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ORIGINAL REPORT

Use of Tanning Beds and Incidence of Skin Cancer

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ABSTRACT

Purpose
We sought to evaluate the risk effect of tanning bed use on skin cancers among teenage and young adults. We also expected to determine whether a dose-response relationship was evident.

Patients and Methods
We observed 73,494 female nurses for 20 years (from 1989 to 2009) in a large and well-characterized cohort in the United States and investigated whether frequency of tanning bed use during high school/college and at ages 25 to 35 years were associated with a risk of basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma. We used Cox proportional hazards models and carefully adjusted for host risk factors, ultraviolet index of residence, and sun exposure behaviors at a young age.

Results
During follow-up, 5,506 nurses were diagnosed with BCC, 403 with SCC, and 349 with melanoma. The multivariable-adjusted hazard ratio (HR) of skin cancer for an incremental increase in use of tanning beds of four times per year during both periods was 1.15 (95% CI, 1.11 to 1.19; $P < .001$) for BCC, 1.15 (95% CI, 1.01 to 1.31; $P = .03$) for SCC, and 1.11 (95% CI, 0.97 to 1.27; $P = .13$) for melanoma. Compared with tanning bed use at ages 25 to 35 years, we found a significantly higher risk of BCC for use during high school/college (multivariable-adjusted HR for use more than six times per year compared with no use was 1.73 during high school/college *v* 1.28 at ages 25 to 35 years; *P* for heterogeneity $< .001$).

Conclusion
Our data provide evidence for a dose-response relationship between tanning bed use and the risk of skin cancers, especially BCC, and the association is stronger for patients with a younger age at exposure.

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INTRODUCTION

Skin cancer is the most common malignancy among whites in the United States, and its incidence has been rising rapidly over the past several decades for young women.[1,2] Some have suspected that this increased incidence may be attributable to behavioral changes, including expanded use of indoor tanning and more outdoor recreation in combination with early screening. Indoor tanning produces artificial exposure to ultraviolet (UV) radiation,[3] which is known to contribute to skin cancer development.[4-6] Consistent with our prior knowledge about UV exposure, abundant epidemiologic studies on indoor tanning have suggested it as a risk factor for both melanoma and nonmelanoma skin cancers, including basal cell carcinoma (BCC) and squamous cell carcinoma (SCC).[7-9] A 2007 meta-analysis by the International Agency for Research on Cancer reported positive associations of ever-use of tanning beds with increased risk of melanoma and SCC.[7] In 2009, the International Agency for Research on Cancer classified UV radiation from tanning beds as "carcinogenic to humans" (group 1) on the basis of its meta-analysis.[10]

However, the results regarding BCC were inconsistent; the association was not significant in the meta-analysis.[7] In addition, although a dose-response relationship has been suggested for melanoma,[11,12] it was inconsistent in previous studies, and a meta-analytic synthesis was not possible because of differences among studies in metrics for assessing duration.[7] Another limitation of previous studies is that most of them were case-control studies except for two studies on melanoma among the same cohort population.[13,14] We conducted a cohort study among the Nurses' Health Study II (NHSII) cohort, a large and well-characterized cohort of 116,678 young women in the United States with 20-year follow-up. We simultaneously

investigated the frequency of tanning bed use during high school/college, from age 25 to 35, and overall average use in relation to three types of skin cancer (BCC, SCC, and melanoma) in the same cohort.

PATIENTS AND METHODS

Study Population

Our study population consisted of participants in the NHSII, which was established in 1989 when 116,678 female registered nurses between the ages of 25 and 42 years and residing in the United States at the time of enrollment responded to an initial questionnaire on their medical histories and baseline health-related exposures. Updated information was obtained by questionnaire every 2 years. Details of this cohort have been described previously.[15] The protocol for this study was approved by the institutional review board at Brigham and Women's Hospital and the Harvard School of Public Health (Boston, MA).

Identification of Skin Cancer

Participants reported new skin cancer diagnoses biennially. With their permission, their medical records were obtained and reviewed by physicians to confirm the diagnoses. Eligible cases consisted of women with incident BCC, SCC, or melanoma diagnosed any time between the baseline and the 2009 follow-up cycle with no previously diagnosed cancer. Only pathologically confirmed invasive cases of cutaneous melanoma and SCC were included. SCC/melanoma in situ, SCC/melanoma of the oral mucosa or genitalia, actinic keratoses, and dysplastic nevi were excluded. Medical records were not obtained for self-reported cases of BCC, but previous reports have demonstrated high validity of self-report of BCC, with more than 90% confirmed by histopathology records.[16,17] On the basis of these criteria, we included 5,506 women with BCC, 403 women with SCC, and 349 women with melanoma.

Exposure Data

We obtained information regarding tanning bed usage, pigmentation traits, and other skin cancer risk factors from prospective biennial questionnaires. In the 2005 questionnaire, we collected information on the frequency of tanning bed usage during high school/college and between ages 25 and 35 years ("none," "1 to 2 times per year," "3 to 5 times per year," "6 to 11 times per year," "12 to 23 times per year," and "24 or more times per year"). Data on childhood tendency to sunburn ("practically none," "some redness only," "burn," "painful burn," and "burn with blisters"), self-reported mole count on legs ("none," "1 to 2," "3 to 4," "5 to 9," and "10 or more"), number of severe sunburns between ages 15 and 20 years (summarizing those on the face, limbs, and back and then categorizing into "none," "1 to 2," "3 to 4," "5 to 9," and "10 or more"), and family history of melanoma in first-degree relatives were collected in the baseline questionnaire in 1989. Information on natural hair color at age 20 years (black, dark brown, light brown, blond, and red) was collected in the follow-up questionnaire in 1991. According to the state of residence at birth and between ages 15 and 30 years reported in the 1993 questionnaire, we estimated the UV index and categorized into three categories (UV index $\leq$ 5: AK, ME, MI, MN, NH, OR, PA, VT, WA, WI; UV index = 6: CT, DE, IL, IN, IA, MD, MA, MO, NE, NJ, NY, ND, OH, RI, SD, UT, WV; UV index $\geq$ 7: DC, ID, KY, MT, NC, SC, TN, VA, WY, AL, AR, CO, GA, KS, LA, MS, NV, OK, AZ, CA, FL, HI, NM, TX). In 1997, family history of melanoma was updated from the original 1989 report. Information on outdoor sun exposure in the middle of the day (between 10 in the morning and 3 in the afternoon) was collected for high school/college and between ages 25 and 35 years in 2005 ("$<$ 1 hour per week," "2 to 4 hours per week," and "5 or more hours per week").

Statistical Analysis

All participants selected for this analysis were US non-Hispanic whites. Participants who did not provide information on tanning bed use either during high school/college or between ages 25 and 35 years in the 2005 questionnaire were excluded (n = 13,555). Participants with self-reported cancers at baseline according to the 1989 questionnaire, including skin cancer and nonskin cancer, were also excluded. The primary exposures were self-reported frequency of tanning bed use during high school/college or between ages 25 and 35 years and the average use during both periods. We grouped women into four categories for tanning bed use during high school/college and between ages 25 and 35 years ("none," "1 to 2 times per year," "3 to 5 times per year," and "6 or more times per year"). To test for linear trends across each category, we modeled these exposures into continuous variables by using the median value of each category. The average tanning bed use in both periods was calculated based on the continuous variables. Participants contributed person-time data from the baseline in June 1989 to the end of follow-up. Accumulation of follow-up time ceased at the first report of BCC, the first report (followed by confirmation) of SCC, the first report (followed by confirmation) of melanoma, death, or the end of follow-up, whichever came earlier.

We used age- and multivariable-adjusted Cox proportional hazards models to calculate the hazard ratios (HRs) and 95% CIs for each type of skin cancer. In the multivariable regression models, we adjusted for age, family history of melanoma, hair color at age 20 years, number of moles on the legs, childhood tendency to burn, number of severe sunburns between ages 15 and 20 years, outdoor sun exposure during high school/college and between ages 25 and 35 years, and UV index in the state of residence at birth, at age 15 years, and at age 30 years. To compare the risk effect of tanning bed use during high school/college and between ages 25 and 35 years, we used the Q statistic for heterogeneity test. To summarize multiple variables of pigment traits, we constructed a multivariable confounder score on the basis of natural hair color and reaction to sun exposure during childhood or adolescence.[18] Briefly, we applied the logistic regression coefficients from a multivariable model for skin cancer risk—including age, natural hair color, and reaction to sun exposure during childhood or adolescence—to each individual's values for the latter two of these variables and summed the values to compute a pigment score in the logit scale. We used the median value for this score among controls to identify women with low and high pigmentation. All of the statistical analyses were carried out using Statistical Analysis System software (version 9.1.3; SAS Institute, Cary, NC). All *P* values were two-sided.

RESULTS

We included 73,494 female nurses in the analysis, and the mean follow-up time was 18.5 years. During 20 years of follow-up from 1989 to 2009, 5,506 women were diagnosed with BCC, 403 with SCC, and 349 with melanoma. The basic characteristics of participants with different frequencies of tanning bed usage are presented in Table 1. People who used tanning beds more often either during high school/college or between ages 25 and 35 years tended to be younger and have more outdoor sun exposure. They also tended to live in states with higher UV indices. However, they had less tendency to burn during childhood than those who never used tanning beds or who used them less often. In addition, people who used tanning beds more often during high school/college tended to have more moles on their arms and more severe sunburns between ages 15 and 20 years. The distribution of other skin cancer risk factors, including family history of melanoma and red/blond hair color, were similar across the different categories.

The relative risks and 95% CIs of skin cancers from tanning bed use during high school/college, use between ages 25 and 35 years, and overall average use are summarized in Table 2. We found a dose-response relationship between frequency of tanning bed use and risk of skin cancers. The multivariable-adjusted HR for an incremental increase of use of tanning beds 4 times per year during high school/college and between ages 25 and 35 years was 1.15 (95% CI, 1.11 to 1.19; $P < .001$) for BCC, 1.15 (95% CI, 1.01 to 1.31; $P = .03$) for SCC, and 1.11 (95% CI, 0.97 to 1.27; $P = .13$) for melanoma. Compared with the use of tanning beds between ages 25 and 35 years, use during high school/college revealed a stronger effect on BCC

Table 1. Basic Characteristics of Participants in Different Categories of Tanning Bed Use

Characteristic	Tanning Bed Use							
	During High School/College				Between Ages 25 and 35 Years			
	None	1-2 Times/ Year	3-5 Times/ Year	> 6 Times/ Year	None	1-2 Times/ Year	3-5 Times/ Year	> 6 Times/ Year
Person-years	1,234,431	57,750	28,341	39,880	1,090,451	109,140	57,694	103,059
Proportion of tanning bed use, %	90.7	4.3	2.1	3.0	80.2	8.0	4.2	7.6
BCC, No.	4,877	259	122	236	4,340	466	243	451
SCC, No.	366	16	10	10	306	41	19	35
Melanoma, No.	311	17	8	12	278	25	14	32
Mean age at baseline, years	35.1	33.0	32.5	31.8	35.3	33.5	33.0	32.5
Outdoor sun exposure ≥ 5 hours/week, %								
At high school/college	59.9	65.2	72.2	75.8	59.3	63.2	65.6	72.0
Between ages 25 and 35 years	50.0	52.8	58.4	60.8	48.6	54.0	56.9	65.8
UV index in the state of residence ≥ 7, %								
At birth	18.4	20.0	20.2	22.3	18.0	19.6	20.6	23.1
At age 15 years	18.7	19.3	19.2	21.6	18.3	19.7	20.5	23.2
At age 30 years	24.9	25.8	24.6	27.6	24.9	24.5	24.8	26.9
Family history of melanoma, %	5.4	5.8	7.2	6.5	5.5	5.7	4.9	5.7
Red/blonde hair, %	20.2	21.6	22.9	22.1	20.1	21.2	22.2	21.5
No. of moles on legs ≥ 3, %	32.2	34.3	34.8	35.6	32.1	33.9	32.9	34.2
Childhood tendency to burn/severe burn, %	48.7	45.7	44.4	43.2	49.8	43.6	41.9	39.7
No. of severe sunburns between ages 15 and 20 years ≥ 5, %	9.8	10.6	11.9	14.3	10.0	9.6	10.4	10.3

Abbreviations: BCC, basal cell carcinoma; SCC, squamous cell carcinoma; UV, ultraviolet.

(multivariable-adjusted HRs for use 4 times per year was 1.40 during high school/college *v* 1.19 between ages 25 and 35 years), a weaker effect on SCC (1.19 during high school/college *v* 1.43 between ages 25 and 35 years), and a similar effect on melanoma (1.17 between ages 25 and 35 years *v* 1.16 during high school/college). Of note, for BCC, the multivariable-adjusted HR for tanning bed use more than 6 times per year compared with no use was 1.73 (95% CI, 1.52 to 1.98) for use during high school/college

Table 2. Tanning Bed Use and Risk of Skin Cancer

Tanning Bed Use	Risk of BCC				Risk of SCC				Risk of Melanoma			
	Age-Adjusted		Multivariable-Adjusted*		Age-Adjusted		Multivariable-Adjusted*		Age-Adjusted		Multivariable-Adjusted*	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
During high school/college												
None	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
1-2 times/year	1.28	1.13 to 1.45	1.25	1.10 to 1.41	1.14	0.69 to 1.88	1.13	0.68 to 1.86	1.26	0.77 to 2.06	1.20	0.74 to 1.97
3-5 times/year	1.26	1.05 to 1.51	1.20	1.00 to 1.43	1.52	0.81 to 2.86	1.49	0.79 to 2.80	1.24	0.61 to 2.51	1.14	0.56 to 2.32
> 6 times/year	1.83	1.61 to 2.10	1.73	1.52 to 1.98	1.16	0.62 to 2.19	1.12	0.60 to 2.11	1.35	0.75 to 2.41	1.23	0.69 to 2.20
4 times/year	1.46	1.35 to 1.58	1.40	1.30 to 1.52	1.21	0.86 to 1.71	1.19	0.84 to 1.67	1.25	0.89 to 1.75	1.17	0.83 to 1.63
P		< .001		< .001		.26		.33		.19		.37
At ages 25-35												
None	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref	1.00	Ref
1-2 times/year	1.19	1.08 to 1.31	1.19	1.08 to 1.31	1.60	1.15 to 2.21	1.60	1.15 to 2.22	0.95	0.63 to 1.43	0.94	0.62 to 1.41
3-5 times/year	1.21	1.06 to 1.37	1.21	1.06 to 1.38	1.49	0.94 to 2.38	1.51	0.95 to 2.42	1.02	0.60 to 1.75	1.02	0.60 to 1.76
> 6 times/year	1.30	1.17 to 1.43	1.28	1.16 to 1.41	1.62	1.13 to 2.30	1.61	1.13 to 2.31	1.34	0.92 to 1.94	1.31	0.90 to 1.91
4 times/year	1.20	1.13 to 1.27	1.19	1.12 to 1.26	1.42	1.15 to 1.76	1.43	1.15 to 1.76	1.17	0.93 to 1.48	1.16	0.92 to 1.47
P		< .001		< .001		.001		.001		.19		.22
Average use in both periods†												
4 times/year	1.16	1.13 to 1.20	1.15	1.11 to 1.19	1.16	1.02 to 1.32	1.15	1.01 to 1.31	1.13	0.99 to 1.28	1.11	0.97 to 1.27
P		< .001		< .001		.02		.03		.08		.13

Abbreviations: BCC, basal cell carcinoma; HR, hazard ratio; Ref, reference; SCC, squamous cell carcinoma.
*Adjusted by age; family history of melanoma; hair color at age 20 years; No. of moles on the legs; childhood tendency to sunburn; No. of severe sunburns between ages 15 and 20 years; outdoor sun exposure at high school/college and between ages 25 and 35 years; and UV index in the state of residence at birth, age 15 years and age 30 years.
†Average No. of tanning bed uses during high school/college and between ages 25 and 35 years.

Table 3. Stratified Analysis of Tanning Bed Use and Skin Cancer Risk by Pigmentation Score

Tanning Bed Use	Risk of BCC					Risk of SCC					Risk of Melanoma				
	High Pigmentation		Low Pigmentation		*P* for Interaction*	High Pigmentation		Low Pigmentation		*P* for Interaction*	High Pigmentation		Low Pigmentation		*P* for Interaction*
	HR	95% CI	HR	95% CI		HR	95% CI	HR	95% CI		HR	95% CI	HR	95% CI	
During high school/college															
None	1.00	Ref	1.00	Ref		1.00	Ref	1.00	Ref		1.00	Ref	1.00	Ref	
1-2 times/year	1.35	1.09 to 1.66	1.19	1.01 to 1.39		0.85	0.31 to 2.32	1.25	0.70 to 2.24		1.36	0.60 to 3.12	1.17	0.63 to 2.14	
> 3 times/year	1.61	1.35 to 1.93	1.43	1.25 to 1.65		0.71	0.26 to 1.94	1.60	0.96 to 2.67		1.68	0.84 to 3.35	0.99	0.54 to 1.84	
4 times/year	1.48	1.30 to 1.69	1.35	1.22 to 1.50		0.80	0.39 to 1.67	1.38	2.94 to 2.03		1.42	0.84 to 2.39	1.06	0.68 to 1.65	
P		< .001		< .001	.23		.55		.10	.25		.19		.79	.42
Between ages 25 and 35 years															
None	1.00	Ref	1.00	Ref		1.00	Ref	1.00	Ref		1.00	Ref	1.00	Ref	
1-2 times/year	1.25	1.06 to 1.46	1.17	1.03 to 1.31		2.04	1.21 to 3.46	1.39	0.91 to 2.12		0.95	0.47 to 1.88	0.93	0.55 to 1.55	
> 3 times/year	1.38	1.21 to 1.57	1.17	1.05 to 1.30		1.82	1.13 to 2.94	1.45	0.99 to 2.12		0.88	0.48 to 1.62	1.34	0.92 to 1.96	
4 times/year	1.26	1.14 to 1.38	1.14	1.06 to 1.23		1.56	1.11 to 2.19	1.35	1.02 to 1.77		0.91	0.58 to 1.43	1.26	0.96 to 1.67	
P		< .001		< .001	.11		.01		.03	.41		.69		.10	.31
Average use in both periods†															
4 times/year	1.18	1.12 to 1.24	1.12	1.07 to 1.17		1.07	0.85 to 1.35	1.20	1.03 to 1.40		1.05	0.82 to 1.34	1.13	0.97 to 1.33	
P		< .001		< .001	.09		.57		.02	.53		.70		.12	.69

NOTE. Pigmentation score adjusted by age; family history of melanoma; No. of moles on the legs; No. of severe sunburns between ages 15 and 20 years; outdoor sun exposure at high school/college and between ages 25 and 35 years; and UV index in the state of residence at birth, age 15 years, and age 30 years. Categorized into subgroups of low and high pigmentation by the medium value of pigmentation score (on the basis of natural hair color and tendency to tan/burn after sun exposure during childhood or adolescence) among the controls.

Abbreviations: BCC, basal cell carcinoma; HR, hazard ratio; Ref, reference; SCC, squamous cell carcinoma; UV, ultraviolet.

*Interaction between average number of tanning bed uses and pigmentation subgroups.

†Average tanning bed use during high school and between ages 25 and 35 years.

and 1.28 (95% CI, 1.16 to 1.41) for use between ages 25 and 35 years (*P* for heterogeneity < .001). For SCC, the multivariable-adjusted HR for use more than 6 times per year was 1.12 (95% CI, 0.60 to 2.11) during high school/college and 1.61 (95% CI, 1.13 to 2.31) between ages 25 and 35 years, but the *P* value for heterogeneity was not significant (*P* for heterogeneity = .33). The association between tanning bed use and skin cancer risk remained similar after mutually controlling for use during high school/college and between ages 25 and 35 years. No statistically significant interaction was observed between the use of tanning beds during the two periods.

We also conducted a stratified analysis by pigment score. As shown in Table 3, the associations of tanning bed use with skin cancer risk did not differ between the two pigment score subgroups (high and low pigment score) for each type of skin cancer.

DISCUSSION

BCC is the most prevalent type of skin cancer among whites. An important study in 2002 reported that ever-use of indoor tanning significantly increased the risk of BCC by 50% and early age at first use tended to be associated with a higher risk.[9] However, the trend of risk effects on the basis of age at first use was not significant, and no dose-response relationship was investigated in that study.[9] In addition, subsequent studies of the association between tanning bed use and BCC risk were inconsistent, and the 2007 meta-analysis and two subsequent studies did not support a significant association.[7,8,19] By using a large and well-characterized cohort, we found a significantly increased risk of BCC among participants who used tanning beds during high school/college or between ages 25 and 35 years (*P* < .001), and a dose-response effect was detected with 15% increased risk for use 4 times per year. This association was robust after controlling for potential confounders, including host risk factors, outdoor tanning behavior, and UV index in the state of residence. Consistent with the findings of the meta-analysis[7] and several subsequent studies,[11-13,19,20] we also detected an elevated risk of SCC and melanoma among the participants with tanning bed use. An increased risk of 15% for SCC and 11% for melanoma was detected for tanning bed use 4 times per year.

Previous studies on melanoma reported the strongest association with tanning bed use among people who used tanning beds in their youth,[7,11,14] which suggested a greater vulnerability of younger people to the carcinogenic impact of indoor tanning. Consistent with this hypothesis, we detected a significantly higher increased risk of BCC for individuals who used tanning beds during high school/college than for those who used tanning beds between ages 25 and 35 years (*P* for heterogeneity < .001). As for SCC, which is more sensitive to cumulative exposure than to exposure at early ages, we found a stronger

effect for tanning bed use between ages 25 and 35 years than for use during high school/college. However, this difference was not significant (P for heterogeneity = .33). In addition, no significant difference was detected for melanoma. The relatively small number of patients with melanomas and SCC compared with those with BCC may limit the power of the heterogeneity test.

Given that individuals with poor ability to tan are likely to use indoor tanning beds more often but are also more sensitive to UV damage,[21] some have argued that these individuals are more susceptible to skin cancer after indoor tanning.[22,23] The Australian/New Zealand Standard on Solaria for Cosmetic Purposes AS/NZS 2635: 2002[24] suggests that individuals with fair skin that does not tan (skin type 1) and those under age 15 years be barred from access to indoor tanning equipment. However, in the current study, we found that the risk effect of tanning bed use among women with low pigment score was similar to that among women with high pigmentation, suggesting that tanning is equally deleterious for all skin types.

Taking advantage of a large and well-characterized cohort, we evaluated dose-effects of tanning bed use on the risk of BCC, melanoma, and SCC simultaneously in the same cohort. We investigated the use during high school/college and between ages 25 and 35 years, as well as the average use during both periods. One other strength was that we collected the information on host risk factors and controlled for potential confounders, including outdoor tanning behaviors and UV index in the state of residence. Taking into account these confounders, we detected robust association between tanning bed use and skin cancer risk with mostly negligible differences between the age-adjusted and the multivariable-adjusted models.

One limitation of our study is that this is a prospective-retrospective mixed cohort study based on information on tanning bed use collected in 2005, which may introduce recall bias among women who developed skin cancer before that questionnaire cycle. To address this issue, we have conducted a secondary analysis restricted to the incident cases of BCC diagnosed after report of tanning bed use. As a result, 2,731 women with BCC were diagnosed after the 2005 questionnaire cycle, and the multivariable-adjusted HR for an incremental increase of tanning bed use 4 times per years during high school/college and between ages 25 and 35 years was 1.16 (95% CI, 1.11 to 1.22; $P < .001$), which was similar to that of our primary analysis using overall participants (multivariable-adjusted HR, 1.15; 95% CI, 1.11 to 1.19; $P < .001$). Besides, previous reports demonstrated substantial reproducibility in reporting the use of tanning devices[25,26] as well as other skin cancer–related risk factors.[19,27-30] The impact of recall bias on risk estimates resulting from skin cancer diagnosis was shown to be minimal.[19,31,32] Hence the recall bias on tanning bed use and its influence was unlikely to be substantial in our study. Another limitation of this study is that we detected only a nonsignificant trend for melanoma, which may result from the modest sample size of participants with melanoma. However, the effect estimate and CI were not materially different from those for BCC.

It is also of note that tanning beds used before the late 1970s had different UV-emitting tubes from those in use today. Tanning lamps used before the late 1970s emitted a broad spectrum of radiation with substantial fractions of UVB (22%–40%) and UVC (0.1%–20%) in addition to UVA, whereas those used after the late 1970s produced predominantly UVA and only a small fraction of UVB (< 0.1%–2.1%).[33] UVA and UVB were reported to have different carcinogenic effects in skin cancer development.[34-37] UVB can directly cause DNA damage and mutations, whereas UVA can indirectly cause oxidative damage and stress.[6,38] UVA has longer wavelengths than UVB and thus penetrates deeper into skin; its role in skin carcinogenesis has been increasingly recognized.[39] Several studies have supported the role of UVA radiation in developing both nonmelanoma skin cancer and melanoma.[40-43] To further investigate the risk effect of modern tanning beds primarily with UVA radiation, we conducted a stratified analysis on BCC by examining the risk effects among the individuals under age 35 years at enrollment (1989), who primarily used the modern tanning beds, and among those above age 35 years, who primarily used the old tanning beds. As a result, the risk estimates on BCC were the same for the two subgroups (multivariable-adjusted HR of 1.15 for an incremental increase of use 4 times per year among both subgroups). Consistent with previous reports, our finding suggested a similar risk effect of exposure to either UVA or UVB tanning lamps on skin cancer risk. The notion that modern tanning beds predominantly with UVA are safer than the old ones is not substantiated. In addition, tanning lamps have been produced to emit greater amounts of UVB that mirror the solar spectrum for a more dramatic tan.[44] A review of 133 Scottish tanning beds between 2004 and 2005 also reported that 83% produced UVB radiation levels that exceeded the European standards, which was a substantial increase from 1998.[45]

Our data reveal positive associations between tanning bed use and the risks of the three most common types of skin cancers (BCC, SCC, and melanoma) with a dose-response effect. These findings provide evidence to support warning the public against future use of tanning beds and enacting state and federal legislation to ban tanning bed use for those under age 18, initiatives that have been launched in many countries including Brazil, Australia, France, and Germany as well as successfully enacted in California on October 9, 2011. According to the findings of this study and evidence from previous studies, we strongly suggest that policy makers promote restrictions on the indoor tanning industry.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

The author(s) indicated no potential conflicts of interest.

AUTHOR CONTRIBUTIONS

Conception and design: Mingfeng Zhang, Abrar A. Qureshi, Jiali Han
Collection and assembly of data: Mingfeng Zhang, Jiali Han
Data analysis and interpretation: All authors
Manuscript writing: All authors
Final approval of manuscript: All authors

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