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Original Research

Tackling the tobacco epidemic in the Nordic countries and lower cancer incidence by 1/5 in a 30-year period—The effect of envisaged scenarios changing smoking prevalence

Therese M.-L. Andersson [a,b,*], Gerda Engholm [c], Anne-Line Brink [d], Eero Pukkala [e,f], Magnus Stenbeck [g], Laufey Tryggvadottir [h,i], Elisabete Weiderpass [a,j,k,l], Hans Storm [b]

[a] Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden
[b] Danish Cancer Society, Copenhagen, Denmark
[c] Department of Documentation & Quality, Danish Cancer Society, Copenhagen, Denmark
[d] Department of Cancer Prevention & Information, Danish Cancer Society, Copenhagen, Denmark
[e] Finnish Cancer Registry – Institute for Statistical and Epidemiological Cancer Research, Helsinki, Finland
[f] Faculty of Social Sciences, University of Tampere, Tampere, Finland
[g] Department of Clinical Neuroscience, Division of Insurance Medicine, Karolinska Institutet, Stockholm, Sweden
[h] Icelandic Cancer Registry, Reykjavik, Iceland
[i] Faculty of Medicine, University of Iceland, Reykjavik, Iceland
[j] Department of Research, Cancer Registry of Norway, Institute of Population-Based Cancer Research, Oslo, Norway
[k] Genetic Epidemiology Group, Folkhälsan Research Center, Helsinki, Finland
[l] Department of Community Medicine, University of Tromsø, The Arctic University of Norway, Tromsø, Norway

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Prevention;
Population attributable fraction;
Potential impact

Abstract ***Background:*** Tobacco smoking is a leading cause of cancer and the most preventable cause of cancer worldwide. The aim of this study was to quantify the proportion of the cancer burden in the Nordic countries linked to tobacco smoking and estimate the potential for cancer prevention by changes in smoking prevalence.
Methods: The Prevent macro-simulation model was used, estimating the future number of cancer cases in the Nordic countries over a 30-year period (2016–2045), for 13 cancer sites, under different scenarios of changing smoking prevalence, and compared to the projected number of cases if constant prevalence prevailed.

* *Corresponding author*: Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Box 281, 171 77 Stockholm, Sweden.
E-mail address: therese.m-l.andersson@ki.se (T.M.-L. Andersson).

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fraction;
Nordic countries;
Prevent macro-simulation model

Results: A total of 430,000 cancer cases, of the 2.2 million expected for the 13 studied cancer sites, could be avoided in the Nordic countries over the 30-year period if smoking was eliminated from 2016 onwards. If prevalence of smoking is reduced to 5% by year 2030 and to 2% by 2040, 230,000 cancer cases could be avoided. The largest proportion of cancers can be avoided in Denmark, where smoking prevalence is the highest, and similar to the prevalence in many European countries.
Conclusion: A large amount of cancers could be avoided in the Nordic countries if smoking prevalence was reduced. The results from this study can be used to understand the potential impact and significance of primary prevention programmes targeted towards reducing the prevalence of tobacco smoking in the Nordic countries.

1. Introduction

Tobacco smoking is the leading cause of cancer and casually linked to cancer of the lung, larynx, oral cavity, lip and pharynx, paranasal sinuses, oesophagus, urinary bladder, kidney, ureter and renal pelvis, pancreas, liver, stomach, uterine cervix, colorectum, as well as mucinous tumours of the ovary and myeloid leukaemia [1,2]. Tobacco smoking is the most preventable cause of cancer worldwide and in the Nordic countries [3–7]. Trends in smoking-related cancers for men and women are converging, decreasing in men and increasing in women [8]. More so in Denmark where female smoking rates and resulting cancers have peaked and reached the male incidence [9]. Earlier studies have estimated the population attributable fraction (PAF) of tobacco smoking on the cancer burden [10–12]. However, for primary prevention purposes, it is more important to understand the impact of different alternative exposure levels. The Nordic countries that are front runners in smoking and tobacco consumption, particularly among women, serve as an example of what to expect from other European countries where female smoking is on the rise. The aim of this study was to quantify the fraction of the cancer burden in the Nordic countries linked to tobacco smoking and how the cancer burden would change under different smoking prevalence levels. This was performed by investigating alternative levels of changing smoking prevalence and extrapolating different scenarios into the future to get an understanding of the potential of smoking elimination intervention programmes.

2. Materials and methods

We modelled projections of the future number of cancer cases in the Nordic countries in the coming 30 years (2016–2045). We studied different prevalence scenarios of tobacco smoking, compared to the projected number of cases estimated if the age and sex specific prevalence remained constant at the levels observed in the last year of available data. The predictions were calculated using the Prevent macro-simulation model [13,14], as adapted for the EUROCADET project [15–19]. The calculations performed in the Prevent model are described in detail elsewhere [14,20]. We used the same approach as described in a previous paper on avoidable cancer due to overweight and obesity in the Nordic countries [21]. Data needed for use of the Prevent model are disease incidence, demographic data (projected population sizes), risk factor prevalence (current and historical information), relative risk (RR) estimates and change in risk factor prevalence under the scenarios of interest.

We applied the Prevent model separately to each country and to 13 cancer sites, namely lung, larynx, oral cavity, lip and pharynx, oesophagus, stomach, colorectum, pancreas, liver, kidney, renal pelvis and ureter, bladder, uterine cervix, mucinous tumours of the ovary and myeloid leukaemia (also listed in Table 1), which are causally linked to tobacco smoking [1,2]. These analyses entailed 65 separate estimations for each scenario investigated. We chose not to include cancer of the paranasal sinuses due to the small number of incident cases and lack of RR information among smokers.

Incidence rates, by country, sex and 5-year age groups (except 85+), of each cancer were obtained from NORDCAN [9,22]. The ICD-10 codes defining the cancer sites are shown in Table 1 along with information on the average annual number of cases in the Nordic countries. To reduce random variation due to small numbers within a single year, we used the average incidence for the years 2009–2013. We chose to consider cancer incidence from age 15 years and older. Data on estimated projections of the population size by gender and 5-year age groups in the period 2016–2045 were obtained from the statistical bureaus in the respective countries [23–27]. When several population projections were presented, for example with low, medium and high levels of deaths or birth rates, the middle categories were used.

The measure used for tobacco smoking was the prevalence of daily smokers, which was obtained from nationally representative surveys in each of the five Nordic countries [28–33]. We also used historical

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Table 1
Cancer sites, relative risk (RR) estimates and the average annual incident cases (2009–2013) in the Nordic countries.

Cancer site	ICD-10 codes	RR for current versus never smokers[a]	Average number of cases per year
Colorectum	C18-20	(M) 1.24 (F) 1.30	17,080
Lung	C33-C34	(M) 21.3 (F) 12.5	13,752
Urinary bladder	C67-68 D09.0-1 D30.3-9 D41.1-9	(M) 3.0 (F) 2.4	6830
Kidney, renal pelvis and ureter	C64-C66 D30.0-2	(M) 2.5 (F) 1.5	3949
Pancreas	C25	2.2	3874
Lip, Oral cavity and Pharynx	C00-C06, C09, C10.0, C10.2-9 C11-14	(M) 10.9 (F) 5.1	2804
Stomach	C16	(M) 2.2 (F) 1.5	2524
Liver	C22	(M) 2.3 (F) 1.5	1672
Oesophagus	C15	(M) 6.8 (F) 7.8	1483
Myeloid leukaemia	C92-C93, C94.05, C94.7	(M) 1.9 (F) 1.2	1330
Cervix	C53	1.5	1293
Larynx	C32 C10.1	(M) 14.6 (F) 13.0	684
Ovary (mucinous)	C56, C57.7-9 Morphology: 84703,84713, 84803,84813, 90153	2.1	256

[a] (M) RR for males, (F) RR for females.

data to account for the lag time between the observed exposure levels and the effect on the incidence. The age groups and the number of years included in the historical data differ across countries. More detailed information about the surveys and data used for each country can be found in Appendix A, together with a table showing the prevalence in each country by sex and age group in the last available calendar year.

We used the same RR estimates for current smokers compared with never smokers as used in a study by Parkin *et al.* on tobacco-attributable cancer burden in the United Kingdom (UK) [11] for all sites (Table 1). Even though some of these are RR estimates for cancer mortality and not cancer incidence, the estimates were similar to RR estimates for cancer incidence presented in a report by the National Board of Health and Welfare in Sweden [34]. The lung cancer RR (and resulting numbers of avoidable cancers) for women might be underestimated because the RR for women is only half of that for men in the article by Parkin. An Icelandic cohort study found higher RR for lung cancer incidence in females than males [35]. However, we chose to use the RR estimates from Parkin *et al.* for all sites.

The Prevent model takes into account that there is a time lag between changes in exposure prevalence and changes in risk of disease by the use of LAT and LAG times. LAT is the number of years that the risk remains unchanged after a change in risk factor, and LAG is the number of years it takes from the time the risk among previously exposed starts to change until the risk among previously exposed is the same as for unexposed. We have used a LAT of 5 years and a LAG of 15 years, with an exponential LAG function, so the risk decreases quickly at first and then more slowly approaches the risk of never smokers. This seems to correspond fairly well to what has been found about the reversal of risk on quitting smoking [36].

We set up four hypothetical scenarios A, B, C and D to show the potential impact of changes in tobacco smoking prevalence on the cancer burden relative to a continued constant smoking prevalence. The scenarios were

A. Elimination:

A total elimination of smoking. This is comparable to estimates of PAFs.

B. 5% smoking prevalence by 2030 and 2% by 2040:

The prevalence decreases with a constant annual percentage change to reach 5% in 2030. Because the prevalence differs across age, sex and country, the annual percentage change will differ by age group, sex and country. From 2031 to 2040, the prevalence drops from 5% to 2%, also with a constant annual percentage change. After 2040, the prevalence is assumed to stay at 2%. This scenario is similar to the goal set by the Danish Cancer Society and 'TrygFonden' [37], with a maximum of 5% of adults (15+ years) smoking in the year 2030, and the same goal set by the ASH Finland [38]. A similar initiative has been introduced in Sweden [39].

C. Country-specific interventions:

The interventions are as follows:

(i) raising taxes on tobacco products,
(ii) expanding the smoke-free air law,
(iii) banning point-of-sale tobacco displays,
(iv) introducing plain packaging and
(v) running mass media campaigns.

Some of these interventions are already in place in some of the Nordic countries, and therefore, all the interventions (i)–(v) were not applied to all countries. The results from this scenario are, therefore, not directly comparable across countries. For Denmark, interventions (i)–(v) were applied, for Finland, (i), (iv) and (v) were applied, for Iceland, (i), (ii), (iv) and (v) were applied, for Norway, (i), (iv) and (v) were applied and for Sweden, (i) and (iii)–(v) were applied. The interventions are assumed to act independently on smoking prevalence

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(so the effects can be added), and after 15 years, the prevalence will stay constant at the new levels reached. Data on other likely effective means to control tobacco consumption such as reducing points of sale to special shops rather than supermarkets, strict enforcement of existing regulation of not selling to minors and use and availability of cessation services are unfortunately not available in a format suitable for our analysis. Based on literature reviews, it was assumed that

(i) A 10% increase in tobacco retail prices each year from 2016 to 2030 will result in a 2% decrease in smoking prevalence each year [40–43].
(ii) Total worksite smoking ban and smoking ban in all hospitality premises will result in a 2% reduction in the first year after implementation [44].
(iii) Point-of-sale display ban in all shops will result in a 1% decrease in smoking prevalence within the first year and a 0.5% decrease for years 2–15 [45–49].
(iv) Plain packaging will result in a 3% decline in smoking prevalence within the first year and a 1% decrease the following years until 2030 [50,51].
(v) Moderately publicised campaign run through the years 2016–2030 will result in a 1.5% reduction per year [52].

D. Continuation of the observed annual percentage trend:

The estimated trend in prevalence was estimated assuming that the log of prevalence changes linearly with calendar year, separately in each country, sex and age group, based on the available prevalence estimates for each group (see Appendix A for more information). This log-linear trend gives the same percentage change each year, which was used to build this scenario. The trends are assumed to continue until 2035, and the prevalence is constant after this. For groups with an increasing trend, we do not apply the trend, so assume a constant prevalence throughout.

All scenarios were assumed to start in 2016, and the number of avoidable cancers under each scenario was calculated for the 30-year period 2016–2045. The trend in the overall smoking prevalence under each scenario is shown by country in Appendix B.

The estimated results and projections are based on the input data and assumptions described previously. Several sensitivity analyses, described in Appendix C, were carried out to estimate the influence of these assumptions on the results. The sensitivity analyses investigated varying LAT and LAG as well as inclusion of a trend in cancer incidence.

3. Results

Fig. 1 (top panel) shows the expected number of incident cases in the Nordic countries for the 13 cancer sites combined, from the base scenario and each investigated scenario. The difference between the expected number of cases in the base scenario and each investigated scenario is the avoidable number of cases and is presented in the bottom panel of Fig. 1. There are no avoidable cancers during the first 5 years, the LAT time.

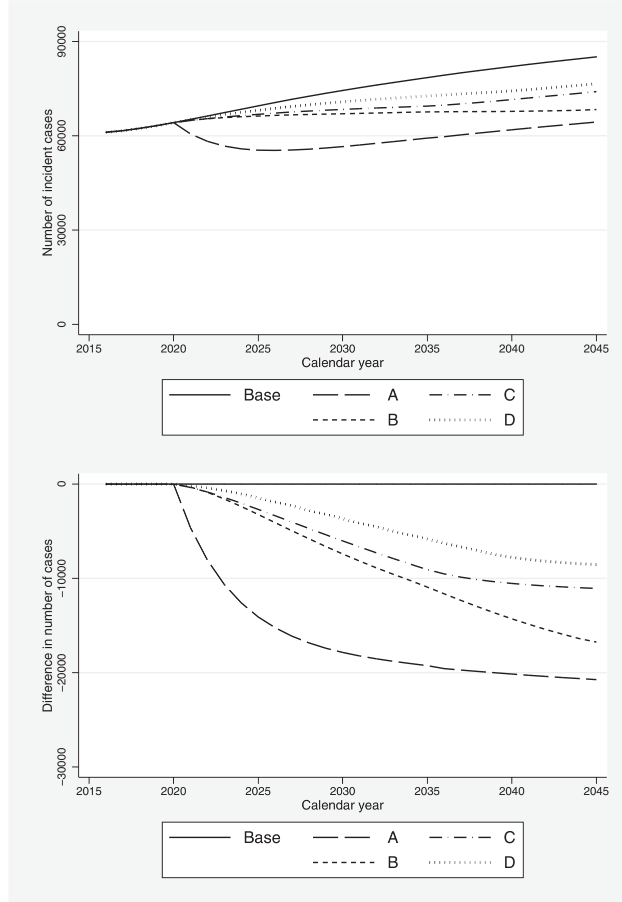

Fig. 1. Top panel: total number of incident cancers for 13 cancer sites associated with tobacco smoking, during 2016–2045 in the Nordic countries, under different scenarios of smoking prevalence. Bottom panel: total number of avoidable cancers for 13 cancer sites associated with tobacco smoking, during 2016–2045 in the Nordic countries, under different scenarios of smoking prevalence, compared to if the prevalence would stay constant. A: elimination, B: 5% prevalence by 2030, C: country-specific interventions and D: continued decreasing trend.

The number and percentage of avoidable cancers, due to tobacco smoking, are presented for each of the 13 cancer sites, by each investigated scenario and each country as well as the Nordic countries combined, in Tables 2–7. The results are presented for the whole 30-year study period and for the year 2045 alone. The reason for presenting the results for the last year is that the intervention scenarios have reached their full effect by this time.

In total, 429,281 cancers could be avoided in the Nordic countries over the period 2016–2045 by eliminating tobacco smoking, 19% of the expected number of cases for these 13 sites under constant prevalence (Table 2, Fig. 2). Lung cancer has the highest number and the

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Table 2
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in the Nordic countries, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	19,675 (960)	2.8 (3.4)	10,518 (776)	1.5 (2.8)	8004 (513)	1.1 (1.8)	5194 (377)	0.7 (1.4)
Lung	249,092 (12,048)	52.1 (67.2)	133,237 (9733)	27.9 (54.3)	101,840 (6423)	21.3 (35.8)	68,438 (4899)	14.3 (27.3)
Urinary bladder	43,198 (2129)	15.3 (19.1)	22,684 (1704)	8.0 (15.3)	17,703 (1141)	6.3 (10.2)	13,109 (952)	4.6 (8.5)
Kidney, renal pelvis and ureter	15,550 (740)	10.4 (13.2)	8430 (605)	5.6 (10.8)	6249 (391)	4.2 (7.0)	4319 (306)	2.9 (5.5)
Pancreas	16,650 (803)	10.7 (13.5)	8854 (647)	5.7 (10.9)	6725 (427)	4.3 (7.2)	4173 (300)	2.7 (5.0)
Lip, oral cavity and pharynx	34,626 (1635)	38.0 (49.0)	18,697 (1329)	20.5 (39.8)	14,062 (873)	15.4 (26.1)	6944 (679)	10.6 (20.3)
Stomach	8704 (425)	8.4 (10.4)	4548 (339)	4.4 (8.3)	3520 (225)	3.4 (5.5)	2464 (178)	2.4 (4.4)
Liver	6065 (290)	9.2 (11.6)	3194 (234)	4.8 (9.4)	2454 (154)	3.7 (6.2)	1648 (117)	2.5 (4.7)
Oesophagus	18,601 (896)	34.7 (44.1)	9942 (724)	18.6 (35.6)	7608 (480)	14.2 (23.6)	5245 (375)	9.8 (18.4)
Myeloid leukaemia	2949 (144)	5.7 (7.3)	1570 (117)	3.0 (5.9)	1206 (77)	2.3 (3.9)	923 (68)	1.8 (3.4)
Cervix	2059 (95)	4.7 (6.1)	1067 (77)	2.4 (5.0)	833 (53)	1.9 (3.4)	598 (42)	1.4 (2.7)
Larynx	11,150 (528)	50.5 (65.3)	6143 (433)	27.8 (53.5)	4559 (283)	20.6 (35.0)	3328 (234)	15.1 (28.9)
Ovary (mucinous)	962 (45)	11.2 (14.8)	507 (37)	5.9 (12.1)	403 (25)	4.7 (8.2)	229 (15)	2.7 (4.9)
Total[e]	429,281 (20,738)	19.3 (24.4)	229,391 (16,755)	10.3 (19.7)	175,166 (11,065)	7.9 (13.0)	119,312 (8542)	5.4 (10.0)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

Table 3
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in Denmark, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	6297 (301)	3.6 (4.5)	3722 (255)	2.1 (3.8)	2692 (167)	1.5 (2.5)	2378 (168)	1.3 (2.5)
Lung	83,669 (3962)	56.7 (73.0)	50,134 (3381)	34.0 (62.3)	36,003 (2205)	24.4 (40.6)	32,178 (2232)	21.8 (41.4)
Urinary bladder	14,916 (720)	19.8 (24.9)	8914 (614)	11.8 (21.2)	6409 (401)	8.5 (13.9)	6028 (424)	8.0 (14.7)
Kidney, renal pelvis and ureter	4041 (187)	13.4 (17.2)	2428 (161)	8.1 (14.8)	1719 (104)	5.7 (9.5)	1560 (107)	5.2 (9.8)
Pancreas	5182 (245)	13.9 (17.6)	3070 (208)	8.2 (14.9)	2213 (136)	5.9 (9.8)	1948 (136)	5.2 (9.8)
Lip, oral cavity and pharynx	10,931 (492)	44.1 (57.7)	6592 (424)	26.6 (49.7)	4634 (274)	18.7 (32.1)	4011 (271)	16.2 (31.8)
Stomach	2450 (117)	11.7 (14.7)	1464 (100)	7.0 (12.6)	1045 (65)	5.0 (8.2)	978 (69)	4.7 (8.7)
Liver	1738 (81)	12.6 (16.1)	1047 (70)	7.6 (13.9)	742 (45)	5.4 (8.9)	678 (47)	4.9 (9.3)
Oesophagus	6673 (313)	40.8 (52.3)	3997 (268)	24.4 (44.7)	2861 (175)	17.5 (29.2)	2582 (179)	15.8 (29.9)
Myeloid leukaemia	1047 (51)	7.5 (9.6)	623 (44)	4.5 (8.3)	452 (29)	3.2 (5.4)	428 (31)	3.1 (5.8)
Cervix	691 (31)	5.8 (7.6)	394 (26)	3.3 (6.4)	295 (18)	2.5 (4.4)	229 (16)	1.9 (3.9)
Larynx	4313 (198)	54.9 (71.5)	2615 (170)	33.3 (61.4)	1840 (110)	23.4 (39.7)	1665 (113)	21.2 (40.8)
Ovary (mucinous)	182 (8)	14.7 (18.6)	109 (7)	8.8 (16.3)	80 (5)	6.4 (11.6)	60 (4)	4.8 (9.3)
Total[e]	142,130 (6706)	24.6 (31.2)	85,109 (5728)	14.7 (26.6)	60,985 (3734)	10.6 (17.3)	54,723 (3797)	9.5 (17.6)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

highest percentage of avoidable cases in all countries except Finland where the highest percentage is observed for laryngeal cancer. The number of avoidable lung cancers in Denmark in a 30-year period if tobacco smoking was eliminated in 2016 (scenario A) is 83,669 (57%), in Finland, 43,942 (47%), in Iceland, 3377 (51%), in Norway, 56,683 (55%) and in Sweden, 61,421 (49%) (Tables 3–7). After lung cancer, the number of avoidable cancers is highest for bladder cancer, with 43,198 (15%) in the Nordic countries over the 30-year period. The percentage is highest, after lung cancer, for laryngeal cancer, with 11,150 (51%) cases in the Nordic

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Table 4
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in Finland, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	2458 (115)	2.1 (2.6)	1161 (88)	1.0 (2.0)	925 (59)	0.8 (1.3)	266 (20)	0.2 (0.4)
Lung	43,942 (2068)	46.7 (60.3)	20,130 (1558)	21.4 (45.4)	16,762 (1047)	17.8 (30.5)	5663 (413)	6.0 (12.0)
Urinary bladder	5915 (282)	12.6 (15.7)	2782 (215)	5.9 (11.9)	2238 (142)	4.8 (7.9)	844 (62)	1.8 (3.4)
Kidney, renal pelvis and ureter	3245 (151)	8.7 (11.0)	1654 (120)	4.4 (8.8)	1224 (76)	3.3 (5.6)	404 (29)	1.1 (2.1)
Pancreas	3669 (172)	8.1 (10.1)	1705 (130)	3.8 (7.7)	1381 (87)	3.1 (5.1)	386 (28)	0.9 (1.6)
Lip, oral cavity and pharynx	6317 (295)	33.5 (43.2)	3204 (233)	17.0 (34.1)	2392 (149)	12.7 (21.8)	786 (57)	4.2 (8.3)
Stomach	1835 (87)	6.9 (8.5)	888 (67)	3.3 (6.6)	695 (44)	2.6 (4.3)	249 (18)	0.9 (1.8)
Liver	1564 (73)	7.7 (9.5)	758 (57)	3.7 (7.4)	592 (37)	2.9 (4.8)	197 (14)	1.0 (1.8)
Oesophagus	3310 (156)	29.7 (37.7)	1599 (120)	14.4 (29.0)	1252 (79)	11.3 (19.1)	378 (28)	3.4 (6.8)
Myeloid leukaemia	404 (19)	4.7 (5.9)	200 (15)	2.3 (4.6)	153 (9)	1.8 (2.8)	61 (4)	0.7 (1.2)
Cervix	218 (10)	4.3 (5.6)	110 (8)	2.1 (4.5)	83 (5)	1.6 (2.8)	33 (2)	0.6 (1.1)
Larynx	1941 (90)	47.2 (62.1)	1007 (72)	24.5 (49.7)	736 (45)	17.9 (31.0)	240 (17)	5.8 (11.7)
Ovary (mucinous)	153 (7)	9.4 (12.5)	76 (6)	4.7 (10.7)	65 (4)	4.0 (7.1)	18 (1)	1.1 (1.8)
Total[e]	74,971 (3525)	17.1 (21.6)	35,274 (2689)	8.0 (16.5)	28,498 (1783)	6.5 (10.9)	9525 (693)	2.2 (4.2)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

Table 5
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in Iceland, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	157 (8)	2.4 (3.0)	78 (6)	1.2 (2.2)	64 (4)	1.0 (1.5)	55 (4)	0.9 (1.5)
Lung	3377 (173)	51.2 (64.1)	1687 (135)	25.6 (50.0)	1367 (89)	20.7 (33.0)	1108 (79)	16.8 (29.3)
Urinary bladder	467 (24)	14.0 (17.0)	226 (19)	6.8 (13.5)	188 (13)	5.6 (9.2)	145 (11)	4.3 (7.8)
Kidney, renal pelvis and ureter	229 (11)	9.2 (11.0)	114 (9)	4.6 (9.0)	91 (6)	3.6 (6.0)	76 (5)	3.0 (5.0)
Pancreas	135 (7)	10.2 (12.7)	68 (5)	5.1 (9.1)	54 (4)	4.1 (7.3)	47 (3)	3.6 (5.5)
Lip, oral cavity and pharynx	289 (15)	35.8 (44.1)	142 (11)	17.6 (32.4)	116 (8)	14.4 (23.5)	107 (8)	13.3 (23.5)
Stomach	100 (5)	7.0 (7.9)	47 (4)	3.3 (6.3)	41 (3)	2.9 (4.8)	32 (2)	2.2 (3.2)
Liver	52 (3)	9.0 (12.5)	26 (2)	4.5 (8.3)	21 (1)	3.6 (4.2)	17 (1)	2.9 (4.2)
Oesophagus	323 (17)	32.8 (40.5)	160 (13)	16.3 (31.0)	131 (9)	13.3 (21.4)	99 (7)	10.1 (16.7)
Myeloid leukaemia	27 (1)	5.5 (4.8)	13 (1)	2.6 (4.8)	11 (1)	2.2 (4.8)	9 (1)	1.8 (4.8)
Cervix	27 (1)	4.5 (4.5)	13 (1)	2.2 (4.5)	11 (1)	1.8 (4.5)	11 (1)	1.8 (4.5)
Larynx	102 (5)	46.8 (52.5)	52 (4)	24.9 (50.0)	41 (3)	19.6 (37.5)	31 (2)	14.8 (25.0)
Ovary (mucinous)	5 (0)	11.6 (0)	3 (0)	7.0 (0)	2 (0)	4.7 (0)	2 (0)	4.7 (0)
Total[e]	5290 (270)	20.9 (25.6)	2629 (210)	10.4 (19.9)	2138 (142)	8.5 (13.5)	1739 (124)	6.9 (11.8)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

countries over the 30-year period. The cancer with the smallest relative effect is colorectal cancer, less than 4% over 2016–2045 in all countries. For all cancer sites, Denmark with the highest smoking prevalence consequently had the highest percentage of avoidable cancer.

If the smoking prevalence would reduce to 5% by 2030 and 2% by 2040 (scenario B), a total of 229,391 cancers could be avoided over the period 2016–2045, which corresponds to 10% of the expected cancers for the 13 studied cancer sites (Table 2, Fig. 2). The country-specific interventions (scenario C) would lead to 175,166 fewer cancers (8%) than expected under a constant smoking prevalence, and with a continued trend (scenario D), 119,312 (5%) could be avoided (Table 2, Fig. 2). Scenario D can also be seen as an alternative base scenario, and the difference between the number of

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Table 6
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in Norway, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	5191 (264)	3.0 (3.7)	2890 (217)	1.7 (3.0)	2010 (134)	1.2 (1.9)	1322 (99)	0.8 (1.4)
Lung	56,683 (2873)	54.6 (69.2)	31,660 (2353)	30.5 (56.6)	22,076 (1457)	21.3 (35.1)	15,685 (1166)	15.1 (28.1)
Urinary bladder	8929 (462)	16.4 (20.0)	4879 (373)	8.9 (16.1)	3462 (234)	6.3 (10.1)	2708 (205)	5.0 (8.9)
Kidney, renal pelvis and ureter	4076 (202)	11.7 (14.6)	2303 (167)	6.6 (12.0)	1570 (102)	4.5 (7.4)	1228 (90)	3.5 (6.5)
Pancreas	3616 (185)	11.9 (14.6)	2006 (151)	6.6 (11.9)	1400 (94)	4.6 (7.4)	919 (69)	3.0 (5.5)
Lip, oral cavity and pharynx	6702 (334)	40.4 (51.1)	3761 (274)	22.7 (42.0)	2596 (169)	15.7 (25.9)	1965 (144)	11.9 (22.1)
Stomach	1912 (98)	9.2 (11.3)	1048 (79)	5.1 (9.1)	740 (49)	3.6 (5.6)	575 (43)	2.8 (4.9)
Liver	874 (44)	10.0 (12.2)	477 (36)	5.4 (10.0)	337 (22)	3.9 (6.1)	261 (19)	3.0 (5.3)
Oesophagus	3360 (170)	37.0 (46.2)	1873 (139)	20.6 (37.8)	1304 (86)	14.4 (23.4)	948 (71)	10.4 (19.3)
Myeloid leukaemia	631 (32)	6.1 (7.6)	342 (26)	3.3 (6.2)	243 (16)	2.4 (3.8)	201 (15)	2 (3.6)
Cervix	465 (22)	4.5 (5.8)	236 (18)	2.3 (4.8)	176 (12)	1.7 (3.2)	155 (11)	1.5 (2.9)
Larynx	2209 (110)	52.1 (65.9)	1247 (91)	29.4 (54.5)	858 (56)	20.3 (33.5)	675 (50)	15.9 (29.9)
Ovary (mucinous)	113 (6)	12.7 (17.6)	64 (5)	7.2 (14.7)	43 (3)	4.8 (8.8)	29 (2)	3.3 (5.9)
Total[e]	94,761 (4802)	19.9 (24.6)	52,786 (3929)	11.1 (20.2)	36,815 (2434)	7.7 (12.5)	26,671 (1984)	5.6 (10.2)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

Table 7
Number (#) and percentage of avoidable cancers during 2016–2045 and in 2045 in Sweden, under different scenarios of prevalence of tobacco smoking, compared to a constant prevalence.

Cancer site	Scenario A[a]		Scenario B[b]		Scenario C[c]		Scenario D[d]	
	#	%	#	%	#	%	#	%
Colorectum	5572 (272)	2.3 (2.9)	2667 (210)	1.1 (2.3)	2313 (149)	1.0 (1.6)	1173 (86)	0.5 (0.9)
Lung	61,421 (2972)	48.8 (63.8)	29,626 (2306)	23.6 (49.5)	25,632 (1625)	20.4 (34.9)	13,804 (1009)	11.0 (21.7)
Urinary bladder	12,971 (641)	12.7 (16.0)	5883 (483)	5.8 (12.1)	5406 (351)	5.3 (8.8)	3384 (250)	3.3 (6.3)
Kidney, renal pelvis and ureter	3959 (189)	8.8 (11.3)	1931 (148)	4.3 (8.9)	1645 (103)	3.7 (6.2)	1051 (75)	2.3 (4.5)
Pancreas	4048 (194)	9.8 (12.6)	2005 (153)	4.9 (9.9)	1677 (106)	4.1 (6.9)	873 (64)	2.1 (4.2)
Lip, oral cavity and pharynx	10,387 (499)	34.5 (44.7)	4998 (387)	16.6 (34.7)	4324 (273)	14.4 (24.5)	2775 (199)	9.2 (17.8)
Stomach	2407 (118)	7.1 (8.9)	1101 (89)	3.2 (6.7)	999 (64)	2.9 (4.8)	630 (46)	1.8 (3.5)
Liver	1837 (89)	8.2 (10.6)	886 (69)	4.0 (8.2)	762 (49)	3.4 (5.8)	495 (36)	2.2 (4.3)
Oesophagus	4935 (240)	30.7 (39.3)	2313 (184)	14.4 (30.2)	2060 (131)	12.8 (21.5)	1238 (90)	7.7 (14.8)
Myeloid leukaemia	840 (41)	4.6 (6.0)	392 (31)	2.2 (4.5)	347 (22)	1.9 (3.2)	224 (17)	1.2 (2.5)
Cervix	658 (31)	4.2 (5.5)	314 (24)	2.0 (4.2)	268 (17)	1.7 (3.0)	170 (12)	1.1 (2.1)
Larynx	2585 (125)	45.6 (59.0)	1222 (96)	21.5 (45.3)	1084 (69)	19.1 (32.5)	717 (52)	12.6 (24.5)
Ovary (mucinous)	509 (24)	10.7 (14.1)	255 (19)	5.4 (11.2)	213 (13)	4.5 (7.6)	120 (8)	2.5 (4.7)
Total[e]	112,129 (5435)	16.0 (20.4)	23,593 (4199)	7.6 (15.7)	46,730 (2972)	6.7 (11.1)	26,654 (1944)	3.8 (7.3)

The numbers in parentheses refer to single year 2045.
[a] A total elimination of tobacco smoking in the year 2016.
[b] A smoking prevalence of 5% by 2030 and 2% by 2040.
[c] Country-specific interventions. Raising taxes on tobacco products, ban point-of-sale tobacco displays, introduce plain packaging and running mass media campaigns.
[d] A continued decreasing trend.
[e] Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

avoidable cancers for scenarios A, B or C and the number for scenario D gives an estimate of avoidable cancers if the expected prevalence of tobacco smoking continues to follow a trend based on the observed annual percentage change.

Results from the sensitivity analyses are presented in Appendix C. The number of avoidable cancers differs somewhat between the different analyses, although the percentage of avoidable cancers is fairly robust.

4. Discussion

We have estimated the number of avoidable cancers in the Nordic countries during 2016–2045, under different

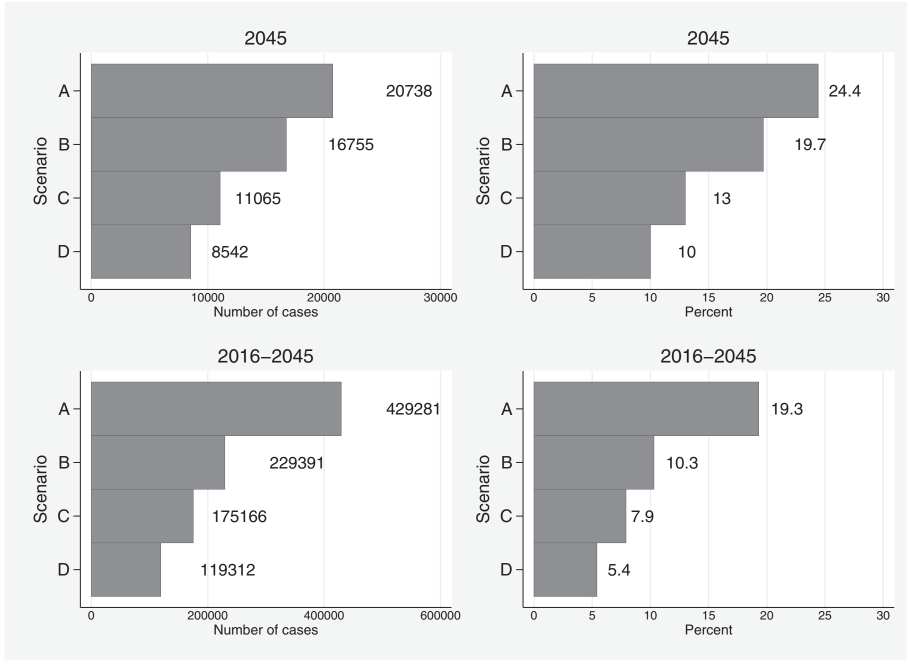

Fig. 2. Number and percentage∗ of avoidable cancers during 2016–2045 and in 2045 in the Nordic countries under different scenarios of tobacco smoking prevalence, compared to if the prevalence would stay constant. A: elimination, B: 5% prevalence by 2030, C: country-specific interventions and D: continued decreasing trend. ∗Percentage of avoidable cancers of the total number of expected cases for the 13 selected cancer sites.

prevalence scenarios of tobacco smoking, compared to if the prevalence of smoking would stay constant. In total, approximately 430,000 cancers, of the 2.2 million expected cancers for the 13 studied cancer sites, could be avoided in the Nordic countries over the 30-year period if smoking was entirely eliminated from 2016 onwards. The effect is greatest, in absolute numbers, for lung cancer (approximately 250,000) and bladder cancer (approximately 43,000), while the largest percentage is observed for lung cancer (52%) and laryngeal cancer (51%). The annual number of avoidable cancers is approximately 20,000 by the year 2045 in the Nordic countries.

Results from our scenario A are comparable to estimates of PAFs during years beyond the LAT and LAG time, and we have chosen to present the results for the year 2045. When comparing our results with estimates of the PAF in the UK [4,11,53], our results are in general lower due to lower smoking prevalence in the Nordic countries, except for cancer of the cervix uteri in Denmark. The proportions of avoidable cancers in our study are also higher for ovarian cancer and leukaemia, but we restricted to mucinous ovarian cancer and myeloid leukaemia and not all cases of these sites as in the UK study, and the results are, therefore, not comparable for these sites. Results from an Australian study also showed higher estimates of PAF for most cancer sites, compared with our results [12], which might be explained by higher smoking prevalence in Australia. In a Nordic study from 1997 [5,10,54], the PAF of tobacco smoking in 2000 was estimated for most of the sites included in our study. Their estimates are similar to ours for most sites, but our estimates are lower for lung, bladder, oesophageal and cervical cancer, due to the decreasing smoking prevalence in the last decades.

We were unable to take the effect of environmental tobacco smoke into account in our calculations, due to lack of reliable information, and we might, therefore, have underestimated the number of avoidable cases of lung cancer. However, environmental tobacco smoke accounts for about 1–2% of all lung cancers [55,56] so the underestimation will be small. Another limitation with our exposure data is that we only know the proportion of daily smokers, and we, therefore, miss the occasional smokers, which could have resulted in an underestimation of the numbers of preventable cancer cases. Also, a proportion of those responding that they are daily smokers might smoke pipe or cigars and not cigarettes. We were not able to include differences by socio-economic groups in our estimation, even though it is known that smoking prevalence is higher among low socio-economic groups [57]. However, this should not have a large impact on our estimates because there is no reason to believe that the RRs of cancer differ between socio-economic groups.

One limitation of the Prevent model is that it does not provide confidence intervals or any other measure of uncertainty. However, the purpose of the model is not to produce valid predictions of the future cancer incidence but rather to produce the difference in the number of cases under alterations in exposure prevalence. The Prevent model results depend heavily on the input data, and it is, therefore, important to do sensitivity analyses according to trends in cancer incidence, LAT and LAG. In our study, such sensitivity analyses showed that the percentage of avoidable cancers is fairly robust to such changes. Even so, the results should be interpreted with caution, especially when comparing the results for the different countries, due to potential differences in data quality and data sources for smoking prevalence. For the rather homogenous Nordic countries in most aspects and with quite similar comprehensive monitoring of both smoking and health, it may be less of a problem compared to estimations for a greater Europe. However, even for the Nordic countries when the smoking prevalence data are divided into small age groups, the results are limited by sample size. Also, even if the data are representative on age, sex, geography and education for the whole sample, it might no longer be representative on geography and education when divided into age groups. For example, in 2015 and 2016, a representative survey among 2000 16 to 25-year-olds in Denmark was conducted. These surveys showed that the prevalence of daily smokers in this age group was 13% (2015) and 15% (2016), which is higher than shown in the data used for our calculations.

A large amount of cancers could be avoided in the coming 30 years even with small changes in the prevalence of smoking. Unfortunately, the Prevent model does not allow distinguishing between interventions that aim to reduce smoking prevalence by having current smokers stopping and that aim to prevent individuals from starting smoking. If current smokers stop smoking, we would expect to see an effect on cancer incidence sooner than if the prevalence is reduced because fewer individuals start smoking. It is assumed that the interventions proposed and used will influence the entire population, and all age groups, in the same way, albeit it is likely that regulation may have a larger effect in avoiding the recruiting of new and young smokers. Hence, we may underestimate the long-term effect as these young non-smokers grow older. With the available and published data, it is impossible to predict if cessation programmes and the proposed regulations leave hardcore heavy smokers and lower social classes as continuous smokers at high risk for cancer. However, studying smoking cessation by gender and education, the cessation trends are similar albeit at different levels at the outset and with higher cessation rates among the highly educated [57]. Even so, the results from this study can be an important step in setting priorities in cancer control planning and showing the potential for prevention programmes in the Nordic countries and be an example to follow for European countries with a sufficient population size and high quality cancer registration and monitoring for smoking prevalence.

Our results suggest that it is important to continue with and scale-up interventions for reducing tobacco smoking, because the number of avoidable cancers is lowest for our scenario where the observed trend in smoking prevalence continues. The introduction of lung cancer screening in many countries could potentially lead to an increased awareness of the dangers of smoking, and thus, lead to higher cessation rates among heavy smokers than previously observed. Another potential reason for higher future cessation rates is increasing use of e-cigarettes in formerly heavy smokers, although use of e-cigarettes could also lead to higher rates of nicotine addiction among younger groups [58]. Elimination of tobacco smoking would result in more than twice as many avoided cancers compared with elimination of overweight and obesity in the Nordic countries in the 30-year period [21], showing the high importance of continuing efforts to reduce the smoking prevalence.

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Conflicts of interest statement

None declared.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejca.2018.02.031.

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