Cancer Epidemiology 59 (2019) 199–207

Contents lists available at ScienceDirect

Cancer Epidemiology

journal homepage: www.elsevier.com/locate/canep

The future burden of cancer in Canada: Long-term cancer incidence projections 2013–2042

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ARTICLE INFO

Keywords:
Cancer
Incidence
Canada, projections
Trends
Lung cancer
Colorectal cancer
Prostate cancer
Breast cancer
Bladder cancer

ABSTRACT

Background: Cancer is the leading cause of death in Canada and the estimated annual spending associated with cancer is approximately $7.5 billion. Projecting the future burden of cancer in Canada is essential for health planning and evaluation. We aimed to estimate the future incidence of cancer in Canada to 2042.

Methods: Age-sex-region-specific cancer incidence data were obtained for the years 1983-2012 and cancer incidence was projected from 2013 to 2042 for the top five cancer sites. The modelling algorithm combined a mixture of cancer projection methods to select the best-fitted model. When the chosen model produced by the modelling algorithm resulted in estimates that were not consistent with expert opinion, an alternate model was selected that took into consideration historical changes in policy, screening and lifestyle behaviours. Incidence projections were made for Canada and its provinces.

Results: Lung cancer incidence is estimated to rise to 14,866 cases in men and 19,162 in women in 2042. Colorectal cancer incidence is estimated to rise to 28,146 in men and 21,102 in women. Cases of bladder cancer are projected to rise to 10,708 and 3,364 in men and women, respectively. Breast cancer incidence is predicted to rise to 40,712 and prostate cancer incidence is projected to rise to 92,949.

Conclusion: These cancer incidence projections up to 2042 can be used for planning cancer control strategies and prevention programs. Given the ongoing changes in the prevalence of risk factors and in cancer prevention policies, these estimates should be interpreted with caution.

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https://doi.org/10.1016/j.canep.2019.02.011
Received 19 November 2018; Received in revised form 23 January 2019; Accepted 12 February 2019
Available online 01 March 2019

1. Introduction

Cancer is the leading cause of death in Canada, responsible for 30% of all deaths in 2012 [1]. According to the Canadian Cancer Society, approximately 49% of males and 45% of females will develop cancer in their lifetime and 25% of Canadians will die from cancer. Based on the projected cancer incidence estimates for 2017, the four most common cancer types (prostate, breast, lung and colorectal) account for over half of all cancers diagnosed in Canada [1]. In men, the most common cancer type is prostate, followed by colorectal cancer and lung cancer. In women, the most common cancer type is breast, followed by lung and colorectal cancer. In addition to its health burden, cancer also leads to substantial economic cost. Between 2005 and 2012, the economic burden of cancer care in Canada rose from $2.9 billion to $7.5 billion annually, mostly due to hospital expenditures and physician care costs [2].

Given the considerable health and economic burden of cancer in Canada, projecting cancer incidence is essential for resource planning and informing cancer control programs. Furthermore, it is imperative to understand epidemiologic trends and cancer incidence to decrease the burden, by targeting and prioritizing prevention initiatives. Previous Canadian estimates projected an 84% increase in the number of incident cancer cases between 2003–2007 and 2028–2032 in men and a 74% increase in women [3,4]. The four most common types of cancer in Canada were projected to rank in the same way by 2028–2032 [3].

Cancer incidence and mortality rates can be projected by extrapolating past trends to estimate plausible future trends, using statistical models. In previous models used to project cancer incidence frequencies and rates in specific countries and the world, trends over age at diagnosis, year of diagnosis (period) and/or year of birth (cohort) as well as hybrids of these models have been adopted [5–7]. In recent years, the age-period-cohort [8] and the age-drift-period-cohort (Nordpred) [9] models have been widely used. The Nordpred model has been used for previously completed cancer projections in Canada [3,4], however, our approach builds on this previous model by including a series of models, rather than only the Nordpred model in a ‘one size fits all’ approach, which can lead to inaccurate results. In so doing, the most appropriate model could be used for our analyses

As part of the large Canadian population attributable risk of cancer (ComPARe) study [10], we produced comprehensive estimates of future cancer incidence and age-standardized incidence rates (ASIR) for prostate, breast, lung and colorectal cancer until 2042, using a modeling algorithm and expert opinion.

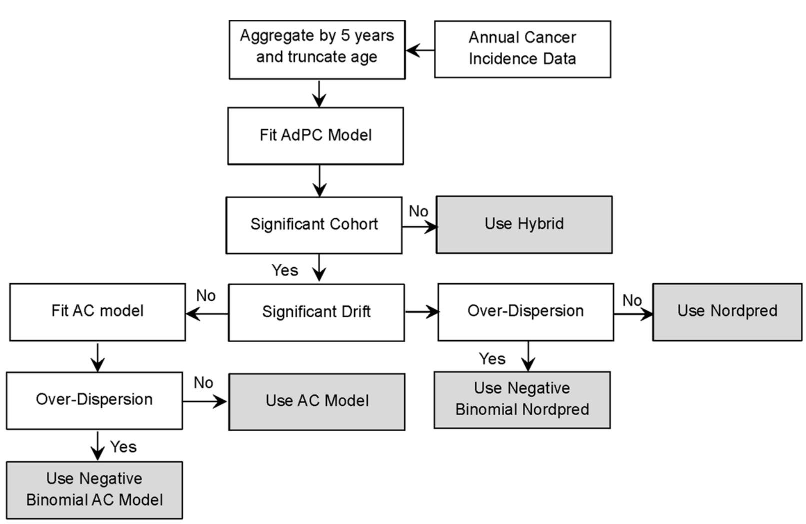

Fig. 1. Decision tree for cancer incidence projection model selection in Canproj.
Abbreviations: AC = Age-cohort model, AdPC = Age-drift-period-cohort model, Hybrid = age-only model or age-period model.
Footnotes: Adapted from: Canproj-The R package of cancer projection methods based on generalized linear models for age, period and/or cohort. Alberta Health Services: 2011-12-16.

2. Material and methods

2.1. Input data

We obtained cancer incidence data for 1983–1991 from the National Cancer Incidence Reporting System (NCIRS) and for 1992–2012 from the Canadian Cancer Registry (CCR). The CCR is a national registry of cancer cases covering the entire population of Canada, with data available by province and territory. Each Canadian province and territory has a legislated responsibility for cancer data surveillance and control, which ensures completeness [11]. Statistics Canada produces annual data quality reports for the CCR to ensure that individual provinces are meeting national standards. Data by province, sex and five-year age groups were obtained up to 2012, which was the most recent year of national data available at the time of the study (except for Quebec data which were extrapolated from 2010 by Statistics Canada). Cancer cases are coded in the CCR using the International Classification of Diseases for Oncology, 3rd Edition (ICD-O-3). Cases from the NCIRS were coded using equivalent ICD-9 codes. Methods used to account for changes in cancer definitions over time have been previously published [1]. Due to small frequencies, the cancer incidence estimates for the Atlantic provinces (Nova Scotia, New Brunswick, Newfoundland and Labrador and Prince Edward Island) were combined, as these populations are considerably smaller than the other provinces in Canada.

Population data for Canada for 1983–2042 by sex and five-year age group were also obtained from Statistics Canada. Estimates used were the final intercensal (e.g. estimate of population between censuses), values up to 2010, final postcensal from 2011 to 2012, updated postcensal from 2013 to 2014 and preliminary postcensal for 2015 [12]. For 2016 to 2042, Statistics Canada projected population estimates using the medium growth scenario [13], which incorporates medium growth and historical trends in interprovincial and national migration. Population projections for provinces were only available to 2038 and therefore cancer incidence projections for provinces were only estimated to 2038. Due to low numbers of incident cancer cases in the Canadian territories, we were unable to produce valid projection estimates for the individual territories or combined.

2.2. Cancer incidence projection modelling

The R package, Canproj, combines cancer projection methods to select the best-fitting model, using a decision tree algorithm [14]. The R package, CanProj, was previously developed in collaboration with the Canadian Partnership Against Cancer to systematically model cancer incidence trends in Canada [14]. Rather than using a single approach, Canproj combines cancer projection methods to select the best fitting

Table 1
Models chosen for cancer incidence projections.

Cancer Site	Sex	ICD-O-3 Topography Codes	Model Chosen
Colorectal	Male Female	C18.0–18.9, C19.9, C20.9, C21.0–21.2, C21.8	Negative-binomial based age-drift-period-cohort
Lung	Male Female	C34.0–34.3, C34.8–34.9	Poisson based age-cohort
Bladder	Male Female	C67.0–67.9	Negative-binomial based age-drift-period-cohort
Breast	Female	C50.0–50.6, C50.8–50.9	Poisson based age-drift-period-cohort
Prostate	Male	C61.9	Negative-binomial based age-specific trend

model for the data, using a decision algorithm to identify the most appropriate projection (Fig. 1). The models available in Canproj include: age-only, age-period (including common trend and age-specific trend), age-cohort and Nordpred (age-drift-period-cohort) [9]; negative-binomial distribution may replace the Poisson distribution when over-dispersion appears. Details of each model are presented in the Appendix. Validation analyses have shown that the flexibility of the Canproj algorithm outperforms various other traditional approaches [15,16], such as the Poisson regression method [17], the polynomial regression and natural spline methods [18], the Joinpoint method [19] and the Bayesian Markov Chain Monte Carlo methods [20], by taking advantage of specific aspects of all of these methods to fit the best model, depending on the unique aspects of different cancer site trends. A previous study showed that the Canproj method outperformed both the independent Nordpred (age-period-cohort generalized linear model) and hybrid (age-period) models for both short term and long term cancer incidence projections [21].

Since some models chosen by Canproj were not reasonable because of changes in primary and secondary prevention initiatives (e.g. prostate cancer, colorectal cancer, cervical cancer), we evaluated all findings, to inspect the face validity of the projections with consultation from content area experts. In instances where the algorithm selected a method that was not plausible, we identified the method that was in accordance with the recommendations of the content area experts.

Table 2
Reported and projected cancer incidence in Canada by sex and age (number of new cases each year).

Cancer Site	Sex	Age	Incidence (number of cases)						
			1983	1993	2003	2013	2023	2033	2042
Colorectum	Male	< 45	255	275	300	399	541	647	638
		45 – 54	580	685	975	1184	1209	1650	2110
		55 – 64	1470	1715	2160	2951	3530	3630	4719
		65 – 74	2055	2645	3200	4110	5863	7041	7060
		75 – 84	1450	1975	2590	3234	4771	7045	8638
		≥ 85	410	520	705	1273	2004	3269	4981
	Female	< 45	230	290	260	366	501	559	546
		45 – 54	575	600	790	985	968	1397	1651
		55 – 64	1250	1175	1435	1919	2288	2346	3165
		65 – 74	1820	2110	2155	2659	3572	4357	4526
		75 – 84	1635	2150	2715	2726	3554	4972	6139
		≥ 85	755	960	1300	1952	2521	3597	5075
Lung	Male	< 45	245	265	200	131	204	214	197
		45 – 54	1025	1010	940	813	603	876	947
		55 – 64	2880	2850	2510	2775	2564	2007	2734
		65 – 74	3475	4570	4140	4493	4966	4716	3714
		75 – 84	1845	2705	3300	3621	4125	4839	4839
		≥ 85	325	540	765	1248	1585	2000	2435
	Female	< 45	190	280	245	163	197	197	182
		45 – 54	540	755	1055	1024	743	874	899
		55 – 64	1055	1585	2020	2814	2879	2198	2600
		65 – 74	1165	2215	2785	3917	5425	5566	4202
		75 – 84	485	1375	2365	3130	4502	6352	6958
		≥ 85	140	330	675	1325	2071	3033	4322
Bladder	Male	< 45	130	120	90	89	106	118	115
		45 – 54	280	280	360	339	268	335	411
		55 – 64	740	770	900	1103	1094	947	1165
		65 – 74	1155	1360	1465	1815	2408	2566	2300
		75 – 84	720	1045	1355	1723	2329	3363	3805
		≥ 85	210	265	435	805	1178	1885	2912
	Female	< 45	35	60	45	39	47	53	52
		45 – 54	110	110	130	135	102	131	166
		55 – 64	225	250	305	354	371	303	364
		65 – 74	315	390	405	507	658	738	643
		75 – 84	280	375	505	523	686	959	1151
		85 +	140	160	245	378	495	728	989
Breast	Female	< 45	1540	2110	2260	2292	2967	3470	3387
		45 – 54	2100	3140	4270	4910	4481	5932	7313
		55 – 64	2745	3310	4670	6177	7056	6650	8362
		65 – 74	2500	3840	3850	5609	7601	8826	8452
		75 – 84	1560	2470	2965	3293	4914	6879	8194
		≥ 85	575	855	1065	1697	2274	3606	5004
Prostate	Male	< 45	10	25	55	99	195	293	303
		45 – 54	145	425	1375	2372	3167	4368	4985
		55 – 64	1100	3350	5240	8526	11424	11321	12731
		65 – 74	2770	7810	7470	9511	12708	13826	12772
		75 – 84	2475	4950	4385	4138	4586	5654	6363
		≥ 85	785	1165	1155	1241	983	1090	1489

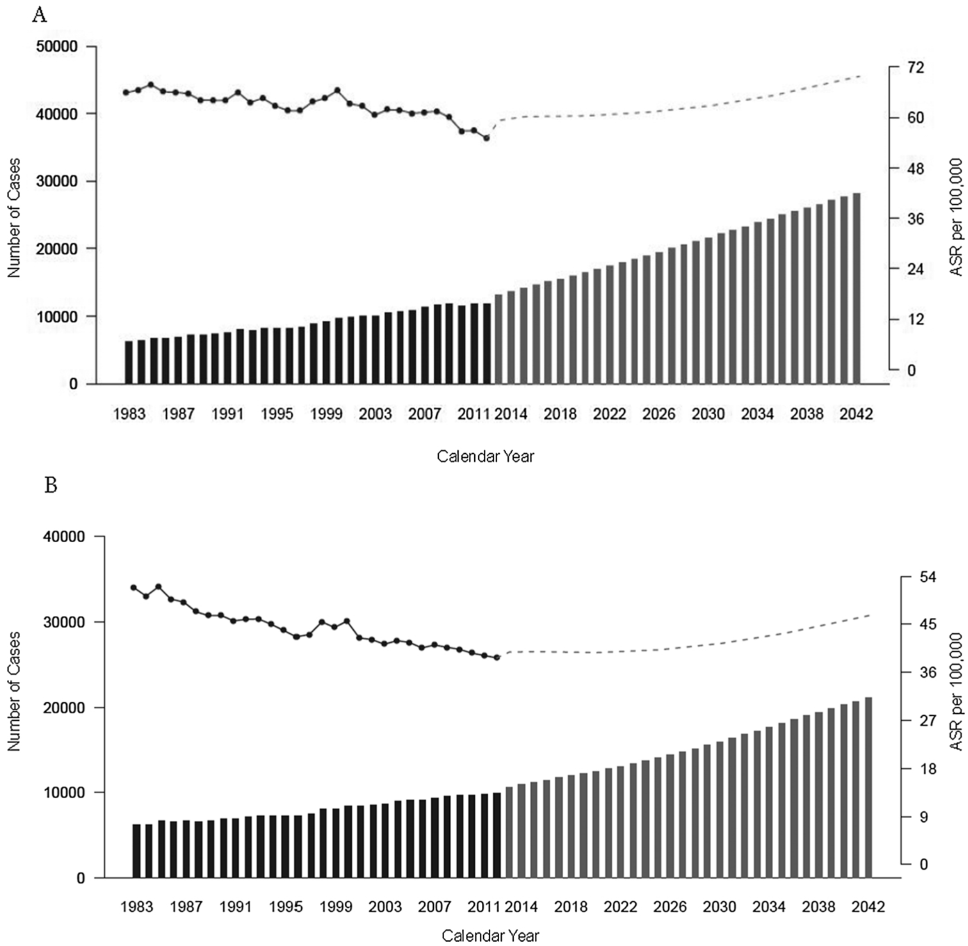

Fig. 2. Incident cancer cases and age-standardized incidence rates of colorectal cancer 1983–2042 in men (A) and women (B).
Footnotes: The negative-binomial based age-drift-period-cohort model was used for colorectal cancer projections in men and women. Cancer incidence data were obtained from the National Cancer Incidence Reporting System (1983–1991) and the Canadian Cancer Registry (1992–2012). The bars represent the number of incident cancer cases; the line graph represents the age-standardized rate.

In our analyses we projected cancer incidence, by cancer site, from 2013 to 2042 in Canada and to 2038 for provinces. We projected forward for a maximum of 30 years, which was reasonable given the uncertainty surrounding cancer projections and the availability of population projection estimates in Canada. ASIRs were weighted according to the 1991 Canadian standard population.

3. Results

The models selected for colorectal, lung, bladder, breast and prostate cancer are presented in Table 1. The negative-binomial based age-drift-period-cohort model was selected for colorectal and bladder cancer. The Poisson-based age-cohort model was used for lung cancer and the negative-binomial based age-specific trend and Poisson-based age-drift-period-cohort models were used for prostate and breast cancer, respectively.

In Canada, the incidence of colorectal cancer is predicted to rise to 49,248 cases by 2042, compared to 21,690 in 2012 (Table 2, Fig. 2). Although the incidence of colorectal cancer in men and women was very similar in 1983 (6,220 cases in men and 6,265 cases in women), more men (28,146 cases) than women (21,102) are expected to be diagnosed with colorectal cancer in 2042 (Fig. 2). In 2012, there were 24,325 incident cases of lung cancer in Canada and a projected 34,029 cases are estimated for 2042. The number of incident lung cancer cases has historically been higher in men, but the incidence of lung cancer is estimated to be higher in women starting in 2016 (Fig. 3). The number of incident cases of bladder cancer in 2042 is estimated to rise to 14,073 by 2042 from 7,495 in 2012, with a higher incidence in men every year (Fig. 4). Breast cancer incidence in women is expected to reach 40,712 cases by 2042 compared to 22,960 cases in 2012 (Fig. 5). The third highest number of incident cases was estimated for prostate cancer, with 38,643 cases estimated for 2042, up from 20,935 in 2012 (Fig. 6). Cancer incidence by province is presented in Table 3. The incidence trends in the provinces were generally similar to the trends observed for Canada.

The ASIRs for Canada and provinces using the 1991 Canadian standard population are presented in Table 4. Based on our estimates, colorectal cancer incidence rates are expected to increase in males and females in Canada and all provinces. In Canada, rates are expected to reach 69.8/100,000 in men and 46.7/100,000 in women in 2042 compared to 55.0/100,000 and 38.7/100,000 in 2012, respectively (Fig. 2). The highest projected ASIRs for colorectal cancer in 2038 were observed in Saskatchewan for men, with an ASIR of 84.0/100,000 and the Atlantic provinces for women with an ASIR of 61.9/100,000. In Canada, the ASIR of lung cancer is expected to decrease in both men in women (Fig. 3). In men, the ASIR is estimated to decrease from 59.5/100,000 in 2012 to 36.3/100,000 in 2042. In women, the ASIR for lung cancer is expected to rise from 28.8/100,000 in 1983 to 47.7/100,000 in 2014 and is estimated to decrease to 39.6/100,000 by 2042. The highest projected ASIRs in 2038 for lung cancer were in Quebec for both men (48.9/100,000) and women (57.2/100,000). The ASIRs for bladder cancer in Canada were more than three times higher in men than women for all years. In men, the ASIR of bladder cancer is expected to decrease from 26.5/100,000 in 2012 to 23.1/100,000 in

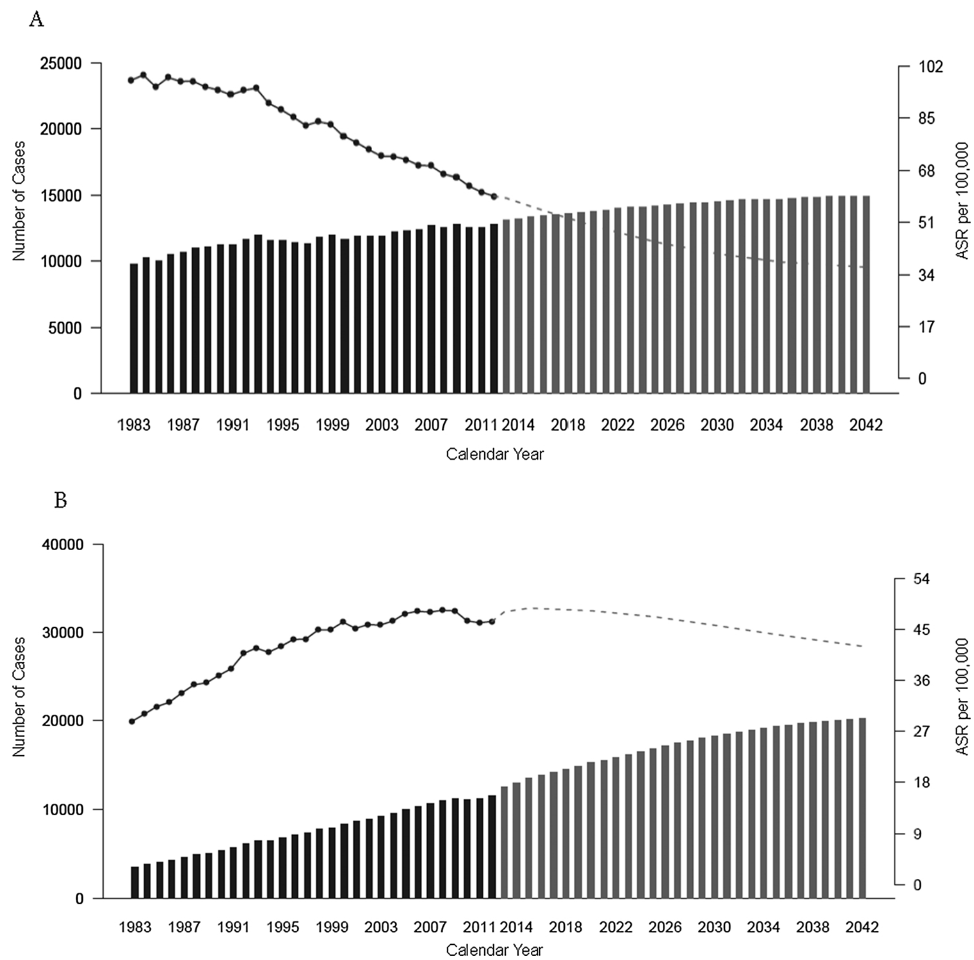

Fig. 3. Incident cancer cases and age-standardized incidence rates of lung 1983–2042 in men (A) and women (B).
Footnotes: The Poisson based age-cohort model was used for lung cancer projections in men and women. Cancer incidence data were obtained from the National Cancer Incidence Reporting System (1983–1991) and the Canadian Cancer Registry (1992–2012). The bars represent the number of incident cancer cases; the line graph represents the age-standardized rate.

2042. In women, the ASIR of bladder cancer is expected to decrease from 7.2/100,000 in 2012 to 6.6/100,000 in 2038 (Fig. 4). The highest estimated ASIRs for bladder cancer in 2038 were observed in Quebec for men (33.7/100,000) and women (11.0/100,000). ASIRs for both breast and prostate cancers are projected to increase. The ASIR for breast cancer is estimated to increase from 97.6/100,000 in 2012 to 116.3/100,000 in 2042 (Fig. 5) and the ASIR for prostate cancer is estimated to increase from 95.0/100,000 in 2012 to 115.1/100,000 in 2042 (Fig. 6). The highest ASIR for breast cancer in 2038 was estimated for British Columbia (125.0/100,000) and the highest ASIR for prostate cancer was estimated for the Atlantic Provinces (174.5/100,000).

4. Discussion

In men, the number of incident cases of colorectal, lung, bladder and prostate cancers is projected to increase from 50,190 in 2012 to 92,362 in 2042. In women, the number of incident colorectal, lung, bladder and breast cancer cases is projected to increase from 46,270 to 84,342. These increases in incidence are largely driven by the aging population in Canada and, to a smaller extent, by an increase in population size, as previously noted [3]. In Canadian men, we estimate that by 2042 the ASIRs for colorectal and prostate cancer will increase and the ASIRs for lung and bladder cancer in men will decrease. In Canadian women, we estimate that ASIRs for colorectal and bladder cancer will decrease between 1983 and 2042 and the ASIR for female lung cancer and breast cancer will increase

A previous analysis of future cancer incidence trends in Canada estimated that the ASIR for colorectal cancer in men would decrease slightly to 57.0/100,000 in men and 38.6/100,000 in women by 2028–2032 [3]. Our estimates suggest that although the ASIRs for colorectal cancer in men and women have been decreasing, the rates will increase after 2013 and continue to rise. This increase in colorectal cancer in Canada is likely attributable to various factors, which may include the projected increasing prevalence of obesity and reduced levels of physical activity [22], as obesity is known to be associated with colorectal cancer [23]. Sub-optimal colorectal cancer screening uptake (˜55%] in Canada [24] could likely also contributes to the projected increase in colorectal cancer. For lung cancer, previous estimates suggest that the ASIR will decrease to 46.4/100,000 in men and marginally decrease to 39.6/100,000 in women by 2028–2032 [3]. Our estimates are similar, with slightly lower ASIRs for men and a slower decrease for women by 2042. Lung cancer incidence in Canada is largely driven by the prevalence of tobacco smoking, as up to 85% of lung cancer has been shown to be attributable to smoking [25–28]. The delayed decrease in lung cancer incidence rates for women is because the prevalence of smoking in women did not begin to decrease until the mid-1980s, whereas the prevalence of smoking in men began to decrease in the mid-1960s [29].

Consistent with our estimates, the incidence rates of bladder cancer in men and women were previously estimated to decrease slightly and then remain generally stable by 2028-2032 with ASIRs of 24.0/100,000 and 7.3/100,000, respectively [3]. From our analysis, bladder cancer

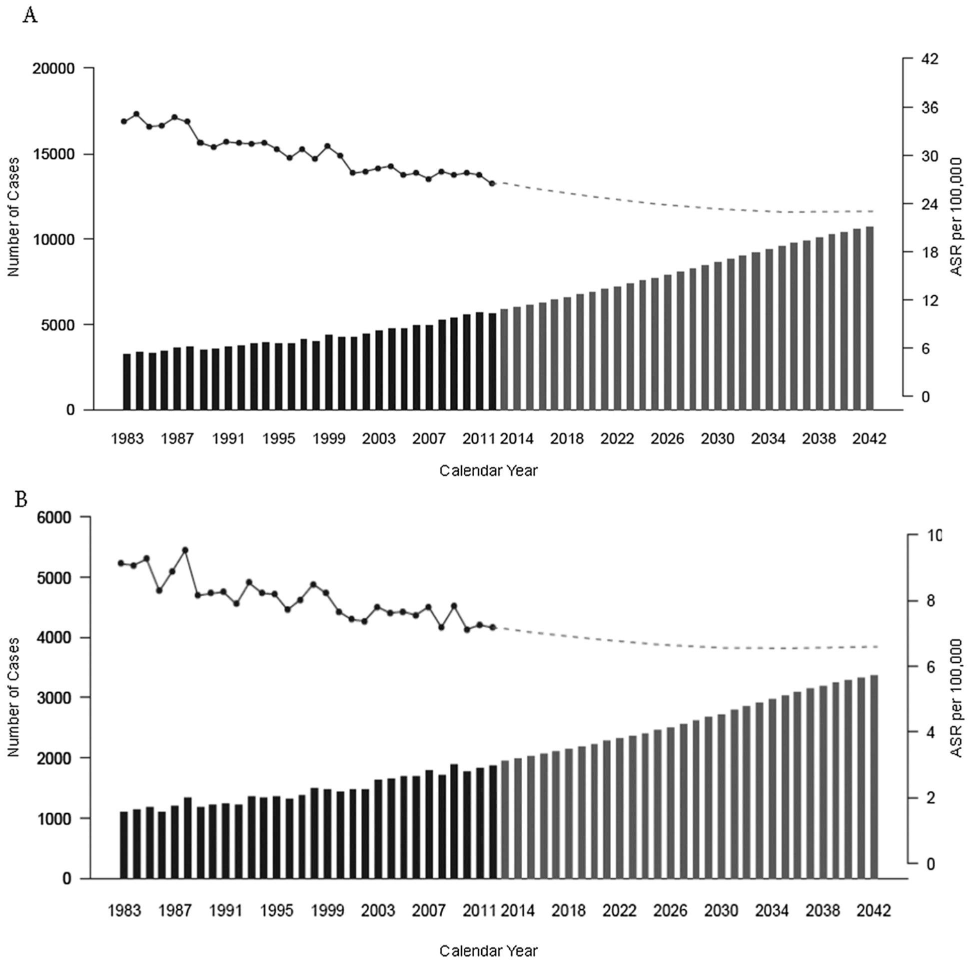

Fig. 4. Incident cancer cases and age-standardized incidence rates of bladder cancer 1983–2042 in men (A) and women (B).
Footnotes: The negative-binomial based age-drift-period-cohort model was used for bladder cancer projections in men and women. Cancer incidence data were obtained from the National Cancer Incidence Reporting System (1983–1991) and the Canadian Cancer Registry (1992–2012). The bars represent the number of incident cancer cases; the line graph represents the age-standardized rate.

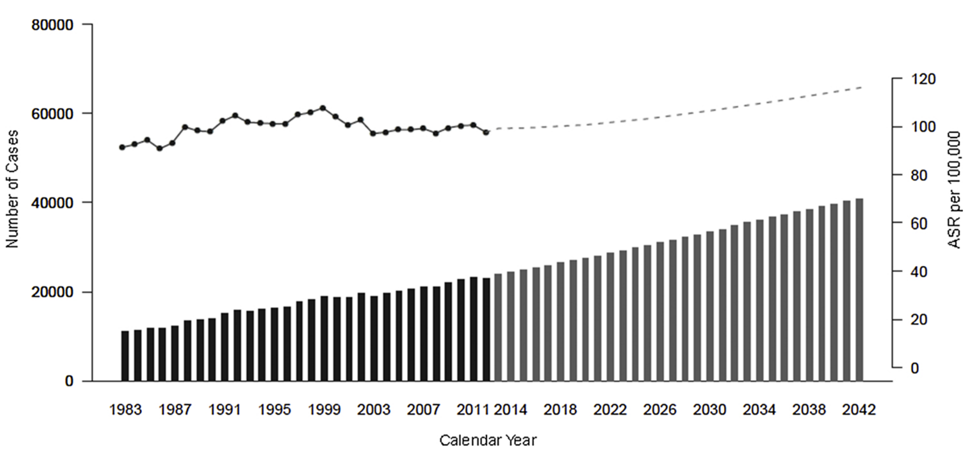

Fig. 5. Incident cancer cases and age-standardized incidence rates of breast cancer 1983-2042 in women.
Footnotes: The Poisson based age-drift-period-cohort model was used for breast cancer projections in women. Cancer incidence data were obtained from the National Cancer Incidence Reporting System (1983–1991) and the Canadian Cancer Registry (1992–2012). The bars represent the number of incident cancer cases; the line graph represents the age-standardized rate.

incidence rates are estimated to slightly decrease until 2023 and then remain generally stable to 2042. As with lung cancer, the greatest preventable cause of bladder cancer is smoking, with previous Canadian studies estimating that up to 40% of bladder cancer is attributable to smoking [26,28]. Therefore, as with lung cancer, it is likely that the rate of bladder cancer in women will continue to decrease in the future. Compared to colorectal, lung and breast cancer, the variability in the incidence of bladder cancer, as shown in Fig. 4, seems to be greater between 1983 and 2012. This perceived variability could be due to the lower incidence of bladder cancer cases compared to colorectal, lung and breast cancer, which causes the variability to seem greater, even if the variability across cancer sites is similar. In addition, the variability observed for bladder cancer could stem from differences in registration between 1983 and 2012 and by province. As previously reported [30], there has been a lack of consistency in the reporting on noninvasive (in-situ) bladder tumours over time and although the provincial registries are held to a high standard by the Canadian Cancer Registry, there may have been inconsistencies between 1983 and 2012.

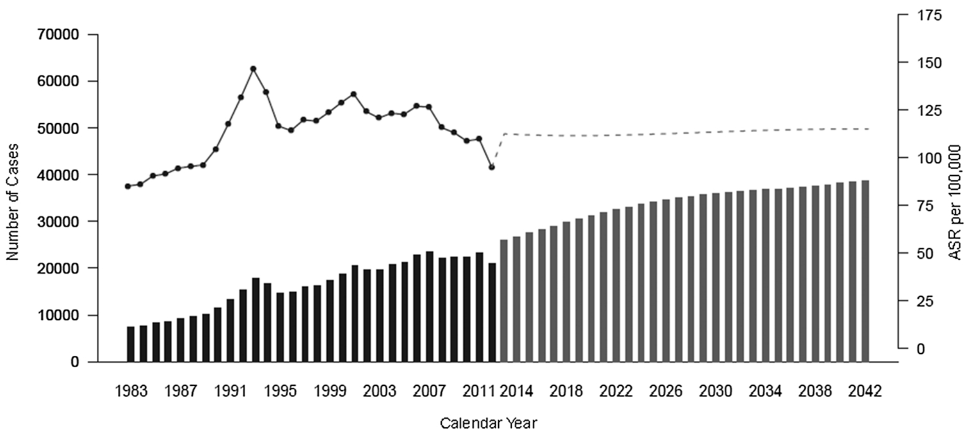

Fig. 6. Incident cancer cases and age-standardized rates of prostate cancer 1983–2042 in men.

Footnotes: The negative-binomial based age-specific trend model was used for prostate cancer projections in men. Cancer incidence data were obtained from the National Cancer Incidence Reporting System (1983–1991) and the Canadian Cancer Registry (1992–2012). The bars represent the number of incident cancer cases; the line graph represents the age-standardized rate.

Table 3
Reported and projected cancer incidence in Canadian provinces (number of new cases each year).

Cancer Site	Sex	Year	Incidence						
			AB	AT	BC	MB	ON	QC	SK
Colorectum	Male	1983	410	550	715	285	2275	1665	285
		2012	1065	1165	1610	470	3990	3085	455
		2038	3073	2085	3081	953	9028	6264	828
	Female	1983	380	565	710	275	2360	1725	250
		2012	795	910	1310	320	3540	2610	345
		2038	2106	1717	2469	709	7487	4296	545
Lung	Male	1983	555	865	1100	415	3455	3010	350
		2012	940	1215	1475	400	4370	3975	365
		2038	1879	1262	1711	599	4663	4588	454
	Female	1983	225	250	510	150	1450	880	100
		2012	970	1000	1450	440	4100	3250	345
		2038	2064	1629	1890	679	6083	6106	493
Bladder	Male	1983	200	235	405	140	1155	980	130
		2012	570	525	860	185	1515	1760	175
		2038	1381	931	1446	389	2650	3494	277
	Female	1983	60	60	135	60	420	340	35
		2012	170	145	270	80	525	590	70
		2038	399	216	347	114	839	1341	77
Breast	Female	1983	820	810	1410	545	4050	2975	415
		2012	2160	1745	2960	815	8900	5670	665
		2038	4639	2420	5542	1343	14918	8137	961
Prostate	Male	1983	615	555	1090	390	2405	1790	455
		2012	2365	1835	3170	615	7805	4360	755
		2038	5402	3401	3964	784	18484	6338	1218

Abbreviations: AB, Alberta; AT, Atlantic provinces (New Brunswick, Newfoundland and Labrador, New Brunswick and Prince Edward Island); BC, British Columbia; MB, Manitoba; ON, Ontario; QC, Quebec; SK, Saskatchewan.

Our ASIR projection estimate for female breast cancer of 116.3/100,000 is higher than the previously estimated 98.7/100,000 for 2028–2032 [3]. Although estimates show some plateauing of incidence between 1993 and 2013, the rate of female breast cancer is projected to increase again from 2023 to 2042. The increase in incidence could be explained by various factors. New practice guidelines released in 2013 by the Canadian Association of Radiologists recommend women aged 40 to 49 be screened annually and biennial screening for women between the ages of 50 and 74 [31]. In addition, breast-feeding and parity have been shown to be associated with a reduced risk of breast cancer [32]. Therefore, decreasing fertility rates in Canada [33] could also contribute to the increasing incidence of breast cancer. Finally, we previously estimated that up to 50% of breast cancer is attributable to modifiable factors such as physical inactivity, excess body fat, alcohol consumption and hormone use [34]. Changes in these behaviours on a population level could help explain the increase in incidence of breast cancer in addition to the aging population and longer life spans in Canada [35].

Previous prostate cancer incidence projections estimated that the incidence rates will remain stable from the period of 2003–2007 to 2028–2032 at 123.3/100,000 [3]. However, these projections are based on a long-term projection of constant rates, since the authors of the previous projections were unsatisfied with the extreme increase in incidence projected using the Nordpred model in their analysis. Our estimates suggest that after a slight decrease in the incidence rate of prostate cancer up to 2013, the rate will stabilize. The peaks in prostate cancer incidence in 1993 and 2001 can be explained by the two waves of intensified prostate-specific antigen (PSA) screening [4]. Population-based PSA screening is no longer recommended in Canada [36].

As with any long-term projections, projecting cancer incidence to 2042 involves uncertainty and should be interpreted with caution. To reduce the uncertainty, we used high quality cancer incidence data from the CCR for 1992–2012, which misses very few incident cancer cases in Canada (> 99% case ascertainment) [11]. However, data for the province of Quebec for the years 2011 and 2012 were carried forward by Statistics Canada, since data after 2010 are not available for Quebec. Ethnicity is not included in incidence data released by the CCR, to maintain the confidentiality of cases. The projections also depend on the population projections, which are based on assumptions about fertility, mortality and migration at both the national and provincial levels.

Cancer incidence projections from statistical models rely on the assumption that past trends in the data will continue into the future, which further highlights the importance of continuously updating projections. To reduce some of the errors associated with failing to account for future changes in risk behaviours and screening practices, we used expert opinion when the statistical model produced implausible results that were possibly driven by artifacts in data collection (e.g. changes in registration practices, over diagnosis due to screening, etc.). We, as content experts in cancer epidemiology, reviewed the projections and evaluated the findings independently of goodness-of-fit, to increase the plausibility of the projections. To further validate our results, we compared our projections for 2015 with data released from the CCR after our analyses were completed. A comparison of our projections and actual incident frequencies is presented in Supplementary Table 1. In general, our projections are within 1,500 cases of the actual number of incident cases in 2015. However, our projected incidence estimates for prostate cancer was over 8,000 cases higher than the actual number of cases diagnosed in 2015. This difference was also seen for the previous Canadian estimates [3] and is likely due to past spikes in incidence caused by PSA testing, as previously mentioned. Although these spikes were taken into consideration, the residual effects of the PSA testing is leading to an overestimation of future prostate cancer. These discrepancies show the potential impact of a change in screening practice or technology on future cancer rates. Our estimates assume no additional changes in these practices which may be unreasonable, given recent technologies focus on screening and early detection of pre-cancerous lesions.

Table 4
Reported and projected age standardized incidence rates of cancer in Canada and provinces by sex.

Cancer Site	Sex	Region	ASIR /100,000 persons						
			1983	1993	2003	2013	2023	2033	2038*
Colorectum	Male	Canada	65.8	63.6	60.5	59.3	60.9	64.2	69.8
		AB	58.5	51.9	58.4	57.7	59.7	62.1	63.7
		AT	63.5	71.9	71.2	71.0	70.8	71.3	71.7
		BC	60.3	58.5	53.3	52.6	53.1	56.2	58.5
		MB	60.5	67.6	64.9	67.9	69.4	70.5	70.9
		ON	65.9	62.8	56.2	54.5	55.4	59.6	62.8
		QC	73.7	69.0	66.7	64.5	65.1	66.4	67.8
		SK	62.4	60.9	63.7	67.7	73.5	80.0	84.0
	Female	Canada	51.9	46.0	41.3	39.8	40.0	42.5	46.7
		AB	45.5	37.8	38.6	36.9	37.2	38.6	39.7
		AT	53.0	51.3	47.2	49.7	52.8	58.5	61.9
		BC	48.6	42.3	37.5	36.3	36.9	40.6	43.2
		MB	47.8	46.0	39.4	43.5	44.0	46.0	47.1
		ON	51.9	45.1	39.8	37.9	38.8	42.4	44.9
		QC	56.7	50.9	44.4	41.6	40.0	40.3	40.8
		SK	48.9	41.6	44.5	43.3	44.7	46.8	48.1
Lung	Male	Canada	97.3	94.8	72.6	58.9	46.6	39.1	36.3
		AB	74.5	74.6	65.4	52.3	44.4	40.3	39.3
		AT	92.7	99.2	82.6	71.6	58.0	50.5	48.4
		BC	87.5	76.8	58.5	47.4	38.4	34.2	33.2
		MB	87.3	90.0	70.2	59.3	51.1	47.8	47.2
		ON	94.1	84.6	61.0	50.5	39.4	33.2	31.0
		QC	121.0	130.2	100.0	78.5	63.3	52.7	48.9
		SK	74.7	79.0	63.0	56.5	48.2	45.1	44.4
	Female	Canada	28.8	41.7	45.8	47.7	46.6	42.9	39.6
		AB	25.1	37.9	45.1	45.9	44.2	40.5	38.7
		AT	23.4	37.2	44.4	53.1	54.7	53.0	51.7
		BC	33.6	48.1	44.8	42.2	37.8	32.4	29.9
		MB	26.0	38.4	54.5	53.5	51.3	47.5	45.9
		ON	31.2	39.3	40.0	41.8	39.1	35.9	34.5
		QC	27.3	44.8	53.9	58.2	62.0	59.5	57.2
		SK	19.1	30.5	44.1	50.1	48.1	44.5	42.7
Bladder	Male	Canada	34.2	31.5	28.4	26.6	24.3	23.1	23.1
		AB	27.8	28.5	26.3	29.3	27.9	26.7	26.1
		AT	26.0	31.1	31.2	30.7	29.0	28.7	28.5
		BC	33.9	31.9	29.1	28.6	26.4	24.3	23.7
		MB	31.3	29.6	28.9	28.2	27.7	26.9	26.6
		ON	33.4	26.1	22.3	18.8	16.4	15.5	15.4
		QC	44.1	39.6	37.8	33.9	32.1	33.0	33.7
		SK	28.0	32.3	27.8	28.2	25.2	22.7	22.1
	Female	Canada	9.1	8.5	7.8	7.1	6.7	6.6	6.6
		AB	7.1	9.3	10.1	7.3	6.9	6.4	6.1
		AT	5.6	9.8	9.3	8.5	7.5	6.3	5.7
		BC	9.0	10.5	8.0	7.1	5.9	5.4	5.3
		MB	10.7	11.7	7.4	7.1	6.9	6.6	6.5
		ON	9.2	6.8	5.9	4.6	3.8	3.7	3.8
		QC	11.2	10.1	9.2	9.8	10.1	10.7	11.0
		SK	6.5	7.4	8.3	7.9	7.2	6.6	6.3
Breast	Female	Canada	91.3	101.8	97.1	99.2	102.3	109.0	116.3
		AB	92.6	102.2	101.6	97.6	98.8	103.3	106.0
		AT	78.5	99.5	95.9	97.9	98.9	99.1	99.3
		BC	98.2	107.0	92.5	100.2	109.2	119.9	125.0
		MB	101.2	105.3	101.1	104.0	107.2	109.8	111.2
		ON	89.8	100.9	96.1	98.6	100.9	107.3	111.0
		QC	94.4	99.8	99.7	100.0	100.3	104.8	107.5
		SK	85.1	106.2	96.0	97.7	101.2	106.5	109.5
Prostate	Male	Canada	85.1	146.3	120.8	112.5	111.9	114.1	115.1
		AB	94.7	149.0	158.0	126.0	124.4	126.8	127.6
		AT	68.3	154.6	124.9	138.4	155.4	170.6	174.5
		BC	97.6	178.8	114.2	106.8	93.4	86.9	85.6
		MB	89.7	193.9	116.8	92.6	76.6	69.5	68.2
		ON	77.9	135.1	123.6	126.6	136.9	146.9	149.5
		QC	90.7	130.3	104.1	86.5	81.8	80.8	80.7
		SK	99.4	163.7	148.3	130.0	133.5	138.5	139.9

*For Canada, data are presented for the year 2042.
Abbreviations: AB, Alberta; ASIR. Age standardized rate; AT, Atlantic provinces (New Brunswick, Newfoundland and Labrador, New Brunswick and Prince Edward Island); BC, British Columbia; MB, Manitoba; ON, Ontario; QC, Quebec; SK, Saskatchewan.

5. Conclusions

The number of incident cases in the top five sites is projected to increase 83% from 96,460 in 2012 to 176,704 in 2042.The greatest decrease in ASIRs is expected for lung cancer in men, with a decrease of 38% between 2013 and 2042. The ASIR of female breast cancer is estimated to increase by 17% between 2013 and 2042.

These estimates were used in our larger ComPARe study [10], in which we were estimating the future burden of cancer attributable to various lifestyle, environmental and infection risk factors. In addition, our projected substantial increase in cancer cases at the top five sites by 2042 highlights the importance of and need for cancer control strategies and prevention programs aimed at reducing exposure to cancer risk factors. Planning for the future of cancer control in Canada needs to account for the increasing numbers of cancer patients expected each year.

Author statement

C.M.F. and D.R.B. were responsible for the study conception. A.E.P. was responsible for acquisition of the data. A.E.P., Y.R., S.D.W., E.L.F., P.J.V., W.D.K., K.D.V., D.O., C.M.F. and D.R.B. contributed substantially to the study design and interpretation of the data. A.E.P. and Y.R. completed the analyses. A.E.P. was responsible for drafting the article. Y.R., S.D.W., E.L.F., P.J.V., W.D.K., K.D.V., D.O., C.M.F. and D.R.B. critically revised the article for intellectual content. A.E.P., Y.R., S.D.W., E.L.F., P.J.V., W.D.K., K.D.V., D.O., C.M.F. and D.R.B. gave final approval of this version to be published and agreed to be guarantors of the work.

Conflicts of interest

No conflicts of interest declared.

Funding sources

This research is supported by a Canadian Cancer Society Partner Prevention Research Grant (grant #703106).

Acknowledgements

We gratefully acknowledge the work of Dr. Zhenguo Qiu, who developed the Canproj R package and provided support throughout these analyses.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.canep.2019.02.011.

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