Original Article

Indoor tanning bed use and risk of food addiction based on the modified Yale Food Addiction Scale

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Abstract

The popularity of indoor tanning may be partly attributed to the addictive characteristics of tanning for some individuals. We aimed to determine the association between frequent indoor tanning, which we view as a surrogate for tanning addiction, and food addiction. A total of 67,910 women were included from the Nurses' Health Study II. In 2005, we collected information on indoor tanning during high school/college and age 25-35 years, and calculated the average use of indoor tanning during these periods. Food addiction was defined as $\geqslant 3$ clinically significant symptoms plus clinically significant impairment or distress, assessed in 2009 using a modified version of the Yale Food Addiction Scale. Totally 23.3% (15,822) of the participants reported indoor tanning at high school/college or age 25-35 years. A total of 5,557 (8.2%) women met the criteria for food addiction. We observed a dose–response relationship between frequency of indoor tanning and the likelihood of food addiction ($P_{trend} < 0.0001$), independent of depression, BMI, and other confounders. Compared with never indoor tanners, the odds ratio (95% confidence interval) of food addiction was 1.07 (0.99-1.17) for average indoor tanning 1-2 times/year, 1.25 (1.09-1.43) for 3-5 times/year, 1.34 (1.14-1.56) for 6-11 times/year, 1.61 (1.35-1.91) for 12-23 times/year, and 2.98 (1.95-4.57) for 24 or more times/year. Frequent indoor tanning before or at early adulthood is associated with prevalence of food addiction at middle age. Our data support the addictive property of frequent indoor tanning, which may guide intervention strategies to curb indoor tanning and prevent skin cancer.

Keywords: indoor tanning, food addiction, cohort study, skin cancer, epidemiology, UV radiation

Introduction

Frequent indoor tanning with artificial ultraviolet (UV) radiation is an established risk factor for skin cancer[1–8]. Despite known risk, tanning devices are used by more than 30 million Americans every year[5]. The well-known motivations for indoor tanning include perceived enhancement of appearance, relaxation, improved mood, and socializing[2,5,9–12]. The popularity of indoor tanning may be partly attributed to the addictive property, as indoor tanners present with opiate-like addictive features and show withdrawal symptoms when treated with an opioid antagonist, naltrexone[1–2,5,10]. A large proportion of indoor tanners meet the criteria for substance abuse with respect to UV radiation and frequent usage of indoor tanning may be a surrogate for UV addiction[10,13]. One recent study showed that an elevation in the level of an opioid peptide, β-endorphin, follows chronic UV exposure in mice and controls the hedonic tanning response[1], suggesting that an endogenous proopiomelanocortin-β-endorphin mechanism mediates tanning seeking behaviors[1,5].

Addiction-like eating behavior, or food addiction, is a stress-related overeating behavior[14–15]. Food addiction is strongly associated with overweight and obesity and is a major concern for public health and well-being.[16]Consumption of highly palatable (high-fat/high-sugar) food can trigger dopaminergic responses and show addiction-like central rewarding properties[16–22]. Cessation of palatable food access may induce withdrawal-like states[23]. β-endorphin has been shown to mediate hedonic balance and emotional response in food choice and intake, serving as an orexigenic neurotransmitter[24–26].

Different behavioral and substance addictions have analogous neural basis and behavioral effects[17,26–27]. Many genes may confer vulnerability to multiple forms of addictions[23,26–28]. Considering the commonalities of addictive disorders, some individuals who experience such cravings for the focus of the addiction (e.g., UV light or food) could be susceptible to more than one form of addiction. Such a common basis might manifest as a link between frequent indoor tanning, which we viewed as a surrogate for tanning addiction, and food addiction. Given the popularity of indoor tanning and the rising incidence of skin cancer, elucidation of the association between indoor tanning and food addiction would demonstrate the addictive property of frequent indoor tanning and provide novel insights to guide intervention strategies to curb indoor tanning and prevent skin cancer. We examined the association based on the Nurses' Health Study II (NHS II).

Materials and methods

Study population

The NHS II began in 1989 when 116,430 female nurses aged 25-42 years completed a baseline questionnaire on medical history and lifestyle practices. Biennially, participants receive a questionnaire, and a response rate of 85-90% has been achieved with each follow-up questionnaire. The study was approved by the institutional review board of Brigham and Women's Hospital. Participants' completion and return of the questionnaire was considered informed consent.

Assessment of main exposure

In 2005, we collected information on the frequency of indoor tanning bed usage during high school/college and age 25-35 years, in the following categories: none, 1-2, 3-5, 6-11, 12-23, or ≥24 times/year. We used methods applied in our prior studies[4,8] to calculate the average use of indoor tanning during these two time periods (based on the midpoint of each category) and summarized it into the following categories: none, 1-2, 3-5, 6-11, 12-23, or ≥24 times/year.

Assessment of food addiction

Food addiction was assessed in 2009, when participants were aged 44-64 years,using a modified version of the Yale Food Addiction Scale[30]. The scale uses nine items, with one question for each of the symptom groups included in the seven diagnostic criteria, plus two items assessing clinically significant impairment and distress[16]. This scale defines food addiction as ≥3 of the symptoms plus clinically significant impairment or distress: (1) eating when no longer hungry ≥4 times per week, (2) worrying about cutting down on certain foods ≥4 times per week, (3) feeling sluggish or fatigued from overeating ≥2 times per week, (4) experiencing negative feelings from overeating that interfere with other activities ≥2 times per week, (5) having physical withdrawal symptoms when cutting down on certain foods ≥2 times per week, (6) continuing to consume the same amount of food despite significant emotional or physical problems due to overeating at any frequency, and (7) feeling the need to eat an increasing amount of food to reduce distress at any frequency. The mYFAS defines clinically significant impairment or distress as either (1) experiencing significant distress related to eating behavior ≥2 times per week or (2) experiencing a decrease in the ability to function owing to issues related to food ≥2 times per week. In our study, we excluded women who left ≥3 food addiction symptom questions blank, who reported to have 1 or 2 food addiction symptoms but left 2

symptom questions blank, who reported to have 2 food addiction symptoms but left 1 symptom question blank, or those who missed information on clinical significance of symptoms. The scale shows good construct validity and reasonably high sensitivity (79%), providing a valid, though conservative, measure of food addiction[29].

Assessment of covariates in the cohort

According to the state of residence at birth, age 15, and age 30 years reported in 1993, we estimated the UV index, which assesses UV radiation reaching the earth's surface. Based on the mean UV index in North America for the month of August (by the National Oceanic and Atmospheric Administration), the 50 states (and the District of Columbia) were divided into the following 3 UV index groups ($\leqslant 5$, 6, $\geqslant 7$). 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, 2-4, or $\geqslant 5$ hours per week) based on which we calculated the average outdoor sun exposure. According to the state of residence in each 2-year follow-up cycle, UV flux for a participant that could have received over a period of time was estimated, taking factors such as cloud cover, altitude, and latitude into account. NHS II collected detailed information on major characteristics. Race/ethnicity was reported in 1989. Data on bodyweight, smoking status, alcohol intake, physical activity, menopausal status and post-menopausal hormone use, and personal history of depression (physician-diagnosed depression or anti-depressant use), rheumatoid arthritis, cancer, cardiovascular diseases, diabetes, and hypertension were comprehensively collected and updated during the cohort follow-up. We derived the 25-hydroxy vitamin D prediction score for each follow-up cycle. In 2001, information was also collected regarding sleep duration and snoring frequency. Natural hair color in early adulthood (age 18 years) was inquired in 1991. Other constitutional factors, including number of cutaneous nevi on lower legs, childhood or adolescent susceptibility to sunburn, and number of teenage severe sunburns were asked in 1989. In a subset of participants who completed the high school diet questionnaire, we collected information on whether they had anorexia nervosa or bulimia nervosa in high school.

Statistical analysis

Among responders to the 1989 (cohort baseline), 2005 (when indoor tanning was asked) and 2009 (when food addiction was assessed) questionnaires ($n = 86,142$), we excluded women with missing data on indoor tanning or who did not provide enough information on food addiction items, a total of 67,910 participants remained.

We used logistic regression analyses to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for the association between indoor tanning and risk of food addiction. The age- and multivariate-adjusted analyses were conducted for indoor tanning at high school or college, age 25-35, and the average indoor tanning during these two periods. For categorical assessment of indoor tanning, those who never used indoor tanning were set as the referent. For continuous assessment, we assigned the median value to each reported category and calculated the trend in risk of food addiction corresponding to each 4-time increase in indoor tanning (the median frequency of indoor tanning is 3~5 times/year).

To elucidate whether outdoor UV radiation was associated with the risk of food addition, secondary analyses were conducted to examine whether UV index at birth, age 15 and 30 years, UV flux, and average outdoor sun exposure change the risk of food addiction, using logistic regression models. Subgroup analyses were conducted for the association between indoor tanning and food addiction, according to categories of these variables. We conducted several sensitivity analyses. First, we restricted the analysis to Caucasians. Second, instead of adjusting for UV index at different life periods, we adjusted for average outdoor sun exposure or cumulative UV flux. Third, we adjusted for the time-varying covariates collected concurrently with food addiction measures (year 2009). Fourth, we further adjusted for major pigmentation traits, including mole count, hair color, childhood reaction to sun, and teenage severe sunburns, which were found to be associated with indoor tanning in our recent study (manuscript under review elsewhere). Fifth, we excluded all women that had a history of depression or major chronic diseases during the follow-up. Sixth, we adjusted for categorical variable of body mass index (BMI) and depression in different definitions (physician-diagnosed depression only or anti-depressant use only). Seventh, in a subset of women with information on anorexia nervosa and bulimia nervosa in high school ($n = 37,234$), a sensitivity analysis was conduct by additionally adjusting for anorexia and bulimia.

Depression is positively associated with food addiction in this cohort[16]. A secondary analysis was conducted to explore the association of indoor tanning with risk of incident depression during the follow-up, for which we used time-dependent Cox proportional hazard models stratified by age and 2-year cycle to estimate the hazard ratios (HRs) of depression. We

included incident cases of depression from 2001 (when participants were 37-54 years) to 2011. For this analysis, we excluded participants who ever self-reported clinician-diagnosed depression, regular use of antidepressants, or had a Mental Health Inventory score body mass index ($\leqslant 52$ in or before 2001, or who lacked complete information on these depression-related variables). We also tested whether depression modified the associations between average indoor tanning and food addiction. In a subset of women ($n = 37,234$), we examined the associations between indoor tanning and the odds of anorexia or bulimia in high school.

All statistical analyses were conducted by using SAS, version 9.2 (SAS Institute, Inc., Cary, NC, USA). All *P* values were two-tailed.

Results

Among 67,910 women, 8.8% (5,970) ever used indoor tanning at high school/college and 18.7% (12,672) ever used indoor tanning at age 25-35 years. Averaging the two periods, 23.3% (15,822) ever used indoor tanning and 5.0% (3,422) used indoor tanning $\geqslant 6$ times/year. Women with more indoor tanning tended to be younger and more physically active. They were more likely to smoke, report outdoor sun exposure and a high UV index in the state of residence (*Table 1*).

A total of 5,557 women (8.2%) met the criteria for food addiction in 2009. We observed an increased risk of food addiction associated with frequency of indoor tanning at high school/college, age 25-35 years, and the average indoor tanning, in a dose–response relationship (all *P*-trend < 0.0001). Compared with never indoor tanners, the OR (95% CI) of food addiction was 1.07 (0.99-1.17) for average indoor tanning 1-2 times/year, 1.25 (1.09-1.43) for 3-5 times/year, 1.34 (1.14-1.56) for 6-11 times/year, 1.61 (1.35-1.91) for 12-23 times/year, and 2.98 (1.95-4.57) for body mass index ($\geqslant 24$ times/year). Each 4 times of average indoor tanning was associated with 17% increased risk of food addiction (OR = 1.17, 95% CI: 1.12-1.21) (*Table 2*). Similar effect estimates were observed for the models with or without adjusting for depression and BMI.

Subgroup analyses by measures of outdoor UV radiation found that the associations between indoor tanning and food addiction appeared stronger among those who had a lower outdoor UV level, with suggestive statistical interactions for the UV index at age 15, age 30, and the cumulative UV flux (*P*-interaction < 0.10 for each) (*Table 3*). None of these measures was associated with increased odds of food addiction (*Table 4*).

In the secondary analysis on indoor tanning and risk of depression ($n = 26,854$), we documented 2,295 incident cases with depression during 203,108 person-

Table 1 **Characteristics of the participants according to average indoor tanning in the Nurses' Health Study II[a]**

	None	1-2 times /year	3-5 times /year	6-11 times /year	12-23 times /year	$\geqslant 24$ times /year
$n = 67,910$	52,088	9,383	2,997	1,959	1,336	147
Age[b], years, mean (SD)	35.2 (4.5)	33.4 (4.7)	32.7 (4.6)	32.1 (4.6)	31.9 (4.6)	31.3 (4.8)
Body mass index[b], kg/m^2, mean (SD)	24.1 (5.0)	23.2 (4.3)	23.2 (4.3)	23.3 (4.6)	23.5 (4.5)	23.6 (4.5)
Race (Caucasian, %)	94.3	97.9	97.9	97.7	97.9	97.3
Physical activity[b], metabolic equivalent hours/week, mean (SD)	26.3 (65.4)	29.8 (63.6)	33.9 (76.4)	33.7 (68.0)	36.9 (71.0)	41.5 (57.4)
Alcohol intake [c], g/d, mean (SD)	3.0 (6.0)	3.8 (6.6)	3.8 (6.4)	3.6 (5.8)	3.9 (6.7)	4.0 (5.9)
Current smoking[b], %	10.8	12.5	14.4	14.7	18.6	25.2
Depression [d], %	12.3	13.2	14.9	14.8	18.9	15.7
Major chronic diseases[b], %	6.6	5.2	5.9	6.0	5.8	5.4
Outdoor sun exposure$\geqslant 5$ h/wk, %						
At high school/college	58.0	64.9	69.8	71.7	76.0	88.8
Between ages 25 and 35 years	48.2	54.4	59.6	63.5	67.4	83.3
UV index in the state of residence$\geqslant 7$, %						
At birth	19.0	20.4	22.7	19.4	26.0	24.6
At age 15 years	19.4	20.3	21.8	20.2	24.9	28.2
At age 30 years	25.9	26.0	26.4	23.1	29.2	32.3

[a] Average indoor tanning was calculated based on the indoor tanning for the periods of high school/college and age 25~35 years. [b] Information for these characteristics in 1989. Major chronic diseases include cancer, cardiovascular disease, diabetes, or hypertension. [c] Information for alcohol intake in 1991. [d] Information for clinician-diagnosed depression in 2003.

Table 2 Odds ratios for the association between indoor tanning and risk of food addiction in the Nurses' Health Study II

Times per year	Average indoor tanning		
	n (cases)	Age-adjusted OR (95% CI)	MV-adjusted OR[a] (95% CI)
Never	52,088(4,164)	1.00 (Ref)	1.00 (Ref)
1-2	9,383 (739)	0.98 (0.90-1.07)	1.07 (0.99-1.17)
3-5	2,997 (269)	1.13 (0.99-1.29)	1.25 (1.09-1.43)
6-11	1,959 (195)	1.27 (1.09-1.48)	1.34 (1.14-1.56)
12-23	1,336 (161)	1.57 (1.33-1.86)	1.61 (1.35-1.91)
⩾24	147 (29)	2.82 (1.88-4.24)	2.98 (1.95-4.57)
Per 4 times		1.15 (1.11-1.19)	1.17 (1.12-1.21)
P-trend		<0.0001	<0.0001

[a] Adjusted for age (continuous), race (Caucasian, Hispanic, African American, or Asian), physical activity (in quintiles), BMI (in continuous variable), smoking (never, past, current smokers with 1-14, 15-34, or ⩾35 cigarettes/day), alcohol intake (0, 1-4, 5-9, 10-14, or ⩾15 g/d), UV index at birth, age 15, and age 30 years (5, 6, or 7 for each), depression (defined as self-reported clinical depression or regular use of anti-depressant medication, yes or no), and major chronic diseases (cancer, diabetes, cardiovascular disease, or hypertension, yes or no). We used the covariate information collected in 1989 or adjacent questionnaire cycles (when information was not collected in 1989) for the analysis.

Table 3 Stratified analyses for the association between per four times of average indoor tanning bed use and food addiction, according to measures of outdoor UV radiation

	n	OR[a] (95% CI)	*P* for interaction[a]
By average summer time sun exposure[b]			
<1	2617	1.00 (0.73-1.36)	0.23
2-4	36,141	1.18 (1.11-1.25)	
⩾5	28,610	1.12 (1.06-1.17)	
By UV index in the state of residence at birth			
⩽5	15,915	1.20 (1.11-1.30)	0.40
6	30,598	1.14 (1.09-1.21)	
⩾7	11,262	1.13 (1.04-1.23)	
By UV index in the state of residence at age 15			
⩽5	15,830	1.21 (1.12-1.31)	0.09
6	30,589	1.16 (1.10-1.22)	
⩾7	11,426	1.08 (0.99-1.18)	
By UV index in the state of residence at age 30			
⩽5	14,213	1.23 (1.13-1.34)	0.03
6	26,969	1.17 (1.10-1.23)	
⩾7	14,421	1.07 (0.98-1.16)	
By cumulative UV flux			
Tertile 1	21,104	1.24 (1.16-1.33)	0.05
Tertile 2	24,258	1.16 (1.09-1.22)	
Tertile 3	22,450	1.11 (1.03-1.18)	

[a] Adjusted for age (continuous), race (Caucasian, Hispanic, African American, or Asian), physical activity (in quintiles), BMI (in continuous variable), smoking (never, past, current smokers with 1-14, 15-34, or ⩾35 cigarettes/day), alcohol intake (0, 1-4, 5-9, 10-14, or ⩾15 g/d),), depression (defined as self-reported clinical depression or regular use of anti-depressant medication, yes or no), and major chronic diseases (cancer, diabetes, cardiovascular disease, or hypertension, yes or no), and UV index (at birth, age 15, or age 30 years, unless examined as the main subgroup variable, 5, 6, or 7 for each). We used the covariate information collected in 1989 or adjacent questionnaire cycles (when information was not collected in 1989) for the analysis. We used the covariate information collected in 1989 or adjacent questionnaire cycles (when information was not collected in 1989) for the analysis.
[b] Summer time outdoor sun exposure in direct sunlight in the middle of the day (between 10 am and 3 pm, hours/week).

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Table 4 **Odds ratios for the association between measures of outdoor UV radiation and the risk of food addiction in the Nurses' Health Study II**

	n (cases)	Age-adjusted OR (95% CI)	MV-adjusted OR[a] (95% CI)
Average outdoor sun exposure[b]			
<1	2617 (237)	1.00 (Ref)	1.00 (Ref)
2-4	36,141 (2876)	0.86 (0.75-0.99)	0.94 (0.82-1.09)
≥5	28,610 (2404)	0.92 (0.80-1.05)	1.05 (0.91-1.21)
UV index in the state of residence at birth			
≤5	15,915 (1247)	1.00 (Ref)	1.00 (Ref)
6	30,598 (2487)	1.04 (0.97-1.12)	1.10 (0.95-1.27)
≥7	11,262 (968)	1.10 (1.01-1.20)	1.15 (0.97-1.35)
UV index in the state of residence at age 15			
≤5	15,830 (1263)	1.00 (Ref)	1.00 (Ref)
6	30,589 (2473)	1.02 (0.95-1.09)	0.94 (0.80-1.11)
≥7	11,426 (964)	1.06 (0.97-1.16)	0.96 (0.80-1.15)
UV index in the state of residence at age 30			
≤5	14,213 (1139)	1.00 (Ref)	1.00 (Ref)
6	26,969 (2176)	1.01 (0.94-1.09)	1.04 (0.92-1.18)
≥7	14,421 (1194)	1.03 (0.95-1.13)	1.09 (0.95-1.25)
Cumulative UV flux			
Tertile 1	21,104 (1782)	1.00 (Ref)	1.00 (Ref)
Tertile 2	24,258 (1943)	0.94 (0.88-1.01)	0.91 (0.85-0.98)
Tertile 3	22,450 (1824)	0.96 (0.90-1.03)	1.04 (0.97-1.12)

[a] Adjusted for age (continuous), race (Caucasian, Hispanic, African American, or Asian), physical activity (in quintiles), BMI (in continuous variable), smoking (never, past, current smokers with 1-14, 15-34, or ≥35 cigarettes/day), alcohol intake (0, 1-4, 5-9, 10-14, or ≥15 g/d),), depression (defined as self-reported clinical depression or regular use of anti-depressant medication, yes or no), and major chronic diseases (cancer, diabetes, cardiovascular disease, or hypertension, yes or no), UV index at birth, age 15, and age 30 years (≤5, 6, or ≥7 for each, unless when examined as the main exposure). We used the covariate information collected in 1989 or adjacent questionnaire cycles (when information was not collected in 1989) for the analysis.
[b] Summer time outdoor sun exposure in direct sunlight in the middle of the day (between 10 am and 3 pm, hours/week).

years' follow-up (2001-2011). We found a significantly increased risk of incident depression associated with indoor tanning at age 25-35 years only (*P*-trend < 0.0001) (***Supplementary Table 1* available online**). No significant effect modifications by depression on the associations between indoor tanning and food addiction were observed (data not shown).

In secondary analyses (*n* = 37,324), we examined the association between indoor tanning and risk of bulimia (*n* = 566) and anorexia (*n* = 1,292) in high school. The frequency of indoor tanning at high school/college was associated with increased odds of bulimia (*P*-trend < 0.0001; OR = 2.54, 95%CI: 1.32-4.91 for ≥24 times/year). In contrast, the association between indoor tanning and anorexia appeared statistically significant only for those with indoor tanning ≥24 times/year (OR = 1.75, 95% CI: 1.02-2.99, ***Supplementary Table 2* available online**). Totally 119 cases with bulimia (119/566, 21.0%) and 135 cases with anorexia (135/1,292, 10.5%) had food addiction in 2009. The sensitivity analysis adjusting for bulimia and anorexia in high

school did not alter the association between indoor tanning at high school/college and risk of food addiction materially (*P*-trend < 0.0001; OR = 1.84, 95% CI: 1.20-2.81 for ≥24 times/year). We found significantly increased risk of food addiction associated with both bulimia (OR = 2.42, 95% CI: 1.94-3.03) and anorexia (OR = 1.30, 95% CI: 1.07-1.57) in high school.

Other sensitivity analyses restricting to Caucasians only, adjusting for outdoor sun exposure or cumulative UV flux, adjusting for information on time-varying covariates collected in 2009, adjusting for major pigmentary traits (hair color, number of sunburns, sunburn susceptibility, and number of moles), adjusting for BMI and depression in other forms, or excluding those with depression or major chronic diseases did not change the results appreciably (data not shown).

Discussion

In our study, a history of indoor tanning at or before early adulthood was significantly associated with

increased odds of food addiction at age 44-64 years. The likelihood of food addiction among women with indoor tanning of ≥ 24 times/year is almost 3 times as high as that among never indoor tanners. To our knowledge, this is the first study reporting an association between frequency of indoor tanning and risk of food addiction.

UV-seeking behaviors may include additional motivations beyond those aforementioned[2,5,9–12]. Indoor tanning may lead to systemically emotional and behavioral consequences, and frequent indoor tanners have opiate-like addictive features[1–2,5,10]. Previous reports on the continued tanning despite individuals' diagnosis of skin cancer also indicate potentially addictive characteristics of indoor tanning[30–31], which points to a commonality with nicotine dependence[32].

Recent laboratory work showed a hedonic action of β-endorphin and anhedonic effect of β-endorphin blockade in tanning response, suggesting that β-endorphin modulates UV seeking behaviors and may be critical underlying the addictive properties of indoor tanning[1]. The endogenous opioid peptide β-endorphin relieves nociception and attenuates other stress responses, of importance for the pathophysiology of the reward-mediated addictive disorders[33–39]. For example, it is known that low β-endorphin level is associated with alcohol addiction and that alcohol consumption elevates the level of β-endorphin[40]. As β-endorphin also plays a role in food addiction[24–26], the potentially shared craving mechanisms such as the β-endorphin basis may partly explain the associations between indoor tanning and food addiction. The ORs for indoor tanning at high school/college appeared larger than those for indoor tanning at age 25-35 years, indicating that frequent indoor tanning at an early age might represent an added risk for potential cross addictions later on. This is an interesting parallel with evidence that the risk for alcohol dependence increases when an individual is exposed to alcohol earlier in life[41]. A possible mechanism that might explain these relationships is that exposure to an addictive substance (be it alcohol or UV light) could have a more profound impact on the developing brain with implications for addictive behaviors later in life[42].

In addition to β-endorphin, other molecules may be crucial for the modulation of tanning seeking behaviors, such as the tumor suppressor p53, a skin-specific knockout of which leads to the abrogation of both tanning responses and behavioral changes[1,43]. Many genes have been identified to convey predisposition to multiple addictions[28]. For example, genetic variants of POMC, which encodes proopiomelanocortin (the precursor of β-endorphin), may be important for substance dependence as well[45]. The genetic variants of ANKK1 have been associated with both tanning addiction and substance addiction[13,44]. A candidate gene approach testing the addiction-related genetic predisposition for tanning addiction and food addiction may shed light on heretofore unknown mechanisms.

The association between indoor tanning and food addiction appeared stronger among those with a lower outdoor UV radiation. Regions that allow for more outdoor UV exposure might coincide with more body-consciousness. A tendency to manifest multiple addictions might manifest in some other forms than food addiction if such pressures were stronger[45], which may help explain the effect modification. We also tested the associations between measures of outdoor UV radiation and food addiction, with an assumption that some people who are addicted to UV light might get 'satisfied' by tanning outdoors in the summer and therefore would be less likely to tan indoors. However, we did not find significant associations, which did not support the addictive characteristics of these measures. However, the measures of outdoor UV radiation (average outdoor sun exposure, UV index and flux) do not necessarily represent tanning outdoors as many people who spend time outdoors may not have the goal of tanning.

We found that frequent indoor tanning at age 25-35 years may be a predictor for middle age depression. It is known that many people engage in addictive behaviors to 'self-medicate' negative mood[46]. As indoor tanning may operate as a dopaminergic form of addiction, it is likely that some individuals went indoor tanning frequently to manage their mood and the negative mood could also be the causes for the later life depression.

We suggest positive associations between indoor tanning at high school/college and risk of bulimia and anorexia, although the NHS II did not collect other eating disorder-related information except bulimia and anorexia in high school. As we put food addiction in the first place, we adjusted for bulimia and anorexia in a sensitivity analysis, which showed that the association of indoor tanning and food addiction was less likely mediated by eating disorders. However, both bulimia and anorexia in high school were significantly associated with food addiction, suggesting that these eating disorders may be strong predictors for food addiction in later life.

We acknowledge several limitations. First, as information on indoor tanning was self-reported in 2005, misclassification is possible. Intrinsic to all questionnaire-based epidemiologic studies, all other data examined were also self-reported, despite the recog-

nized reputation of data quality in the NHS II. However, the high levels of education and familiarity with medical issues among participants allow high-quality information collected on self-administered questionnaires. We yielded significant findings for indoor tanning at both assessed life periods. Misclassification of indoor tanning, if any, also tends to be non-differential across categories of food addiction. Therefore, our results were less likely to be greatly distorted by information bias. Second, our analysis has cross-sectional perspectives. The association between indoor tanning at high school/ college, or age 25-35 years, and risk of food addiction at middle-adulthood does not necessarily suggest a temporal relationship between concurrent indoor tanning and food addiction. As addictive behaviors are characterized by repetitive habits[27], our findings may be suggestive for the extrapolation to concomitant tanning seeking behaviors and food addiction. Third, we do not have the information on depression at high school/college or age 25-35 years and could not adjust for them specifically. Fourth, intrinsic to epidemiologic studies, we cannot rule out the possibility of residual confounding by unmeasured or imperfectly measured confounders.

In conclusion, findings based on a well-established cohort of women suggest a positive association between a history of indoor tanning before or at early adulthood and prevalence of survey-based food addiction at middle age. Exploration in the laboratory setting may contribute to the understanding of potential neuroendocrine changes and other mechanisms underlying tanning seeking behavior, which may provide insights to guide novel intervention strategies to curb indoor tanning and prevent the development of skin cancer.

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