1.25 (1.09 to 1.43). Dose–response calculations highlighted a 1.8% increase in melanoma risk for every additional indoor tanning session per year, and that use of sunbeds before age 35 allowed a summary relative risk of 1.59 (1.36–1.85). Overall the authors reported that from 27 observational studies published in the past 30 years, the risk of cutaneous melanoma increased by 20% in subjects who had tanned indoors at any time in their lives. Extending Lazovich's findings in Minnesota between 2004 and 2007, Boniol et al. found that in the same population from 2005 to 2011, most summary relative risks between tanning and melanoma increased (Lazovich et al., 2010).

A 2014 international systematic review and meta analysis examining 14,956 melanoma cases and 233,106 controls reported an OR of 1.16 (95% CI 1.05–1.28) for melanoma in individuals that had tanned indoors compared with subjects that had not (Colantonio et al., 2014). The association was strongest in those who had tanned indoors for more than 10 sessions (OR 1.34, 95% CI 1.05–1.71). Importantly, the authors reported that their findings were not statistically different between data collected before and after the year 2000, suggesting that current indoor tanning devices are no safer than those used in prior decades. A recent review concluded that more than 10,000 melanoma cases each year across the United States, Europe, and Australia can be attributed to indoor tanning (Wehner et al., 2014). The population proportional attributable risk was found to be 2.6% to 9.4%.

Recent trends in the changing anatomic site of melanomas also support a relationship between melanoma risk and indoor tanning. Over the last 15 years there has been a significant increase in truncal melanomas in females, especially in geographic areas reporting a high prevalence of indoor tanning (Hery et al., 2010; Bradford et al., 2010; Boldeman et al., 2003; Montella et al., 2009). Indoor tanning exposes users to intermittent UVR on typically unexposed anatomical sites such as the trunk, and indoor tanners would thus be expected to show such an increase in melanoma incidence in these areas. It is possible that the observed trend may be explained by changes in sun exposure behavior such as novel fashion trends, increased time spent outdoors, or by population changes in genetic susceptibility to UVR, however there is little current data to support such alternatives (Garbe and Leiter, 2009).

Indoor tanning and sun sensitivity

The cutaneous effects of UVR from outdoor sun exposure are influenced by an individual's genetic and phenotypic characteristics. Exposure to solar UVR is consistently shown to be a major risk factor for melanoma most significantly in fair skinned populations with high sun sensitivity (Holman and Armstrong, 1984; Nikolaou and Stratigos, 2013). The number of common nevi, a response to solar UVR exposure in sun sensitive individuals, has been repeatedly shown as the most powerful predictor of melanoma risk (Gandini et al., 2005).

How artificial UVR from indoor tanning devices affects individuals according to skin type and sun sensitivity remains unclear. It has not been definitively shown whether skin types with reduced sensitivity to outdoor sunlight benefit from a similar reduced sensitivity to the adverse effects of artificial UVR. This area of exploration is especially significant as individuals of low to moderate sun sensitivity are more likely to tan indoors and tan indoors with greater frequency than individuals with higher sensitivity to solar UVR (Cokkinides et al., 2009; Boldeman et al., 1996; Demko et al., 2003; Rhainds et al., 1999). Individuals with low to moderate sun sensitivity therefore represent an important population for anti-indoor tanning prevention efforts. Determining whether adverse events reported in relation to indoor tanning, such as skin erythema and the development of melanomas, disproportionately affect the minority of individuals with increased sun sensitivity who tan indoors, as opposed to uniformly affecting individuals who tan indoors regardless of sun sensitivity, also warrants further investigation.

The Fitzpatrick skin type classification system has been widely used to define an individual's response to UVR (F, 1975). Fitzpatrick skin types range from I to VI according to genetic disposition (factors such as eye and hair color) and reaction to sun exposure (propensity to tan or burn). Other systems to define sun sensitivity include measures of self reported ability to achieve a tan in the sun, self reported susceptibility to burn outdoors, objective dermal response to direct skin phototesting, assessment of skin pigmentation via reflectance wavelength measurement, and determination of UVR-B dose required to produce visible skin redness (termed minimal erythema dose (MED) (Weinstock, 1992; Rampen et al., 1988).

Because a variety of methods have been used to classify skin type, generalization of results is difficult. Further, data exist to suggest that individuals may have limited accuracy in self assessment of sun sensitivity. Harrison and Buttner examined the accuracy of self assessment of skin color and level of protection from solar UVR by measuring the wavelength of light reflected from upper extremity skin sites (Harrison and Büttner, 1999). They found that Caucasians are likely to overestimate skin pigmentation and level of protection from the sun. The authors argue that skin cancer prevention campaigns targeted towards individuals according to sun sensitivity are likely to fail due to poor individual self perception of skin type. Taken together, investigation of a consistent and reliable measure of skin sensitivity, represents an important step in the effort to reduce melanoma incidence.

Populations at increased risk of indoor tanning

The most frequent indoor tanners in the United States are Caucasian females between the ages of 16 and 29 (Swerdlow and Weinstock, 1998). Epidemiological studies have associated increased indoor tanning with factors such as socioeconomic status, education, geographic location, and outdoor sun exposure (Heckman et al., 2008; Stryker et al., 2007; Choi et al., 2010; Lazovich et al., 2004). While these factors may inform prevention efforts, the relationships determining these trends are complex and variable across populations. Appearance concerns are among the most consistent motivators of indoor tanning, and represent an important interventional target (Boldeman et al., 2003; Demko et al., 2003; Survey, 2006; Boldeman et al., 1997; Hoerster et al., 2007; O'Riordan et al., 2006; Frieden, 2010; Mayer et al., 2011; Lazovich et al., 2004). In a study of United States adolescents aged 12–18 years old, girls were more likely than boys to report use of indoor tanning facilities, that it was worth getting burnt to get a good tan, and that tanned skin was preferred over pale skin (Geller et al., 2002). The concerning importance of appearing tan in this age group indicates the need for strong anti-indoor tanning interventions directed specifically towards a young population. In men, indoor tanning has been associated with appearance motivated behaviors, anxiety disorders, and unregulated steroid use (Mosher and Danoff-Burg, 2010; DHHS, 2008). Interventions directed towards individuals at risk for these behaviors should also be considered.

Recently it has been suggested that excessive indoor tanning may lead to physiological addiction in certain individuals (Petit et al., 2013). Such an effect may help explain individuals who continue to tan indoors despite a diagnosis of melanoma (Petit et al., 2013). Additional studies report indoor tanners meeting DSM-IV-TR criteria for substance abuse and dependence with regard to their indoor tanning behaviors (Petit et al., 2013). Exploring the neurobiological factors behind indoor tanning, for example the possible involvement of endogenous opioids, is a relevant avenue for exploration and prevention. In a study examining motivations behind continued indoor tanning despite awareness of risks, the authors cited reasons for indoor tanning beyond cosmetic concerns, specifically enjoyment of the tanning experience, an effect they termed 'mood enhancement' (Noar et al., 2014). Screening individuals at risk for developing a psychological addiction to indoor tanning, and ensuring the proper resources are available to address such a condition, are important areas of anti indoor tanning intervention.

Proximity to indoor tanning salons has also been shown to correlate with increased indoor tanning in certain groups. Mayer et al. found that living within 2 miles of an indoor tanning facility was associated with a greater likelihood of indoor tanning in adolescents (Mayer et al., 2011). Across the United States, indoor tanning facilities are increasing in number (Lamel et al., 2013). The rise in tanning salon prevalence presents a challenge in reducing indoor tanning behaviors. Limiting the density of indoor tanning facilities near residential areas, although difficult, is an important step towards reducing indoor tanning use.

Many states require parental permission for minors to tan indoors, although the effectiveness of this restriction may be limited by parental tanning behaviors and beliefs. Having a parent's permission to tan indoors strongly predicts increased indoor tanning among adolescents (Cokkinides et al., 2009; Lazovich et al., 2004; Hoerster et al., 2007; Mayer et al., 2011; Stryker et al., 2004). Bandi et al. examined the prevalence of indoor tanning, sunburn, and sun protection strategies in parents of adolescents between 1998 and 2004 (Bandi et al., 2010). Parental use of indoor tanning facilities increased between 1998 and 2004, and was most prevalent among parents aged 27 to 45. 50% of parents tanning indoors in the past year reported having tanned over 10 times, and 61% indicated that they had been burned as a result. Activities of parents and children have been shown to correlate positively, and therefore increased indoor tanning among parents presents an increased risk of indoor tanning to their children (Cokkinides et al., 2009). While intervention strategies should be targeted directly towards at risk children and adolescents, efforts directed towards parents should be prioritized as well.

Indoor tanning legislation and prevention in the United States: current approaches

In the United States the use of indoor tanning devices is regulated individually by state. Although most states restrict indoor tanning by age, others currently have no legislation in place. As of 2015, more than 41 states (and the District of Columbia) have passed age related bans on indoor tanning (Aa, 2014). Multiple states further restrict access to indoor tanning in minors by requiring parental consent or a doctor's prescription, while others require tanning salons to display warning signs in their facilities,(Institute NC, 2010).

In May 2014 the FDA issued a final order reclassifying indoor tanning devices as Class II medical devices (FDA, 2014; Updates. FC., 2014). Unlike class I devices, class II devices must obtain FDA clearance prior to marketing, and must display a black-box warning and contraindications for use. Mandatory warning displays on class II indoor tanning devices now include the following statements:

- the product is contraindicated for use on persons under the age of 18 years;
- the product must not be used if skin lesions or open wounds are present;
- the product should not be used on people who have had skin cancer or a family history of skin cancer; and
- people repeatedly exposed to UV radiation should be regularly evaluated for skin cancer.

The new classification is a significant advance towards reducing the use of indoor tanning devices in high risk populations. Class I medical devices are defined as conveying minimal risk to consumers and the class I designation of indoor tanning equipment had historically been promoted by the indoor tanning industry as evidence of tanning bed safety (Administration, 2010).

Internationally, many countries require parental consent for underage tanners, promote the use of eye protection, restrict indoor tanning device use by individuals with Fitzpatrick type 1 skin, and limit the intensity of UV emissions from indoor tanning devices (WHO, 2003). France, Spain, Germany, and Australia have banned indoor tanning in individuals under the age of 18 (Pawlak et al., 2012), while nations such as Brazil, have banned cosmetic indoor tanning completely (Pawlak et al., 2012). Although nation and state specific political and economic concerns may influence the establishment of anti indoor tanning legislation, the disparity of indoor tanning legislation in the US and across the globe highlights a widespread public uncertainty of indoor tanning risks, and suggests the need to further promote the importance of indoor tanning prevention efforts.

Does tanning bed legislation work?

Although enacting legislation to restrict indoor tanning is an important step in reducing negative health effects, the overall effectiveness of such interventions remains to be seen. Studies of US and Australian tanning salons report poor compliance with government laws and recommendations (Kwon et al., 2002; Dobbinson et al., 2006; Culley et al., 2001; Paul et al., 2005). In the United States it was found that 95% of indoor tanners surpass the FDA recommendation for exposure to indoor tanning devices (Hornung et al., 2003). Other studies report salons failing to post information on the risks of indoor tanning, promoting the safety and health benefits of indoor tanning, and providing services to underage tanners (Brouse et al., 2011; Forster et al., 2006; Pichon et al., 2009). It is therefore obvious that the root of the effectiveness of indoor tanning legislation is salon and patron compliance. Regardless of efforts to restrict access to indoor tanning, if the public understanding of risks is poor, these efforts will not likely be successful. The 10% tax on indoor tanning imposed by the Affordable Care Act in 2010 has shown some promise as an effective strategy to reduce indoor tanning (IRS, 2012). In a 2012 study of tanning salons in Illinois, 26% of salons reported a drop in patronage after tax enforcement (Jain et al., 2012). However, the authors noted that they were unable to completely distinguish the impact of the tax from the economic climate at the time of the study, and reported that 78% of responding salons stated that clients did not seem to care about the tax (Jain et al., 2012). Data from a similar effort to reduce cigarette smoking via increased taxation was shown to be effective, especially the young adult population (Bader et al., 2011). Taken together, although financial incentive to reduce indoor tanning may not be an all encompassing solution, it may represent means to produce a small reduction in indoor tanning device use; still a considerable success.

Interventions beyond legislation

Although not examined specifically in the setting of indoor tanning behaviors, educational and attitude-related interventions aimed at reducing outdoor UVR exposure have shown promising results. In their 2008 study, Falk and Anderson investigated different levels of prevention efforts directed towards sun habits, sun protection behavior, and sun related attitudes in a primary healthcare setting (Falk and Anderson, 2008). 308 participants were randomized to groups representing increasing levels of prevention effort. Group one received an educational letter while groups two and three received a personal doctor's consultation. Group three also underwent a phototest with self-reading assessment to determine sun susceptibility, and received a written follow-up of the phototest results. After 6 months, changes in sun habits, behavior, and attitudes were evaluated across groups. The authors found that prevention mediated by a doctor's consultation had a more significant impact on behavioral change than written intervention only. In the subgroup of individuals found to have high UVR sensitivity as determined by the phototest, a significant behavioral change in sun exposure attitudes and behaviors was observed, although across all skin types overall no significant effect was seen. This finding suggests that knowledge of sun sensitivity in individuals with high UVR sensitivity may reinforce a positive outcome in sun exposure habits, and could possibly represent a useful tool for reducing indoor tanning. Additionally the argument for implementation of individual “in office” prevention efforts aimed at reducing indoor tanning is also supported.

It is difficult to compare the effectiveness of widespread legislative and regulatory efforts with individual in office educational and behavioral interventions. However, the successful reduction of indoor tanning behaviors will likely require the adoption of interventions based on both approaches.

Conclusion

Although sufficient evidence associates indoor tanning with an increased risk of melanoma and non-melanoma skin cancers, there is also evidence to suggest that indoor tanning remains a widespread public health issue. These combined observations predict that without intervention, melanoma and other UV-related diseases will become more common in the near future, and require a substantial prevention effort.

While many states have implemented bans on tanning bed use among children aged 18 or younger, this represents only a limited prevention effort, both geographically and by age group. While children are perhaps at the greatest risk of disease related to tanning bed exposure, young adults (over 18) are also at substantially increased risk of melanoma due to tanning bed use. There are few (if any) preventive interventions targeted at tanning bed use in young adults or in older adults, despite fairly substantial evidence of risks across all age groups.

Evidence regarding the motivations to use tanning beds clearly indicates that the general population believes tanning bed use is relatively safe (particularly because the devices used are regulated by the FDA), and that it may be a safer alternative to sun exposure. While it is imperative that tanning bed exposure must be reduced in highly sun sensitive individuals, effective behavioral prevention messages must also be directed towards individuals with low to moderate sun sensitivity who tan indoors frequently. Additional investigation of the effects of indoor tanning according to skin type is also necessary. Reports of consumer misunderstanding of indoor tanning risks support the need for aggressive efforts to spread awareness about what is known about the relationship between tanning bed use and disease outcomes. Education on indoor tanning risks at the individual level may prove to be an effective interventional strategy, and should be further explored.

Melanoma incidence is increasing worldwide, over and above the impact of screening. Without strongly enforced efforts to reduce indoor tanning in the most at risk individuals, the effects of increased tanning bed use will contribute to a further increase in the burden of disease in the near future.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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