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Skin cancer projections and cost savings 2014-2045 of improvements to the Danish sunbed legislation of 2014

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Summary

Background: Sunbed use increases the risk of skin cancer. The Danish sunbed legislation (2014) did not include an age limit.

Aim: To model skin cancer incidences and saved costs from potential effects of structural interventions on prevalence of sunbed use.

Materials and Methods: Survey data from 2015 were collected for 3999 Danes, representative for the Danish population in regards to age, gender and region. Skin cancer incidences were modelled in the Prevent program, using population projections, historic cancer incidence, sunbed use exposure and relative risk of sunbed use on melanoma.

Results: If structural interventions like an age limit of 18 years for sunbed use or complete ban had been included in the Danish sunbed legislation in 2014, it would have reduced the annual number of skin cancer cases with 455 or 4177, respectively, while for the entire period, 2014-2045 the total reductions would be 3730 or 81 887 fewer cases, respectively. The cost savings from an age limit or ban, respectively, are 9 and 129 millions € during 2014-2045.

Conclusion: Legislative restrictive measures which could reduce the sunbed use exists. Danish politicians have the opportunity, supported by the population, to reduce the skin cancer incidence and thereby to reduce the future costs of skin cancer.

KEYWORDS

Campaign, melanoma projections, prevention, questionnaire, skin cancer, ultraviolet radiation

1 | INTRODUCTION

Exposure to ultraviolet radiation (UVR) is the main risk factor for keratinocyte (SCC and BCC) and cutaneous melanoma (CM) skin cancers.[1,2] Intermittent exposure to UVR from the sun and sunbeds are important factors in the aetiology of skin cancer[3,4]. In Denmark, the CM incidence (world standardized rate per 100 000) for men and women increased more than 10-fold since the 1950s to 21.4 and 26.7 in 2010–2014, respectively.[5] Similarly, the basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) incidences for men and women have increased manifold to 103.0 and 104.3 (BCC) and 17.5 and 13.9 (SCC) in 2010–2014, respectively.[5] The increase is presumably a consequence of the increased attention from primary prevention campaigns and improved secondary prevention, improved diagnostics[6,7] and change in sun exposure patterns including increased travelling since the 1960s and introduction and spread of sunbed facilities in the 1980s. Half of the Danish population travel to sunny destinations each year,[8,9]

TABLE 1 Distribution of demographic characteristics and percentage of sunbed use in cross-sectional survey on UV exposure in 2015 in 3999 Danes

Characteristic (%)	Total n (%)	% ever-used sunbed
Total (n)	3999 (100)	
Gender		$P < 0.001$
Male	2013 (50)	35
Female	1986 (50)	58
Age group		$P < 0.001$
15-19	385 (10)	22
20-29	798 (20)	44
30-39	738 (18)	62
40-49	881 (22)	60
50-59	732 (18)	40
60-64	465 (12)	33
Region		0.487
Capital	1290 (32)	47
Zealand	562 (14)	43
Northern Jutland	406 (10)	51
Central Jutland	906 (23)	45
Southern Denmark	835 (21)	47
Education		0.017
<10 y	975 (24)	41
10-12 y	1670 (42)	47
>12 y	1290 (32)	50

P-values are for chi-square test observed vs. expected levels of ever-used sunbed.
Values are percentage.

approximately 60% have ever used a sunbed[10] and 40% were sunburnt annually.[8,11]

In 2009, the International Agency for Research on Cancer classified ultraviolet-emitting tanning devices as 'carcinogenic to humans' with respect to CM.[4,12-16] The increased risk of CM was shown to be especially high among sunbed users younger than 30-35 years, where more than 3 out of 4 CM cases diagnosed at this young age was caused by sunbed use. Increased risk of CM from sunbeds was shown even without the presence of sunburn.[13,15] Boniol et al[17] summarized the risk of CM from sunbed use in a systematic review to be 1.2 for ever-use and 1.59 for use initiated before the age of 35. Additionally, a dose-response relationship was established between frequency of sunbed use and CM with an increased risk of 2% for each extra annual session. The increased risk, from sunbed use, of developing BCC and SCC was summarized by Wehner et al[18] 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 start before age 18 years.[19,20] Sunbed use was estimated to be responsible for 13% and 8% of CM cases in Denmark in women and men, respectively.[17]

1.1 | Legislation of sunbed use

In 2007, the Danish Sun Safety Campaign was launched and the prevalence of sunbed use was significantly reduced afterwards[10,21]; however, more than 1 in 10 Danes still used sunbeds in 2015.[22] Concurrently with campaign activities, the campaign lobbied for regulation of commercial sunbed business, including age limits and staff requirements for sunbed studios. Together with other stakeholders like consumer councils, children organizations and a long range of health professional organizations, the effects of the campaign lead to the initiation of a national sunbed legislation, which was adopted and took effect from August 2014.[23] The legislation contained similar elements as European technical standard 60 335[24] in terms of emission of UV radiation. However, while Danish politicians were advised by a unanimous group of health professionals, children advocates, consumer councils, etc. (except sunbed industry-related), to include an age limit for sunbed use in the legislation, it was not included in the final legislation.[25,26]

The aim of this study was to show the potential effects on (a) future skin cancer incidence and (b) cost savings if the Danish sunbed legislation had included an 18-year age limit on sunbed use as well as an introduction of a complete sunbed ban.

2 | MATERIALS AND METHODS

2.1 | Overview

We estimated the hypothetical effect of the Danish sunbed legislation in two scenarios: age limit and Ban if introduced in 2014. We modelled projections of future cancer incidence, introducing the effects of the legislation and compared with status quo using realistic estimates of relative risks in the intervention scenarios to obtain an indication of the long-term impact of the legislation interventions on cancer incidence.

2.2 | Estimation of prevalence of sunbed use

In 2015, a question on frequency of sunbed use was included in the annual population-based questionnaire on exposure to UV radiation and behaviour and attitude towards UV exposure.[22] In total, 3999 Danes answered the questionnaire. Data were collected by computer-assisted web interview (CAWI) by Epinion. Data were representative for the Danish population by gender, age, region and education (Table 1). Detailed data sampling strategies are available in the annual survey report on skrunedforsolen.dk.

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"); answers to sunbed use were grouped into "ever-users" (all categories except "never") and "never-users".

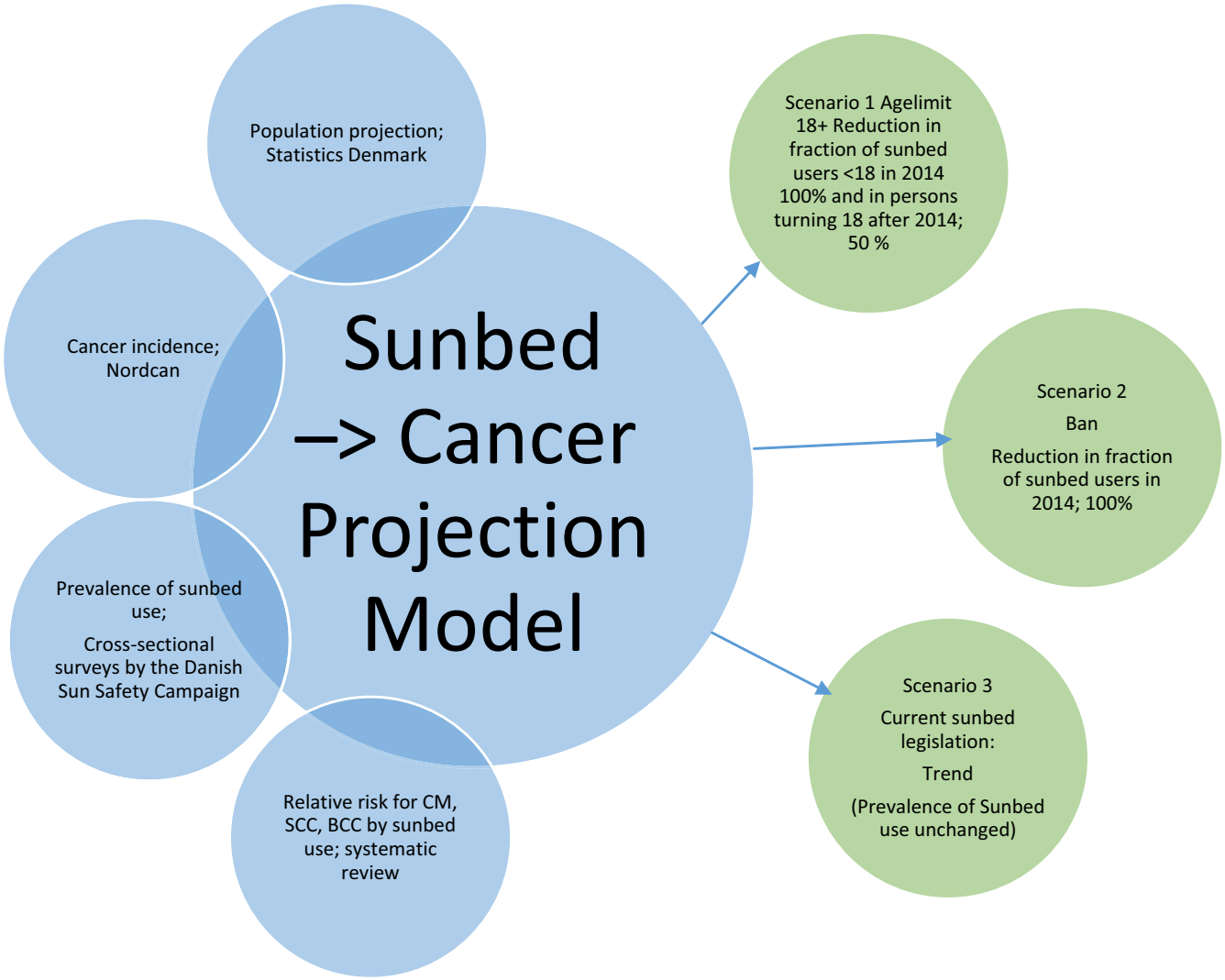
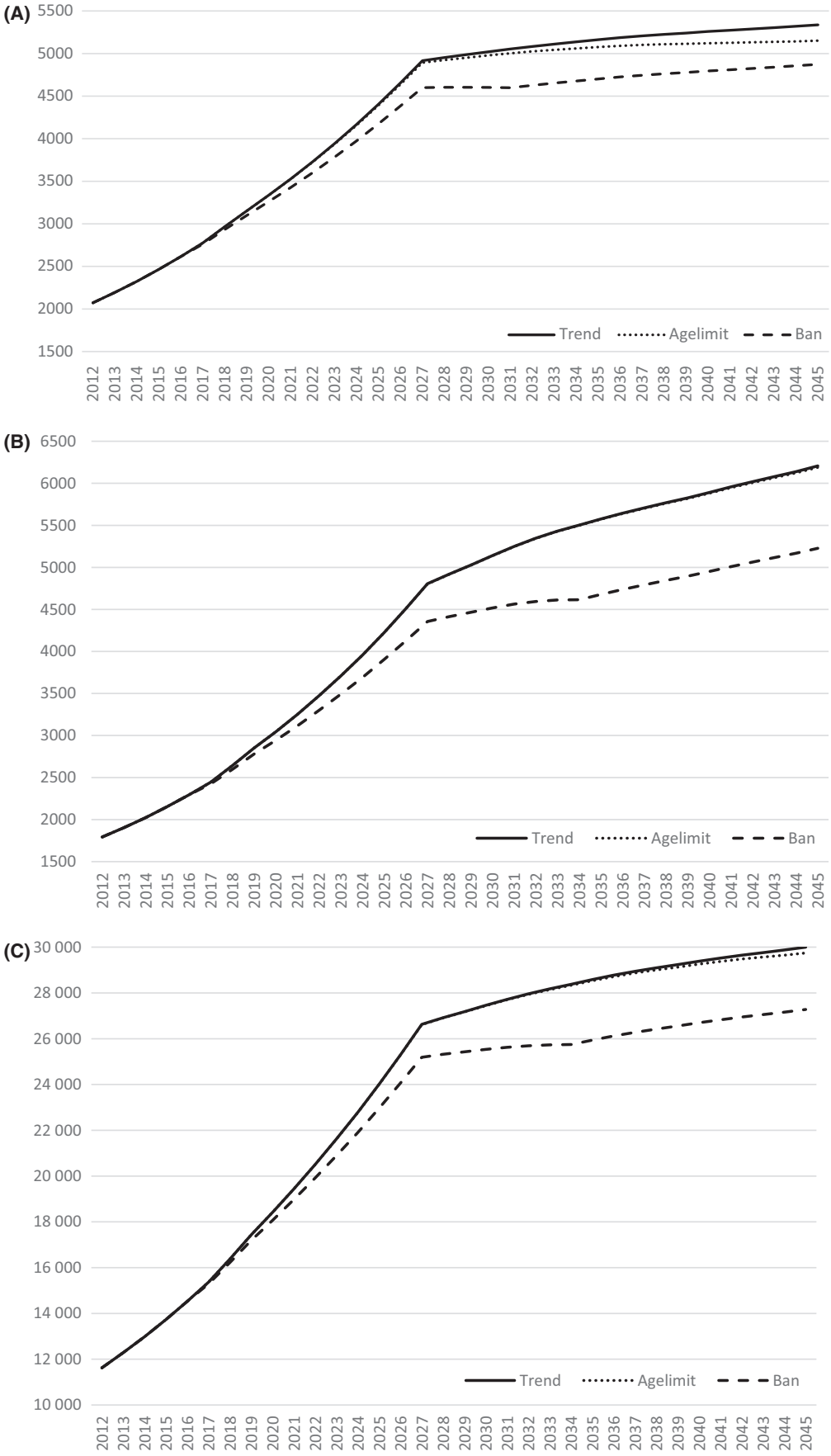


FIGURE 1 Illustration of data projections and scenario [Colour figure can be viewed at wileyonlinelibrary.com]

2.3 | The prevent model

Projection of future incidence was estimated using Prevent.[27,28] This program 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 to 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 (PAF) of sunbed use experience, respectively, on skin cancer (CM, SCC and BCC) incidences 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 skin cancer cases attributable to these risk factors. Three types of data are needed to run the model; demographic data (current and projected population sizes by age and sex), risk factor-related data (prevalence, changes in prevalence as a result of interventions and risk estimates) and disease incidence data (cancer rates and estimated annual percentage change 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.

FIGURE 2 A, Development in melanoma 2014-2045 in 2 scenarios of potential structural interventions decreasing sunbed use after 2014 compared to trend. The expected number of cutaneous melanoma cases, when sunbed use is unchanged, there is an 18 + agelimit or a complete ban. Assumed estimated annual percentage change 2014-2029 (4% increase) and 2030-2045 (0% constant). LAT time of 2 y and LAG time of 18 y. B, Development in squamous cell carcinoma 2014-2045 in 2 scenarios of potential structural interventions decreasing sunbed use after 2014 compared to trend The expected number of squamous cell carcinoma cases, when sunbed use is unchanged, there is an agelimit or a complete ban. Assumed estimated annual percentage change 2014-2029 (4% increase) and 2030-2045 (0% constant). LAT time of 2 y and LAG time of 18 y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2.4 | 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 annual data on UVR exposure continuously since 2007.[8,10,11,21,29,30] In the Prevent model, 2015-prevalence of sunbed use was included as ever/never-use.

2.5 | Incidence data

National incidence rates for melanoma skin cancer and keratinocyte skin cancer (ICD-10 codes: C43 and C44) by sex and 5-year age groups were retrieved from NORDCAN[5]and available in Table S1. The EAPC (estimated annual percentage change) for men and women, respectively, for the past 25 years 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 skin cancer rates for men and women for the modelling. The 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 and 30 years.

2.6 | Population projections

From Statistics Denmark we obtained the size of the population on January 1st, 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 2045, respectively, by 5-year age categories and sex, using the medium national growth estimates.

2.7 | Effect of sunbed use on the incidence of skin cancer

The applied relative risks for sunbed use on the risk of CM and keratinocyte cancers were derived from the largest meta-analysis', on the subject, established by, respectively, Boniol et al and Wehner et al CM: RR = 1.2 for >35-year-olds and RR = 1.59 for <35-year-olds and RR for SCC and BCC all ages of 1.67 and 1.29, respectively. [17,31]. These findings 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 and 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: (a) the time that the risk remains unchanged after a decline in risk factor exposure (LAT) and (b) 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).[27] For this study, we used a LAT of 2 years for sunbed use and a LAG of 18 years for CM and keratinocyte cancers. LAG was modelled as a linearly declining risk. LAT and LAG for sunbed use on risk of CM have not been estimated precisely; however, short time periods were previously used from the knowledge of intermittent exposure pathway[1] and the experiences from Iceland[32] and sunbed use in young people.[12] We assume that after 20 years, the risk is comparable to a non-exposed population.

We have modelled the development in future skin cancer incidence in Denmark in three scenarios. We have used the potential reductions in sunbed use after 2014 to model skin cancer incidences during 2014-45.

- *Scenario* (1) The sunbed legislation includes an age limit of 18 years. We have assumed that the legislation would mean a 100% reduction for 0-18-year-olds in the year of introduction and following a 50% decrease in sunbed use for persons turning 18 onwards as more than 50% of persons that have used a sunbed begins their use before the age of 18.
- *Scenario* (2) The sunbed legislation includes a complete ban. This scenario assumes a 100% reduction of sunbed use for the entire population.
- *Scenario* (3) The expected trend if prevalence of sunbed use is unchanged—current sunbed legislation (trend).

We have applied sensitivity analyses to scenario 2 to examine our assumptions. We have used the applied EAPC for 0 and 30 years, respectively, instead of the 15 years used in the main scenario. We have also applied a shorter or longer LAT+LAG time of either 2 and 8 years or 10 and 20 years.

The cost of skin cancer in Denmark was estimated to 33.3 million € annually in 2004-2008.[33] For assessment of skin cancer cost savings from the structural interventions, we used estimates of average case costs of skin cancer from Bentzen et al[33] Rates were 10 263 € for CM, 6435 € for SCC and 1857 € For BCC. We assumed rates were unchanged from 2004-2008 to 2014 where they were applied with a standard annual 3% discounting. The cost was calculated for avoided number of skin cancer cases in a given year with the discounted cost of that year.

3 | RESULTS

Table 1 shows the distribution of demographic characteristics and prevalence of sunbed use from the 2015 data collection. Answers were collected from 3999 persons. The distribution of participants is representative to the Danish population on gender, age, region and education. More women compared to men and more participants aged 30-50 compared to other ages had ever used sunbeds.

3.1 | The prevalence of sunbed use influence on future skin cancer incidence

In Figure 2A-C, we have modelled the development in the number of future skin cancer cases (CM, SCC and BCC) according to scenarios 1 and 2 in Denmark. The hypothetical results of a sunbed legislation including an 18-year age limit would result in 186, 17 and 252 fewer

TABLE 2 Projected number and change in number and percentage of skin cancer cases 2014-2045 based on modelled scenarios of the change in sunbed use fraction after 2014 in Denmark compared to expected trend

	Projections based on potential structural interventions 2015	Projections based on potential structural interventions 2015	Sensitivity variations of Ban Scenario			
Scenario Expected number of cases with applied parameters	18 + age limit	Ban	EAPC0	EAPC30	LATLAG, 2 + 8 y	LATLAG, 10 + 20 y
CM cases	146 395	146 395	83 147	202 392	146 395	146 395
SCC cases	150 505	150 505	91 494	201 370	150 505	150 505
BCC cases	809 681	809 681	498 822	1 063 463	809 681	809 681
Avoided cases from intervention						
ΔTotal CM	1942 (1.3%)	9161 (6.3%)	4687 (5.6%)	14 125 (7.0%)	10 634 (7.3%)	5850 (4%)
ΔTotal SCC	113 (0.1%)	17 351 (11.5%)	9782 (10.7%)	25 334 (12.6%)	19 550 (13.0%)	11 716 (7.78%)
ΔTotal BCC	1675 (0.2%)	55 375 (6.8%)	29 089 (5.8%)	74 332 (7.0%)	58 328 (7.2%)	33 686 (4.2%)

BCC, basal cell carcinoma; CM, cutaneous melanoma; SCC, squamous cell carcinoma.
EAPC0 and EAPC30 correspond to number of years with the estimated annual percentage change in incidence of 4%. Remaining years are constant (0%).
Main scenarios apply EAPC 4% 2014-2029 and 0% 2030-45 and 2 + 18 y LAT+LAG time.

cases of CM, SCC and BCC, respectively, in 2045 and similarly 1942, 113 and 1675 fewer cases in total during 2014-2045. A complete sunbed ban would result in 475, 980 and 2722 fewer cases of CM, SCC and BCC, respectively, in 2045 and 9161, 17 351 and 55 375 fewer cases of CM, SCC and BCC, respectively, during 2014-2045. Avoided skin cancers in the age limit scenario are most visible in the CM curve, as this skin cancer has a relatively high incidence among young people. The results of the skin cancer projections including relative percentage reductions are summarized in Table 2. It also includes projections of sensitivity variations of the ban scenario, where EAPC and LAT+LAG were examined. Sensitivity variations of the scenario showed they were fairly robust to changes in cancer incidence and time to effect.

In Figure 3, we show the potential cost savings of an age limit or a ban distributed by skin cancer type and total. The potential cost savings are 9 million € for an age limit and, as expected, much larger from a ban with savings of 129 million €. Even though more BCCs are avoided compared to SCC and CM, the contribution in potential savings is approximately equal from the three types of skin cancer because the average cost per case is higher for SCC and especially CM, compared to BCC.

4 | DISCUSSION

We have shown that a sunbed legislation with an age limit as based on economical and health professional advice would have prevented almost 500 cases of skin cancer annually in 2045 and more than 4000 cases in total during 2014-2045. Further, we have shown that progressive legislation, as a sunbed ban would have the largest possible impact on reducing the number of skin cancer cases by more than 80 000 corresponding to about 7% of all skin cancers in Denmark. Furthermore, we showed large cost savings from avoided skin cancer cases by implementation of structural interventions.

4.1 | Strengths and limitations

Regarding a prognosis of the cancer incidence in absolute numbers, there are unknown factors, we are not able to include in the model like improved diagnostics, equipment, change in strength of UV spectrum or output in sunbeds[6,34] or other changes in UV exposure. However, as we are using the difference between two cancer incidence numbers this has minor influence on results. The reductions in skin cancer are based on the assumed reductions in sunbed use. If legislation, for example, is not properly implemented, skin cancer reductions will be influenced accordingly.

The reason that the skin cancer incidence in the years already passed is different from the actual incidence development is that additional factors are involved. About years 2002-2004, the dermatoscope was introduced among dermatologists in Denmark, which probably increased the rate of detection[6] in a period. In the following period, a plateau is seen from around 2011.[5] Most likely, the decreased incidence rate is a consequence of the earlier detection/

treatment, an effect also seen in various screening programmes. While the increasing skin cancer incidences raised the awareness in the media of the disease through the 1990s in 2007, the multicomponent Intervention of the Danish Sun Safety Campaign increased this awareness manifold. The increased awareness could also lead to an increase in mole check by the general physician, which again could lead to an increased number of diagnosed cases. We were not able to measure this. While, for example, the cancer risk after stopping smoking in the exposed population is assumed to be comparable to the non-exposed population after a certain number of years, the skin cancer risk from sunbed may follow a similar pattern; however, the relation between UV radiation and skin cancer is often evaluated for a lifetime and UV exposure from the natural sun continues even though people quit using sunbeds. If the assumption of 20 years LAT+LAG time is shorter or longer, we may under or overestimate the benefits of the reductions in sunbed use; however, as shown in our sensitivity analysis extending the LAT+LAG time to 30 years still provides significant reductions in skin cancer incidence. Furthermore, recent sunbed use was shown to increase risk of skin cancer compared to non-recent use.[35] The model did not include any potential positive health effects of commercial sunbed use, because there was considered to be none, like, for example, from vitamin D–related illness as vitamin D is not a general problem in the population group affected by the discussed interventions.[36] In addition, any vitamin D supplementation needed in subgroups is available from non-harmful sources.

4.2 | 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.[10] Even though large reductions have taken place, the prevalence of sunbed use is now just comparable to other European countries, for example, 14% within the past year in Germany in 2012.[37] The past years the reduction in sunbed use in Denmark has levelled off and structural interventions are needed for further reductions as campaigns are only sufficient to a perceptible audience.

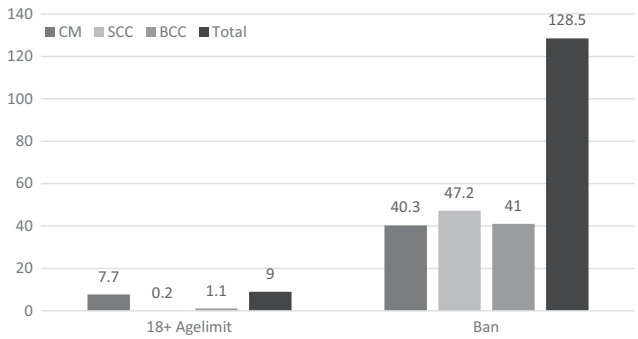

FIGURE 3 Potential saved costs from avoided skin cancers 2014-2045 in million € Cost-savings based on the number of potential avoided cases and the discontinued average case-costs

Sunbed use was shown to be common even at very young ages. We have previously reported that children from the age of 8 years had been using sunbeds in Denmark,[30] which was likewise reported in England.[38] In 2008, 13% of 12-14-year-olds reported sunbed use. In addition to lack of age limits, unstaffed sunbed studios is the main reason that children can be exposed to harmful UV radiation in sunbeds. New strengthening evidence from Lazovich et al[12] of the influence of sunbed exposure for the development of CM in people younger than 30 years of age emphasizes the importance of having means to limit the sunbed use in young people.

In the Danish population, there has been an increasing support in the population for an age limit, which today has reached 4 out of 6 Danes being supportive and 1 out of 6 against while the remaining sixth is undecided.[20]

4.3 | Consequences and recommendations

Guy et al[39] showed that an age limit is effective in reducing the level of sunbed use. Thus, the results we have modelled of structural interventions are realistic predictions that are possible to achieve. We have shown that, had the Danish sunbed legislation of 2014 been based on the professional advice given, this would have added to future reductions in skin cancer. Additionally, we showed that the most efficient way to reduce the level of skin cancer is a complete ban, which was shown to be a feasible legislation in both Australia and Brazil.[40] Gordon et al[41] estimated avoidable skin cancers from average UVR exposure (solar vs. artificial) in Australia previous to their sunbed ban; however, while this method has several strengths compared to ours it does not include effects from the intermittent exposure pathway and as such this conservative method may have underestimated the actual number of avoidable skin cancers.

The WHO suggests that countries ban sunbeds or alternatively restrict (staff supervision, age limit, high-risk individuals), manage (licence, radiation output and time limits, staff training, tax) and inform (health risks, display warning, ban marketing) to protect their populations.[42] In 2017, the majority of countries in western Europe and the majority of American states have introduced age limits for sunbed use to protect children, and states with age limits succeeded in reducing the prevalence of sunbed use.[39] Furthermore, the first countries, Australia and Brazil, have completely banned sunbed use to protect their population against the detrimental effects of sunbed use on human health and to reduce government spending related to skin cancer diagnostics and treatment.[40] Belgium is to our knowledge the first European country to recommend a ban against sunbed use,[43] while Denmark is now one of few remaining western European countries without an age limit to protect children and youth.[44]

Our results show significant skin cancer reductions and cost savings that emphasize both the economic and health potential of the results and we hope to motivate government administration to implement structural interventions to reduce the sunbed use in Denmark, by revision of the Danish sunbed legislation, which was adopted in 2014. The legislation was composed with severe contraries to the unambiguous economic and health professional arguments

provided in the consultation. Other countries with insufficient protection of minors or the population against sunbed use can equally well benefit from our results according to the level of their prevalence of sunbed use.

5 | CONCLUSION

Several legislative restrictive measures exist which would be beneficial to introduce to reduce the sunbed use further at the current stage. Danish politicians have the opportunity, supported by the population, to reduce the skin cancer incidence and thereby reduce the future costs of skin cancer. The health and economic benefits of structural interventions towards sunbed use to protect the Danish population, including minors, are huge.

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CONFLICTS OF INTEREST

The authors have declared that no competing interests exist.

TRANSPARENCY DECLARATION

Brian Køster 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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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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