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Sunbed use 2007–2015 and skin cancer projections of campaign results 2007–2040 in the Danish population: repeated cross-sectional surveys

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ABSTRACT

Objective To evaluate the effect of the Danish Sun Safety Campaign 2007–2015 on the prevalence of sunbed use and to model future effects on the skin cancer incidences 2007–2040.

Design The study has a repeated, cross-sectional design.

Setting Exposure to ultraviolet radiation is the main risk factor for skin cancer. Denmark has the highest prevalence of sunbed use reported and one of the highest incidences of skin cancer worldwide.

Participants During 2007–2015, survey data were collected for 37 766 Danes, representative of the Danish population with regards to age, gender and region.

Interventions In 2007, an ongoing long-term antisunbed campaign was launched in Denmark.

Primary and secondary outcome measures Sunbed use was evaluated by annual cross-sectional surveys. Skin cancer incidence was modelled in the Prevent programme, using population projections, historic cancer incidence, sunbed use exposure and relative risk of sunbed use on melanoma.

Results The prevalence of recent sunbed use in Denmark was reduced from 32% and 18% to 13% and 8% for women and men, respectively. The campaigns results during 2007–2015 are estimated to reduce the number of skin cancer cases from more than 5000 (746malignant melanoma, 1562 SCC, 2673 BCC) totally during 2007–2040. Keeping the 2015 level of sunbed use constant by continued campaign pressure or introduction of structural interventions would potentially prevent more than 750 skin cancer cases annually in 2040 and 16 000 skin cancer cases in total during 2007–2040.

Conclusion We have shown the value of prevention and of long-term planning in prevention campaigning. Sunbed use was reduced significantly during 2007–2015 and further reductions are possible by structural interventions. Consequently, significantly fewer skin cancer cases are anticipated during 2007–2040. The Danish Parliament has population support to enforce structural interventions to avoid a large burden of this disease.

Strengths and limitations of this study

- ► Long-term funding and planning secured the continuity in this study, comparability of data over time and the achievements of results.
- ► High awareness created by the campaign could cause, for example, political correctness bias or selection bias.
- ► Projection models can be influenced by changes in improved diagnostics, equipment, change in strength of the ultraviolet spectrum or output in sunbeds or other changes in population ultraviolet exposure.

INTRODUCTION

Exposure to ultraviolet radiation (UVR) is the main modifiable risk factor for keratinocyte skin cancers, squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) and malignant melanoma (MM) skin cancer.[1 2] Intermittent exposure to UVR from the sun and sunbeds, and sunburn history, are important factors in the aetiology of skin cancer.[3 4] In Denmark, the MM incidence (world standardised rate per 100 000) for men and women increased from 1.4 and 1.9 in 1949–1953 to 21.4 and 26.7 in 2010–2014, respectively.[5] The development is or was similar in most Caucasian populations, including in Northern European countries.[6] Similarly, keratinocyte skin cancer incidence increased manifold in the same period. Presumably because of improved primary and secondary prevention, improved diagnostics[7 8] and change in sun exposure patterns including increased number of Danes travelling abroad since the 1960s and the introduction and spread of sunbed facilities in the 1980s. Half of the Danish population travels to sunny destinations each year;[9 10] approximately 60% have ever used a sunbed[11] and 40% were sunburnt annually.[9 12]

In 2009, the International Agency for Research on Cancer classified ultraviolet-emitting tanning devices as ‘carcinogenic to humans’ with respect to MM.[4 13–17] The increased risk of MM was especially high among sunbed users younger than 30–35 years, and more than 75% of cases diagnosed in this young age were caused by sunbed use. Additionally, sunbed use has been shown to increase the risk of MM without the presence of sunburn.[15 17] Boniol *et al* summarised the risk of MM from sunbed use in a systematic review to be 1.2 for ever-use of sunbed and 1.59 for sunbed use initiated before the age of 35 years. Furthermore, a dose-response relationship was established between frequency of sunbed use and MM with an increased risk of 2% for each extra annual session.[18] The increased risk of developing basal cell carcinoma and squamous cell carcinoma from sunbed use was summarised by Wehner *et al*[19] to 1.29 and 1.67, respectively. Sunbed use is highly prevalent in Denmark, especially in younger age groups and more than half of those recalling their age of initiation of sunbed use reported to have started before age 18 years.[20 21] Sunbed use was estimated to be responsible for 13% and 8% of MM cases in Denmark in women and men, respectively.[18]

Campaign content

In May 2007, an antisunbed campaign was launched, with young people aged 15–25 years as the primary target. The campaign was based mainly on social media and also on magazines and radio, the traditional youth-targeted media. The campaign was very successful, with viral dissemination of video clips, music videos and other materials that made links between sunbed use, negative cosmetic effects and skin damage, and educational programmes including a pocket movie competition in seventh graders making them ambassadors for antisunbed campaigning.

The public activities included lobbying at national and local government levels and a public campaign programme. The lobbying focused on legal prohibition of sunbed use for children under 18 years of age and the removal of sunbeds from, for example, local sports facilities and pools under local government administration. In the summer of 2009, politicians spoke out in favour of legal restriction of sunbed use by children under 18 years of age. During spring and summer of 2009, some local governments started removing sunbeds from public facilities, and in 2017 the majority of local governments have removed sunbeds from their buildings. Only 6 out of 98 local governments still have sunbeds in their buildings and in 2 of those, age restrictions (<18 years) have been implemented. However, the majority of sunbed operators in Denmark is commercial and not influenced by these restrictions. The campaign generated press coverage and political debate which raised public awareness of the health risks associated with sunbed use, and included more than 2700 press clips on sunbed topics during the period of the study.

We studied the development of sunbed use in Denmark after the start of a 10-year national sun protection campaign in March 2007. The aims of this study are: (1) To show the possible effects of the Danish Sun Safety Campaign on prevalence of sunbed use. (2) To estimate potential reductions in future skin cancer incidence by the campaign.

MATERIALS AND METHODS

Overview

We estimated the effect of the Danish Sun Safety Campaign during 2007–2015 in terms of annual reduction in the fraction of ever users of sunbed. We modelled projections of future cancer incidence, introducing the effects of the campaign and compared with the status quo using realistic estimates of relative risks in the intervention scenarios to obtain an indication of the long-term impact of the campaign interventions on cancer incidence.

Questionnaire and confounding

During 2007–2015, a question on frequency of sunbed use was included in the annual population-based questionnaire on exposure to UVR and behaviour and attitude towards UVR exposure. In total, 37 766 Danes answered the 75-item questionnaire. Data were collected by computer assisted web interview by Epinion (2007 and 2014–2015) and Userneeds (2008–2013). Data were collected as representative for the Danish population by gender, age, region and education. The education variable included 7–10 options during the period and it was condensed into the three categories as shown in table 1. For the initial measurements in 2007, there was no higher age limit and persons 65 years and older were categorised as missing to be able to compare with following measurements. Since 2009, a limited number of internet panels were available, which were able to provide the respondent structure requested. To avoid measuring only effect in the panel and not in the population, it was a requirement that maximum 25% of the participants were allowed to participate in the survey the following year, because answering a questionnaire could influence the behaviour. Detailed data sampling strategies are available in annual survey reports on skrunedforsolen.dk.[22] Exposure to artificial UVR was determined by the question: 'How often did you use a sunbed within the past 12 months?': 'More than once a week, Once a week, More than once a month, Once a month, Fewer than four times a year, Not within the past twelve months, Never'; The questionnaire also elicited information on behaviour with respect to exposure to natural UVR; these results will be reported separately. The question about sunbathing was included in the analysis to distinguish between intentional and non-intentional tanning.[1] As data collection methods and demographic participant compositions in web panels have evolved during the data collection period this is reflected in data. Age was included in all analysis as 5-year or 10-year age groups. Teenagers were kept as '15–19 years' as their behaviour was shown to differ from that of the adult population.[23 24] Skin types were determined from self-assessed tan and sunburn reactions, according to Fitzpatrick skin type I (never tan, always burn) to skin type IV–VI (always tan, never burn).[25]

Table 1 Distribution of demographic characteristics in cross-sectional surveys on ultraviolet exposure 2007–2015 of 37 766 Danes

Characteristic (%)	Total (n)	% or mean	March 2007	August 2007	August 2008	August 2009	August 2010	August 2011	August 2012	August 2013	August 2014	August 2015
Total (n)	37 766	**100**	4303	4451	4277	4186	4156	4130	2195	4022	2047	3999
Gender	P<0.001											
Male	18 437	**49**	44	44	50	50	50	50	50	50	50	50
Female	19 300	**51**	56	56	50	50	50	50	50	50	50	50
Age group, years	P<0.001											
15–19	3417	**9**	8	8	10	9	10	9	9	10	10	10
20–29	6017	**16**	9	8	18	17	17	17	17	19	19	20
30–39	7409	**20**	20	20	16	21	21	21	21	19	19	18
40–49	8442	**23**	21	23	23	22	22	22	22	23	22	22
50–59	7547	**20**	20	19	24	20	20	20	20	19	18	18
60–64	3933	**10**	11	10	8	11	10	10	10	11	12	12
missing	1001	**3**	11	11	0	0	0	0	0	0	0	0
Skin type	P<0.001											
I	4550	**12**	12	10	11	10	10	11	11	16	15	15
II	19 316	**51**	51	51	52	52	53	54	51	48	50	50
III	12 203	**32**	34	35	33	34	34	32	33	29	31	28
IV–VI	735	**2**	3	3	2	2	2	1	2	2	2	2
missing	962	**1**	1	1	1	1	1	1	1	1	1	1
Region	P<0.001											
Capital	13 065	**35**	39	46	33	32	32	32	31	32	32	32
Zealand	4680	**12**	11	9	13	12	12	12	15	14	14	14
Northern Jutland	7028	**10**	10	9	10	11	10	10	10	10	10	10
Central Jutland	8086	**21**	21	18	21	22	21	22	23	23	21	23
Southern Denmark	3749	**19**	16	14	18	18	19	18	22	21	23	21
Missing	1158	**3**	3	3	5	5	6	5	0	0	0	0
Education	P<0.001											
<10 years	9372	**25**	18	16	31	32	28	29	28	28	8	24
10–12 years	14 881	**39**	29	28	44	45	49	49	42	40	27	42
>12 years	12 909	**34**	54	55	25	22	22	21	28	31	64	32
Missing/ unspecified	604	**2**	1	1	2	2	2	2	2	1	1	2
Sunbathe	P<0.001											
Yes	24 350	**64**	72	61	65	67	65	61	60	64	66	63
No	13 416	**36**	28	39	35	33	35	39	40	36	34	37
Have children	P<0.001											
Yes	12 527	**33**	35	36	32	33	33	34	25	34	34	32
No	25 239	**67**	65	64	68	67	67	66	75	66	66	68
Temperature	P<0.001	**15.8**	17.4	15.9	16.3	15.6	16.3	15.8	14.3	15.7	17.2	14.1
Sun hours	P<0.001	**241**	285	197	281	250	248	212	203	254	274	210
Days with rain/month	P<0.001	**14.4**	8.5	18	13.5	15.2	11.9	15.6	19.4	12.3	13.3	16.2

Bold type emphasise variable headings and average.
P values are for χ^2 test between factor levels and year of measurement. Values are percentage except for weather variables, which are expressed as means.

The accumulated sun hours and average temperatures of June and July were included in the regression analysis as Danes could be more prone to use sunbed when the weather conditions makes outdoor sunbathing impossible and significant variation in weather measures occurred during the period analysed.

Patient involvement

The Danish Sun Safety Campaign has continuously used information from for example interviews and focus groups with patients, at-risk groups and lay people in an iterative set-up to improve campaign elements as well as annual evaluations of the campaign. Recruitment is described above and dissemination of results will be by scientific publication, national press as well as patient organisation newsletters from the Danish Cancer Society.

Analysis

Answers to sunbed use were grouped into 'recent users' and 'non-recent users' and 'ever users' and 'never users', respectively. Recent use was defined as use within the past 12 months. Similarly, ever use of sunbed was defined as belonging to all categories except the 'never' category. Recent use was modelled to describe immediate changes in sunbed use according to aim 1 and ever use was modelled for use in the cancer projections for aim 2. The homogeneity of, respectively, recent and ever sunbed use over time of survey and demographic variables was examined. The outcome 'sunbed use, yes/no' was analysed using logistic regression. The factors included in the model as categorical variables were gender, age, education, skin type, having children below age 18 years in the household and region. Factors with a statistically significant different distribution were included as possible explanations. Adjusted ORs and 95% CIs were calculated. The P values from the logistic regression analysis refer to either tests for variation between the factor levels by time (year) or trend as stated for the relevant analysis. For all tests, P values <0.05 were considered statistically significant. The logistic procedure in SAS V.9.3 (SAS Institute, Cary, North Carolina, USA) was used for the analyses.

The Prevent model

Projection of future incidence was estimated using Prevent.[26 27] This programme was adapted for the Eurocadet project to model future cancer incidence by implementation of lifestyle preventive strategies. Prevent calculated the percentages of potentially prevented cases under the scenario of interest as compared with the status quo scenario. If the scenario of interest is no exposure or exposure with minimum impact on risk, this percentage is interpretable as the population attributable fraction of sunbed use experience, respectively, on skin cancer (MM, SCC, BCC) incidence by the year 2040: they represent the numbers of cases that would be prevented had the population not used sunbed and therefore the fraction of MM, SCC and BCC cases attributable to these risk factors. Three types of data are needed to run the model: (1) Demographic data (current and projected population sizes by age and sex). (2) Risk factor-related data (prevalence, changes in prevalence as a result of interventions and risk estimates). (3) Disease incidence data (cancer rates and estimated annual percentage change (EAPC) to account for trends in disease incidence that are not associated with modelled risk factor data). The projected numbers of new cancer cases were computed based on the demographic data and under different scenarios of changes in the prevalence of risk factors. Results are projected rates and numbers with and without modelled interventions by risk factor prevalence. The model is summarised in figure 1.

Exposure: sunbed use

The prevalence of sunbed use was derived from sun behaviour questionnaires of the Danish Sun Safety Campaign as described above. The campaign was the only initiative in Denmark collecting data on UVR exposure continuously since 2007.[9 11 12 28-30] In the Prevent model, sunbed use was included as ever/never use. The change in prevalence of sunburn applied in the population projections was from logistic regression analysis.

Incidence data

National incidence rates for melanoma and keratinocyte skin cancer (ICD-10 code: C43 and C44) by sex and 5-year age groups were retrieved from NORDCAN.[5] The EAPC for men and women for the past 25 years, respectively, was 6.4% and 10.9% increase for SCC, 5.4% and 7.4% for BCC, and 4.4% and 4.5% for melanoma.[5] We chose to use a uniform conservative 4% increase in all skin cancer rates for men and women for the modelling. EAPC was applied for the first 15 years after which it remained constant at this level. For sensitivity analysis, we applied an EAPC, respectively, of 0 years and 30 years. The registration of keratinocyte skin cancer C44 is probably more complete in Denmark than in most other countries. Since 2004 the cancer registration has been made by a linkage between the national hospital register, the pathology register, and the cause of death register. For both melanoma skin cancer (C43) and keratinocyte skin cancer (C44), divided into BCC and other keratinocyte skin cancers, mainly SCC, registrations are also included based on a registration in the pathology register alone from 2004 and on.

Population projections

From Statistics Denmark we obtained the size of the population on 1 January of the corresponding period of the latest available incidence data by 1-year age category and sex as well as forecasted population sizes for each year up to 2040 by 5-year age categories and sex, using the medium national growth estimates.

Effect of sunbed use on the incidence of melanoma skin cancer

Relative risks for sunbed use on the risk of MM and keratinocyte cancers were derived from the largest

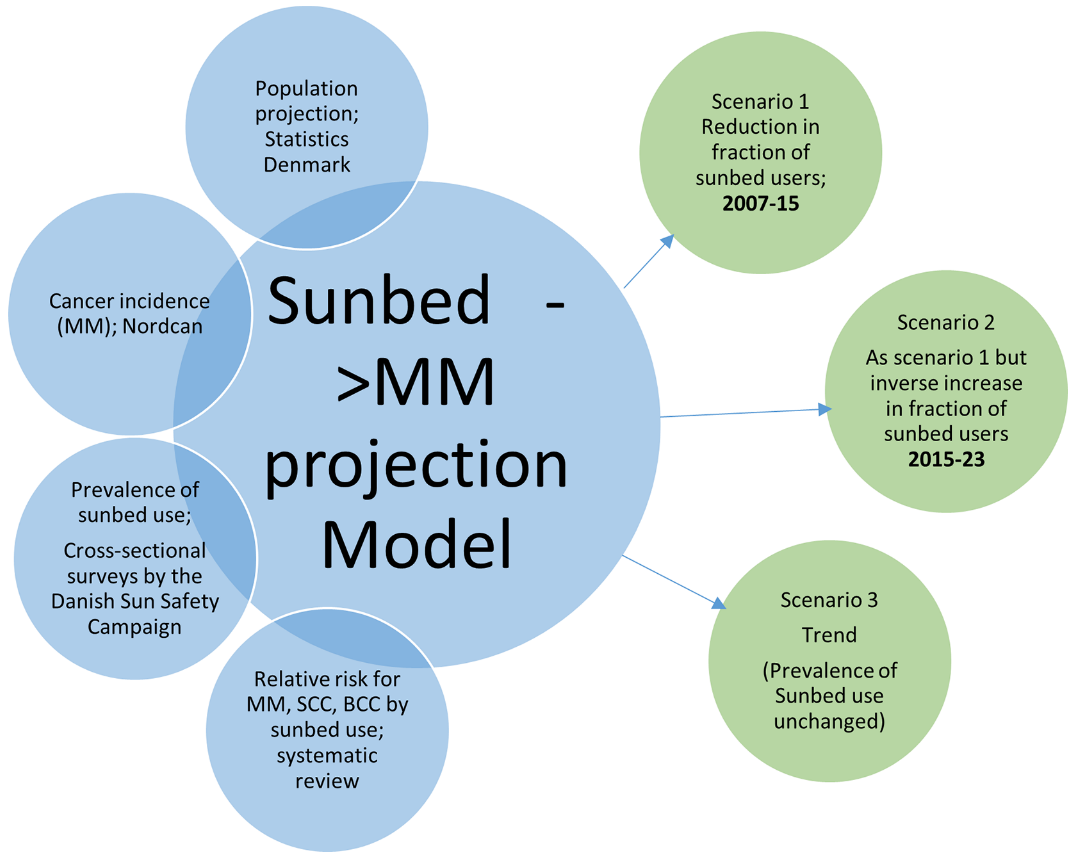

Figure 1 Illustration of data projections and scenarios. MM, malignant melanoma.

meta-analysis on the subject, established by, respectively, Boniol *et al* and Wehner *et al*. MM: RR=1.2 for >35-year-old and RR=1.59 for <35-year-old and RR for SCC and BCC of 1.67 and 1.29, respectively.[18 31] These finding s were used as the relative risks and risk functions in our modelling (figure 1). The relative risks and risk functions were assumed equal for all age groups within age bands included in the study, and across time. The effect of a risk factor exposure on cancer incidence has a latency time. Prevent accommodates this through two time lags: (1) The time that the risk remains unchanged after a decline in risk factor exposure (LAT) and (2) The period during which the changes in risk factor exposure gradually affect the risk of cancer, eventually reaching risk levels of the non-exposed (LAG).[26] Thus, assuming that sunbed users who quit sunbed use following the campaign after a total of (LAT+LAG) years are no longer at increased risk of skin cancer. For this study, we used for sunbed use a LAT of 2 years and a LAG of 5 years for MM and, respectively, 2 years and 8 years for keratinocyte cancers. LAG was modelled as a linearly declining risk. LAT and LAG periods for sunbed use on risk of skin cancers has not been estimated precisely. Pil *et al* used an induction period of 20 years, however we chose shorter time periods for MM from the knowledge of intermittent exposure pathway[1] and the experiences from Iceland[32] and sunbed use in young people.[14] In Iceland, both, a drastic increase and following decrease in melanoma incidence was observed within a 10-year period preceded by complimentary delayed increase and decrease, respectively, in the number of available sunbed salons. The MM incidence change was primarily driven by people below 50 years and trunk site melanomas, which are characteristic for intermittent/sunbed exposure.

We have modelled the development in future skin cancer Incidence in Denmark in three scenarios. We have used the reductions in sunbed use during 2007–2015 to model MM Incidence in 2007–2040.

- Scenario 1: We assume the campaign is discontinued after 2015 and that the rate of sunbed use remains constant afterwards (irreversible campaign effect).
- Scenario 2: Similar to scenario 1, except, we have modelled a conservative 'spring effect' where the prevalence of sunbed use returns to the precampaign level in the inverse rate as it was reduced for 2015–2023 (reversible campaign effect).
- Scenario 3: The expected trend if prevalence of sunbed use is unchanged (trend/no campaign effect).

We have also applied sensitivity analyses to the conservative scenario 2. We have used the applied EAPC for 0, respectively, for 30 years instead of 15 years. We have applied a combined LAT+LAG time of either 0 or twice the time, of the main scenario.

RESULTS

Table 1 shows the distribution of demographic characteristics from annual data collections during 2007–2015.

Answers were collected from more than 4000 persons/survey, except for 2012 and 2014 where 2000 persons/survey was settled for due to challenges with data collection of certain groups, especially young (15–19 years) men. For all included variables, we found significant variation over the years. Only 2007 data collections differed for gender, after which sampling methods were optimised. In 2007 there was no higher limit for age, however, in this analysis persons older than 65 years were excluded, which lead to differences in the distribution of age compared with 2008–2015. There were more people characterised with paler skin types in 2013–2015. Region and education was not used in the sampling for all years, which means that, for example, August 2007 data are over-represented by persons from the region capital. Education was differently distributed in panels and in panel characterisations of education between years. Persons who reported sunbathing, declined during the campaign period. Persons having children 18 years or younger staying at home also varied. Weather varied randomly for the variables mean temperature, mean monthly number of sun hours and mean monthly days with rain.

Online supplemental tables S1a,b show the detailed distribution of sunbed use, recent use and ever use, respectively. In all the annual surveys, there are differences for all included variables except having children. In general, more women used sunbed, and sunbed use decreased with age. More persons with dark skin types used sunbed and sunbed use was more prevalent in Northern Jutland and less prevalent in the regional capital. Fewer persons with more than 12 years of education used sunbed, while more persons who sunbathed also use sunbeds.

Figure 2A,B shows the adjusted OR and 95% CI of the development in sunbed use (recent and ever use, respectively) adjusted for gender, age, education, region and skin type, with the March 2007 measurement as the reference point. The decrease in sunbed use was largest at the beginning of the campaign period and until about 2011/2012, where the decrease levelled. In 2015, the OR for sunbed use was approximately 0.3 compared with the precampaign measurement in March 2007.

Table 2 (ever use) and online supplemental table S2 (recent use) show the logistic regression analysis of the sunbed use in Denmark by demographic factors in the left part of the table and in the right part is shown the annual percentage change in sunbed use per year. Age and skin type are the variables most influential on sunbed use. We have shown the crude OR (95% CI) and a model adjusted for gender, age, skin type, region, education and having children below 18 years in the household. Due to the large differences in education in our analysis of the development of sunbed use, we also tried to exclude education, but that did not change the estimates significantly. In addition, we examined the influence by weather parameters in a model additionally adjusted for temperature, number of sun hours and days with rain. We found that increasing temperature, number of sun hours and number of days with rain was associated with increased sunbed use. In the right side of table 2 and supplemental table S2 is shown the crude reduction by annual measurement. Women reduced their recent sunbed use more than men and young persons more than older persons, especially the 15–29-year-olds. There were no significant differences in reduction by skin type, region, education, sunbathing or among people with or without children. Overall, the adjusted analysis for ever use of sunbed showed an annual reduction of more than 3% per year in the campaign period. For recent sunbed use the annual reduction was 4% per year.

The prevalence of sunbed use influence on future skin cancer incidence

In figure 3A–C, we have modelled the development of the number of future MM, SCC and BCC incident cases according to scenarios 1–3 in Denmark. The effect of the campaign results in a reduction of 103 MM, 271 SCC and 387 BCC skin cancer cases per year in 2040 and in total 2443 MM, 5383 SCC and 8437 BCC cases during 2007–2040, while if the effect of the campaign is reversed to the precampaign level there will be no change in the annual number of skin cancer cases in 2040 but a total reduction of 746 MM, 1562 SCC and 2673 BCC

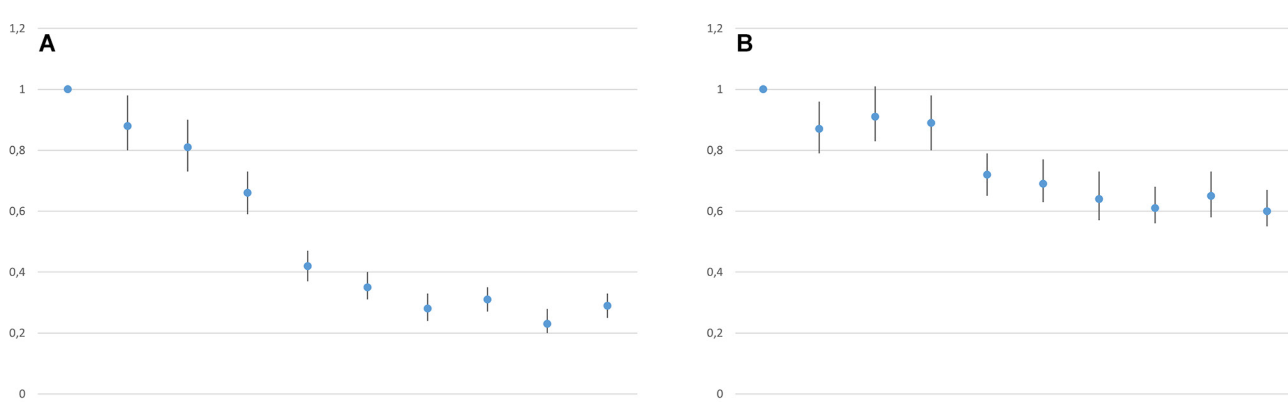

Figure 2 (A) Values are OR (95% CI) sunbed use (recent use) compared with 2007 precampaign measurement adjusted for gender, age, education, region and skin type. (B) Values are OR (95% CI) sunbed use (ever use) compared with the 2007 precampaign measurement adjusted for gender, age, education, region and skin type.

Table 2 Logistic regression analysis of sunbed use (ever use) in Denmark 2007–2015 by demographic factors and annual percentage decrease in sunbed use overall and by factor levels

Characteristic (%) Total (n)	Total (n)	% or mean	Crude OR (95% CI)	Adjusted OR (95% CI)*	Adjusted OR (95% CI)†	Sunbed use annual change	Sunbed use annual change (adjusted)
Total (n)	37 562	18	34 616	34 616	34 616	0.97 (0.97–0.97)	**0.97 (0.97–0.97)**
Gender			P<*0.001*	P<*0.001*	P<*0.001*		
Male	18 325	13	1 (ref)	1 (ref)	1 (ref)	0.99 (0.98–1.00)	
Female	19 237	22	2.78 (2.66 to 2.90)	3.02 (2.88 to 3.16)	2.66 (2.53 to 2.79)	0.95 (0.95–0.96)	
Age group (years)			P<*0.001*	P<*0.001*	P<*0.001*		
15–19	3383	27	1.38 (1.25 to 1.53)	1.30 (1.17 to 1.44)	1.03 (0.92 to 1.15)	0.91 (0.90–0.92)	
20–29	5970	25	3.22 (2.95 to 3.51)	3.28 (2.99 to 3.61)	3.06 (2.78 to 3.37)	0.90 (0.89–0.91)	
30–39	7369	19	4.37 (4.01 to 4.76)	4.53 (4.11 to 4.98)	4.78 (4.33 to 5.28)	0.94 (0.93–0.96)	
40–49	8419	18	2.97 (2.74 to 3.23)	3.01 (2.75 to 3.30)	2.95 (2.69 to 3.24)	1.00 (0.99–1.01)	
50–59	7529	12	1.49 (1.37 to 1.62)	1.48 (1.36 to 1.62)	1.45 (1.32 to 1.58)	1.00 (0.99–1.00)	
60–64	3922	8	1 (ref)	1 (ref)	1 (ref)	0.99 (0.97–1.00)	
Skin type			P<*0.001*	P<*0.001*	P<*0.001*		
I	4534	13	1.08 (0.92 to 1.28)	0.64 (0.54 to 0.76)	0.80 (0.66 to 0.95)	0.97 (0.96–0.98)	
II	19 252	18	1.19 (1.02 to 1.36)	0.92 (0.78 to 1.09)	0.99 (0.83 to 1.17)	0.97 (0.97–0.97)	
III	12 141	19	0.96 (0.82 to 1.13)	0.90 (0.76 to 1.07)	0.93 (0.78 to 1.10)	0.98 (0.96–0.98)	
IV–VI	733	23	1 (ref)	1 (ref)	1 (ref)	0.98 (0.95–1.00)	
Region			P<*0.001*	P<*0.001*	P<*0.001*		
Capital	12 998	15	1 (ref)	1 (ref)	1 (ref)	0.97 (0.97–0.98)	
Zealand	4652	16	0.88 (0.82 to 0.97)	1.15 (1.04 to 1.27)	0.99 (0.92 to 1.07)	0.98 (0.96–0.99)	
Northern Jutland	3730	21	1.17 (1.08 to 1.26)	0.93 (0.87 to 1.01)	1.30 (1.20 to 1.42)	0.97 (0.96–0.98)	
Central Jutland	8042	19	1.08 (1.02 to 1.14)	1.15 (1.08 to 1.22)	1.18 (1.10 to 1.25)	0.96 (0.95–0.97)	
Southern Denmark	6985	18	0.99 (0.94 to 1.06)	1.08 (1.01 to 1.15)	1.11 (1.04 to 1.19)	0.97 (0.97–0.98)	
Education			P<*0.001*	P<*0.001*	P<*0.001*		
<10 years	9313	17	0.64 (0.61 to 0.68)	1.01 (0.94 to 1.07)	1.10 (1.03 to 1.17)	0.97 (0.96–0.98)	
10–12 years	7130	20	1.04 (0.99 to 1.09)	1.12 (1.06 to 1.19)	1.16 (1.10 to 1.22)	0.95 (0.95–0.96)	
>12 years	7682	18	1 (ref)	1 (ref)	1 (ref)	0.98 (0.98–0.99)	
Sunbathe			P<*0.001*	NA	P<*0.001*		
Yes	24 240	24	4.16 (3.85 to 4.49)		2.73 (2.59 to 2.87)	0.96 (0.96–0.97)	
No	13 322	7	1 (ref)		1 (ref)	0.99 (0.99–1.00)	

Continued

Table 2 Continued

Characteristic (%) Total (n)	Total (n)	% or mean	Crude OR (95% CI)	Adjusted OR (95% CI)*	Adjusted OR (95% CI)†	Sunbed use annual change	Sunbed use annual change (adjusted)
Have children <18 years in the household			N *P<0.001*	P=*0.030*	P=*0.085*		
Yes	12 461	18	1.55 (1.49 to 1.63)	1.06 (1.01 to 1.12)	1.05 (0.99 to 1.11)	0.96 (0.96–0.97)	
No	25 101	17	1 (ref)	1 (ref)	1 (ref)	0.98 (0.97–0.98)	
Temperature (°C)			P*<0.001*	NA	P*<0.001*		
			1.11 (1.08 to 1.13)		1.15 (1.11 to 1.19)		
Sun hours (/100/summer)			P*<0.001*	NA	P=*0.004*		
			1.13 (1.08 to 1.19)		1.23 (1.07 to 1.42)		
Days with rain/month			P*<0.001*	NA	P*<0.001*		
			0.99 (0.98 to 0.99)		1.04 (1.03 to 1.06)		

ORs and CIs
*Model adjusted for gender, age, education, skin type, have children and region.
†Model additionally adjusted for sunbathing and weather indicators.
NA, not applicable.

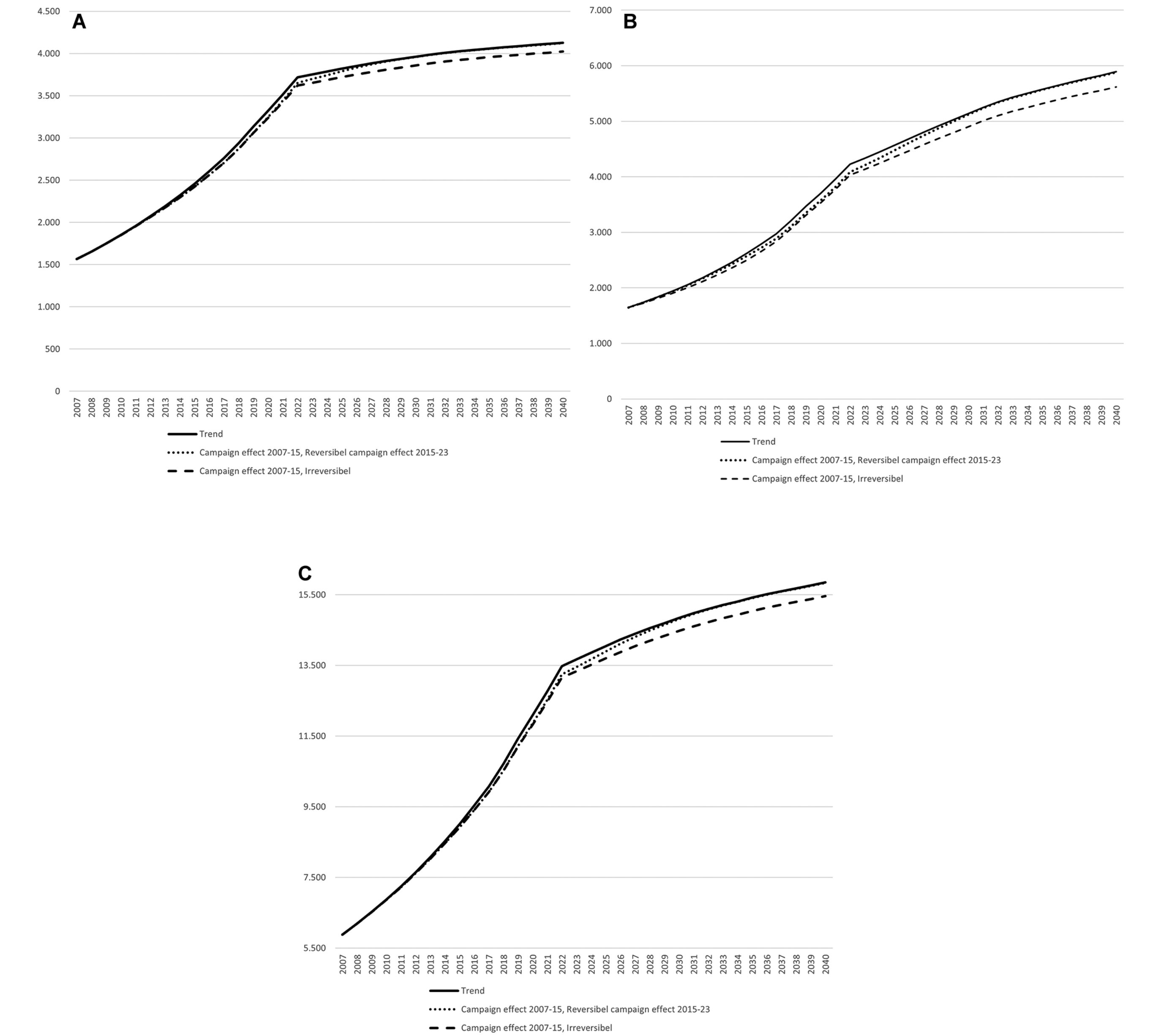

Figure 3 (A) The expected number of malignant melanoma (MM) cases, when sunbed use is unchanged; there is a reversible or irreversible campaign effect. Assumed estimated annual percentage change 2007–2022 (4% increase) and 2022–2040 (0% constant). LAT time of 2 years and LAG time of 5 years. (B) The expected number of SCC cases, when sunbed use is unchanged; there is a reversible or irreversible campaign effect. Assumed estimated annual percentage change 2007–2022 (4% increase) and 2022–2040 (0% constant). LAT time of 2 years and LAG time of 8 years. (C) The expected number of BCC cases, when sunbed use is unchanged; there is a reversible or irreversible campaign effect. Assumed estimated annual percentage change 2007–2022 (4% increase) and 2022–2040 (0% constant). LAT time of 2 years and LAG time of 8 years.

cases during 2007–2040. The results of the skin cancer reduction projections including relative reductions are summarised in table 3. The table also includes the projections for the sensitivity analysis for scenario 2 where EAPC and LAT+LAG were examined. There was a minimum and a maximum of 423 and 869 fewer MM cases, respectively, during 2007–2040. Minimum and maximum of all skin cancer types were 6208 and 11 972 fewer cases totally during 2007–2040. The relative decrease is larger for irreversible campaign effects compared with reversible. The sensitivity analysis variations of scenario 2 were robust to changes in cancer incidence and time to effect.

DISCUSSION

We have shown that the Danish Sun Safety Campaign reduced the recent sunbed use during 2007–2015, from 32% and 18% to 13% and 8% for women and men, respectively. The OR for recent sunbed use in 2015 compared with the precampaign level was 0.3. We have modelled these results with respect to future skin cancer incidences and expect more than 750 fewer cancer cases annually in 2040 and more than 16 000 fewer cases totally until 2040, as the campaign is still ongoing. Had the campaign been terminated after 2015, it may not have influenced the annual number of skin cancers in 2040, however during

Table 3 Projected change in number of skin cancer cases 2007–2040 based on modelled scenarios of the change in sunbed use fraction 2007–2015 in Denmark compared with trend

	Projections based on campaign results 2007–2015		Sensitivity variations of scenario 2			
Scenario	1 (irreversible)	2 (reversible)	*EAPC0	*EAPC30	†LATLAG, 0	†LATLAG, double
Total MM cases	111.353	111.353	63.104	154.525	111.353	111.353
Total SCC cases	136.999	136.999	83.108	184.766	136.999	136.999
Total BCC cases	414.817	414.817	254.859	547.749	414.817	414.817
ΔTotal MM	2.443 (2.2 %)	746 (0.7 %)	423 (0.7 %)	800 (0.5 %)	584 (0.5 %)	869 (0.8 %)
ΔTotal SCC	5.383 (3.9 %)	1.562 (1.1 %)	945 (1.1 %)	1.705 (0.9 %)	1.220 (0.9 %)	1.885 (1.4 %)
ΔTotal BCC	8.437 (2.0 %)	2.673 (0.6 %)	1.623 (0.6 %)	2.898 (0.5 %)	2.107 (0.5 %)	3.131 (0.8 %)

*EAPC0 and EAPC30 correspond to number of years with the estimated annual percentage change (EAPC = 4 %) in incidence. The remaining years are constant, ie, EAPC = 0 %. The main scenarios apply 15 years the indicated EAPC.
†LATLAG, 0 and double, respectively, is the time from an intervention is applied to the effect of the intervention on the risk factor affects the risk of cancer.
MM, malignant melanoma.

2007–2040 more than 5000 skin cancer (MM, SCC and BCC) cases would still have been avoided.

Strengths and limitations

The unique strength of this study is the possibility of long-term planning, securing continuity in the campaign including comparable wordings in the questionnaires and personnel to secure comparable evaluations over the entire period. The high continuous campaign pressure has been made possible by the long-term funding.

There is a risk that the high awareness created by the campaign could have caused political correctness bias meaning that, for example, persons would have falsely stated no to sunbed use in questionnaires. Similarly selection bias may have occurred, for example, if sunbed users were less prone to participate in surveys of this subject.

A prognosis of the cancer incidence in absolute numbers is difficult to provide as there are unknown indicators, which we were not able to include in the model, like improved diagnostics, equipment, change in strength of the ultraviolet spectrum or output in sunbeds,[7 33] or other changes in ultraviolet exposure. As we have used the difference between two cancer incidence rates, this has had minor influence on the results. The Prevent model primarily gives useful measures of the influence of change in use of sunbeds. The model accuracy is as good as the quality of the data input and dependent on the assumptions applied for the scenarios. Exact LAT and LAG times are not determined; however, varying LAT+LAG times were included in the sensitivity analysis and their relative estimates were within a reasonable range. Model-based results should be interpreted with caution and with mention of limitations.

The number of skin cancer cases in the years passed is different from the actual incidence development because it is influenced by factors not included. Around 2002–2004 the dermatoscope was introduced among dermatologists in Denmark, which probably increased the rate of detection[7] for a while. In the following period a plateau is seen from around 2011.[5] The decreasing incidence rate is likely to be a consequence of the earlier detection/treatment, an effect also seen in various screening programmes. While the increasing skin cancer incidences increased media awareness of the disease in the 1990s, in 2007, the multicomponent Intervention of the Danish Sun Safety Campaign raised this awareness manifold. The increased awareness may have led to an increase in mole check by the general physician, which could have increased the number of diagnoses; however we were not able to measure this.

Reduction in sunbed use

Denmark had one of the highest reported frequencies of sunbed use in the world before the Danish Sun Safety Campaign was launched. The largest reductions in sunbed use occurred among the youngest age groups and among women, which had the highest prevalence of sunbed use and were the main targets of the campaign. Even though large reductions in sunbed use occurred, the prevalence of sunbed use in Denmark is now just comparable to that of other European countries, for example 14% within the past year in Germany in 2012.[34] Concerning campaign efficiency, there have been antisunbed campaigns in, for example, UK, Canada, USA and Australia, which have also shown reductions, however our baseline use is not similar and comparable. The past years' reduction in sunbed use has levelled off perhaps as a consequence of a changed focus of the Danish Sun Safety Campaign towards sunny holidays or perhaps the remaining sunbed users are less perceptible of risk communication.

Consequences and recommendations

Pil *et al*[35] have previously modelled the effect of various scenarios thought to prevent skin cancer. Our results are based on an actual intervention with measurable results of the exposure; therefore, our modelling results of the future cancer incidence are a realistic prognosis of the incidence change. Likewise, we have shown the importance of a continued campaign pressure to achieve these goals (difference between models 1 and 2).

WHO suggests countries ban sunbeds or alternatively restrict (staff supervision, age limit, high-risk individuals), manage (license, radiation output and time limits, staff training, tax) and inform (health risks, display warning, ban marketing) to protect their populations.[36] In 2017, the majority of countries in Western Europe and the majority of US states have introduced age limits for sunbed use to protect children, and states with age limits succeeded in reducing the prevalence of sunbed use.[37] Furthermore, Australia and Brazil have completely banned sunbed use to protect their populations against the detrimental effects of sunbed use on human health and to reduce government spending related to skin cancer diagnostics and treatment.[38] Belgium is, to our knowledge, the first European country to recommend a ban against sunbed use,[39] while Denmark is now one of few remaining Western European countries without an age limit to protect children.[40]

Emphasising the health potential of the achieved results, we hope to motivate government administration to implement structural interventions to reduce sunbed use in Denmark as well as in countries with similar problems as in Denmark. We specifically address the need for a revision of the Danish sunbed legislation adopted in 2014.

CONCLUSION

The Danish Sun Safety Campaign has significantly reduced sunbed use in Denmark since 2007. Several legislative restrictive measures exist which would be beneficial to introduce reduction of sunbed use further at the current stage and to avoid sunbed use increase again if campaigning is not available. Because of the campaign, we expect fewer skin cancer cases in Denmark in the future. Danish politicians have the opportunity, supported by the population, to reduce skin cancer incidences further and thereby to reduce the future costs of skin cancer.

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Author note BK affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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