

# Cancer Survival Disparities Between First Nation and Non-Aboriginal Adults in Canada: Follow-up of the 1991 Census Mortality Cohort

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## Abstract

**Background:** The burden of cancer among indigenous people in Canada has been understudied due to a lack of ethnic identifiers in cancer registries. We compared cancer survival among First Nations to that among non-Aboriginal adults in Canada in the first national study of its kind to date.

**Methods:** A population-based cohort of approximately 2 million respondents to the 1991 Canadian Long Form Census was followed for cancer diagnoses and deaths using probabilistic linkage to cancer and death registries until 2009. Excess mortality rate ratios (EMRR) and 5-year age-standardized relative survival rates were calculated for 15 cancers using age, sex, ethnicity, and calendar-time-specific life tables derived from the cohort at large.

**Results:** First Nations diagnosed with cancers of the colon and rectum, lung and bronchus, breast, prostate, oral cavity and

pharynx, cervix, ovary, or with non-Hodgkin lymphoma and leukemia all had significantly poorer 5-year survival than their non-Aboriginal peers. For colorectal cancer, a significant disparity was only present between 2001 and 2009 (EMRR: 1.52; 95% CI, 1.28–1.80). For prostate cancer, a significant disparity was only present between 1992 and 2000 (EMRR: 2.76; 95% CI, 1.81–4.21). Adjusting for income and rurality had little impact on the EMRRs.

**Conclusions:** Compared with non-Aboriginals, First Nations people had poorer survival for 14 of 15 of the most common cancers, and disparities could not be explained by income and rurality.

**Impact:** The results of this study can serve as a benchmark for monitoring progress toward narrowing the gap in survival. *Cancer Epidemiol Biomarkers Prev*; 26(1); 145–51. ©2016 AACR.

## Introduction

People indigenous to Canada are recognized by the Constitution as "Aboriginal" and comprise three groups: First Nations, Métis, and Inuit (1). As of 2011, the 1.4 million people belonging to these groups accounted for just over 4% of Canada's population. The First Nations are the largest of the groups and number approximately 850,000 (2).

Adult life expectancy for First Nations is significantly lower than the national average, and cancer is among the leading causes of death (3, 4). Despite the presence of a comprehensive system of population-based cancer registries in Canada, however, cancer patterns for First Nations and indigenous people more generally have been understudied because, like most administrative health data systems in Canada, cancer registries do not routinely collect information about the ethnicity of cases.

Of the three most common metrics of cancer burden (incidence, survival, mortality), information about survival is par-

ticularly sparse. Provincial studies of cancer survival among First Nations have been limited by small numbers of any particular cancer. Canadian indigenous populations are accordingly lacking an up-to-date perspective on cancer survival. These knowledge and data gaps are barriers to progress, planning, and monitoring of needed cancer control programs tailored to these populations (5–9).

In this article, we describe the results of a study conducted using linkage of four national administrative databases to estimate cancer survival in First Nation people Canada-wide from 1992 to 2009. We compare their survival to the survival of non-Aboriginal people and consider the extent to which differences in income and rurality explain the differences in survival between these populations. The study is large, inclusive, and methodologically rigorous and will contribute to a better understanding of the cancer burden in these populations and how to reduce it.

## Materials and Methods

### Data sources and study population

The 1991 Census Mortality Cohort is the largest population-based cohort in Canada (10, 11). The cohort has been described in detail elsewhere and has since been updated to include longer follow-up (10–12). In brief, individuals were eligible for the cohort if they were aged 25 years and older on June 4, 1991 (Census day), enumerated by the 1991 Long Form Census of the Population and matched to a 1990 and/or 1991 tax filing using standard probabilistic techniques. In the general population, the long form version of the census was distributed to 1 in 5

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households. On participating First Nation reserves, in many northern and remote communities, and in non-institutional collective dwellings (e.g., hotels, school dormitories), however, all residents were administered the long form.

On the basis of these criteria, approximately 2.7 million individuals were eligible to be linked to the Canadian Cancer Registry (1992–2009), the Canadian Mortality Database (1992–2009) and tax summary files including name changes, deaths, and updated postal codes up until 2009 (11, 12). Because of incompatibilities between cancer registration in Quebec and the rest of Canada, residents of Quebec were excluded from the cohort for this study, as they have been from other national-level survival analyses (13–15). This reduced the cohort to approximately 2 million persons.

Respondents were categorized as First Nation if they met any of the following criteria: (i) reported registration under the Indian Act (the principal statute through which the federal government administers Indian status, local First Nations governments, and the management of reserve land and communal monies); (ii) reported membership in a First Nation band, or (iii) reported North American Indian (First Nation) as their singular ancestry. Respondents were categorized as non-Aboriginal if they (i) were not First Nation according to the above definitions; (ii) did not report Métis as one of two or fewer ancestries, and (iii) did not report Inuit ancestry only.

First and higher order invasive cancers were eligible for inclusion in the survival analyses if they were diagnosed between January 1, 1992, and December 31, 2009, in cohort members aged 45 to 90 years at diagnosis. This age range was chosen because background mortality rates could be more precisely estimated (see "Statistical analysis" section below). Cases that were registered based on death certificate only, autopsy only, or had negative survival time were excluded. Multiple cancers in the same individual were counted according to the International Agency for Research on Cancer multiple primary rules (16). Cancers were grouped according to the SEER Site Recode for ICD-O-3 (17).

Area-level income adequacy quintiles were constructed by Statistics Canada based on all responses to the Long Form Census. Income adequacy is based on a ratio of total income from all sources combined across all members of an economic family unit to low-income cutoffs from the 1991 Census Dictionary. Quintiles of income adequacy were constructed within each census metropolitan area, census agglomeration, or rural and small town area to take account of regional differences in housing costs that are not reflected in low-income cutoffs (18). Rurality was a dichotomous variable defined by Statistics Canada and determined at the census subdivision level.

### Statistical analysis

We measured net survival using relative survival methods. Advantages of relative survival over more commonly used cause-specific approaches are that information about the cause of death is not required and that by using this method, one measures the excess mortality associated with the cancer irrespective of whether the death was directly or indirectly attributable to cancer (19, 20).

Relative survival has rarely been used to measure or compare survival in indigenous populations because indigenous-specific life tables (tables of expected survival) are not available or are suspected to suffer from numerator–denominator bias (21–23).

Using information from the cohort at large (not restricted to cancer cases), however, we were able to construct ethnicity, age, sex, and calendar-time–specific life tables that were not subject to numerator–denominator bias.

Life tables were constructed using flexible parametric models implemented with the `stpm2` command in Stata version 13 (StataCorp LP; refs. 24, 25). Given the relatively large amount of random variation in the observed mortality rates at either end of the age spectrum for First Nations, we restricted our life tables to ages 45 to 90 years. Within this age range, mortality rates were more precise and therefore deviation of the models from empirical rates could be identified and model fit improved.

To produce the excess mortality rate ratios for First Nations we used flexible parametric survival models fitted on the log cumulative hazard scale. In the first model (Model A), First Nation ethnicity, age, sex, and decade of diagnosis (1992–2000 vs. 2001–2009) were included as main effects. In Model B, income quintile and rurality were included in the model. We tested all covariates for time-varying effects, where the primary time scale was time since diagnosis. For each cancer, the best fit model and the number of knots for the restricted cubic splines, were determined on the basis of a combination of Akaike's Information Criterion (AIC), Bayes Information Criterion (BIC), log likelihood ratio tests, and subjective judgment of graphical displays since simple use of AIC and BIC can occasionally lead to over-fitting (24).

To generate 5-year survival estimates, we produced a marginal estimate of survival for each age group based on the best-fit model and applied standardization weights. The standardization weights are those described by Corazzari and colleagues (26). Five-year survival estimates were restricted to cancers diagnosed in the 2001–2009 time period because while excess mortality rate ratios tended not to change significantly over time, survival improves over time. During the later time period, there were a sufficient number of cases in First Nations to produce estimates of survival that conformed to Statistics Canada data release guidelines for most cancers.

## Results

The 1991 Canadian Census Mortality Study followed 2.7 million adults for incident cancers from January 1, 1992 until death or the end of the study period, December 31, 2009. After excluding residents of Quebec, nearly 2 million persons were included in the cohort, of whom 54 605 were categorized as First Nations (Table 1). Just over 55% of the First Nations cohort was female. Women made up more than half of all Status First Nation long form respondents and the gender imbalance was further exaggerated by a greater success rate of linkage to 1990 and 1991 tax filings among First Nation women than among men (4).

Non-Aboriginal members of the cohort were more affluent than the population of Canada at large, which is evident based on the unequal distribution of non-Aboriginal cohort members across the five income quintiles. First Nation people were more likely than non-Aboriginal people to fall within the lowest income quintile, to be young, and to live in a rural area. Nearly two thirds of First Nation people included in the cohort lived on reserve at census enumeration and over 90% were registered under the Indian Act (data not shown).

A total of 237 905 cancers occurred among non-Aboriginal ( $n = 234\ 035$ ) and First Nation ( $n = 3\ 870$ ) cohort members during the

**Table 1.** Demographic characteristics of cohort members by ethnicity

	Non-Aboriginals n (%)	First Nations n (%)	P ( $\chi^2$ test)
Total <sup>a,b</sup>	1,967,445 (100.0)	54,605 (100.0)	
Sex			<0.001
Male	982,030 (49.9)	24,080 (44.1)	
Age at census enumeration			<0.001
25–34	546,900 (27.8)	23,265 (42.6)	
35–44	514,705 (26.2)	15,060 (27.6)	
45–54	334,510 (17.0)	8,415 (15.4)	
55–64	257,095 (13.1)	4,525 (8.3)	
65–74	202,385 (10.3)	2,315 (4.2)	
75–84	94,520 (4.8)	880 (1.6)	
85–100	17,335 (0.9)	145 (0.3)	
Income quintile			<0.001
1 (Lowest)	319,690 (16.2)	22,915 (42.0)	
2	377,805 (19.2)	13,775 (25.2)	
3	408,585 (20.8)	9,220 (16.9)	
4	425,340 (21.6)	5,800 (10.6)	
5 (Highest)	436,030 (22.2)	2,900 (5.3)	
Rurality <sup>c</sup>			<0.001
Rural	456,695 (23.2)	42,745 (78.3)	

<sup>a</sup>According to Statistics Canada protocols, the counts in this table, including totals, are randomly rounded either up or down to a multiple of 5. When these data are summed or grouped, the total value may not match the individual values since totals and sub-totals are independently rounded. Similarly, percentages, which are calculated on rounded data, may not necessarily add up to 100%.

<sup>b</sup>Cohort members ages 25 to 100 at cohort entry, excluding persons residing in Quebec on census day.

<sup>c</sup>Compared with the true population of Canada on Census day, the cohort has an over-representation of Registered First Nations living in communities with less than 10,000 people, living on reserves or in the territories because all residents of participating First Nation reserves and many remote and northern communities were enumerated using a long-form questionnaire, rather than the 1 in 5 household in the general population (4).

study period. We excluded 1.3% of non-Aboriginal and 1.9% of First Nation cancer cases based on registration by death certificate or autopsy only or negative survival time. After restricting to the 15 most common cancers among First Nations, a total of

187,475 cases among non-Aboriginals and 3,290 cases among First Nations contributed to our analyses.

After taking into account differences in age, time period, and sex (Model A), First Nation adults appeared to have poorer survival than non-Aboriginals from all cancers except for multiple myeloma, indicated by EMRRs that exceed 1 (Tables 2 and 3). Sex did not act as effect modifier of the association between ethnicity and survival and accordingly, the reported EMRRs are not sex-specific. For colorectal and prostate cancers, the survival disparities associated with being First Nation varied by time period. For colorectal cancer, a significant disparity in survival was only present in the later time period (2001–2009, EMRR: 1.52; 95% CI, 1.28–1.80). For prostate cancer, a disparity in survival was only present in the earlier time period (1992–2000, EMRR: 2.76; 95% CI, 1.81–4.21).

For non-Hodgkin lymphoma, the EMRR associated with being First Nations varied over time since diagnosis. Within the first year, First Nations had an EMRR of 1.78 (95% CI, 1.18–2.69); however, by 5 years post-diagnosis, there was no excess risk associated with being a First Nation person (Table 3). Apart from the exceptional cases listed above, EMRRs for cancers with a significant association between being First Nations and survival ranged from 1.25 (95% CI, 1.14–1.37) for lung and bronchial cancers to 1.90 (95% CI, 1.52–2.39) for breast cancer.

Adjusting for income and rurality (Model B) tended to dampen the association between First Nation ethnicity and survival. For most cancers, the rate ratio reduced by between 15% and 20% after taking income and rurality into account.

Sex- and ethnicity-specific 5-year age-standardized relative survival rates for cancers diagnosed between 2001 and 2009 are presented in Table 4. The largest absolute differences in survival rates between First Nations and non-Aboriginals were for cervical and ovarian cancers, where 5-year relative survival was at least 20 percentage points higher among non-Aboriginals. For colorectal cancer, breast cancer, non-Hodgkin lymphoma, and leukemia, deficits in survival for First Nations were between 10 and 20 percentage points.

**Table 2.** Number of cases and excess mortality rate ratios (EMRR) and their 95% confidence intervals (CI) for 5-year survival for First Nations and non-Aboriginal persons<sup>a,b</sup>

Site	Non-Aboriginals n (%)	First Nations n (%)	Model A <sup>c</sup> EMRR (95% CI)	Model B <sup>d</sup> EMRR (95% CI)
Colorectal	31,220 (16.7)	670 (20.3)		See Table 3
Lung & Bronchus	33,145 (17.7)	605 (18.4)	<b>1.25</b> (1.14–1.37)	<b>1.20</b> (1.09–1.31)
Breast	29,265 (15.6)	580 (17.6)	<b>1.90</b> (1.52–2.39)	<b>1.55</b> (1.23–1.95)
Prostate	41,820 (22.3)	455 (13.8)		See Table 3
Kidney	5,990 (3.2)	215 (6.5)	1.16 (0.89–1.51)	1.07 (0.82–1.41)
NHL	9,175 (4.9)	130 (3.9)		See Table 3
Stomach	4,900 (2.6)	95 (2.9)	1.18 (0.93–1.49)	1.13 (0.89–1.44)
Oral cavity & pharynx	5,040 (2.7)	85 (2.6)	<b>1.54</b> (1.10–2.18)	<b>1.54</b> (1.10–2.18)
Cervix	1,185 (0.6)	80 (2.4)	<b>1.63</b> (1.13–2.35)	<b>1.47</b> (1.01–2.14)
Corpus uteri	6,460 (3.4)	75 (2.3)	1.22 (0.57–2.61)	1.04 (0.48–2.24)
Pancreas	5,345 (2.9)	70 (2.1)	1.07 (0.83–1.39)	1.06 (0.82–1.37)
Ovary	3,380 (1.8)	65 (2.0)	<b>1.56</b> (1.11–2.21)	<b>1.56</b> (1.10–2.22)
Multiple myeloma	3,010 (1.6)	60 (1.8)	1.00 (0.68–1.47)	0.92 (0.63–1.35)
Leukemia	5,910 (3.2)	55 (1.7)	<b>1.70</b> (1.18–2.46)	<b>1.57</b> (1.09–2.28)
Liver	1,630 (0.9)	55 (1.7)	1.28 (0.92–1.77)	1.28 (0.92–1.77)

NOTE: Boldface text indicates a statistically significant result.

Abbreviation: NHL: non-Hodgkin lymphoma.

<sup>a</sup>According to Statistics Canada protocols, the counts in this table, including totals, are randomly rounded either up or down to a multiple of 5. When these data are summed or grouped, the total value may not match the individual values since totals and subtotals are independently rounded. Similarly, percentages, which are calculated on rounded data, may not necessarily add up to 100%.

<sup>b</sup>Cases aged 45 to 90 at diagnosis, diagnosed between January 1, 1992, and December 31, 2009, excluding Quebec.

<sup>c</sup>Model A: Adjusted for age, sex (if applicable), time period.

<sup>d</sup>Model B: Adjusted for age, sex (if applicable), time period, area-level income quintile, rurality.

**Table 3.** Excess mortality rate ratio (EMRR) and 95% confidence interval (CI) for cancers where the EMRR for First Nations was not constant across decades of diagnosis (colorectal and prostate) or time since diagnosis (non-Hodgkin lymphoma)<sup>a</sup>

Site	Model A <sup>b</sup>	Model B <sup>c</sup>	Model A <sup>b</sup>	Model B <sup>c</sup>
	EMRR (95% CI)	EMRR (95% CI)	EMRR (95% CI)	EMRR (95% CI)
	1992–2000		2001–2009	
Colorectal	1.05 (0.83–1.32)	0.95 (0.75–1.20)	<b>1.52</b> (1.28–1.80)	<b>1.38</b> (1.16–1.65)
Prostate	<b>2.76</b> (1.81–4.21)	<b>1.76</b> (1.14–2.73)	1.54 (0.62–3.84)	0.93 (0.42–2.08)
	1 year post-diagnosis		5 years post-diagnosis	
Non-Hodgkin lymphoma	<b>1.78</b> (1.18–2.69)	<b>1.64</b> (1.09–2.48)	0.47 (0.09–2.40)	0.41 (0.07–2.30)

NOTE: Boldface text indicates a statistically significant result.

<sup>a</sup>Cases aged 45 to 90 at diagnosis, diagnosed between January 1, 1992, and December 31, 2009, excluding Quebec.<sup>b</sup>Model A: Adjusted for age, sex (if applicable), and time period for non-Hodgkin lymphoma only.<sup>c</sup>Model B: Adjusted for age, sex (if applicable), area-level income quintile, rurality, and time period for non-Hodgkin lymphoma only.

## Discussion

For all 15 cancers examined, First Nation adults had equal or poorer cancer survival than their non-Aboriginal peers. The largest relative differences in survival were for prostate and breast cancers. Controlling for income and rurality explained little of the disparities between the populations. In this section, we place our results in the context of other studies of indigenous cancer survival, consider reasons for the disparities we have reported, and highlight strengths and limitations that should be considered while interpreting the results.

We are aware of two contemporaneous studies in Canada measuring differences in cancer survival between First Nation people and their non-Aboriginal peers. A small study of 19 oral cavity squamous cell carcinomas diagnosed among First Nations in Alberta between 1998 and 2009 found that First Nations had significantly poorer survival than their non-First Nation peers (27). A much larger study included just fewer than 4,000 cancers diagnosed in First Nations between 1968 and 2001 in Ontario. It found significantly poorer survival among First Nation people for colorectal, breast, prostate, cervical, and lung cancers (the lung cancer disparity was only significant in males; ref. 28). The findings of both these studies are consistent with what we found Canada-wide, with the exception of the lung cancer disparity, which in the current study was consistent across sexes.

Reasons for the disparities reported here are multifactorial and originate at the tumor, patient, and health care system levels. At the tumor level, differences in stage, tumor size, anatomic site,

grade, and hormonal status may all contribute to differences in survival (29). These are mediators of disparity to the extent that differences in these factors may represent differential exposures and/or access to timely diagnosis.

Stage at diagnosis has been cited as one of the most important explanatory factors for ethnic disparities in cancer survival (30–32). Studies of stage distribution among Aboriginal people in Canada are limited and have shown mixed results. In Manitoba, First Nation ethnicity was not associated with stage at colorectal cancer diagnosis (33). In studies from Manitoba and Ontario, however, First Nation women were more likely than non-First Nations to be diagnosed with breast cancer at a later stage (33, 34). In Ontario, differences in survival between First Nations and non-First Nations were only present among women diagnosed with stage I breast cancer (35). Internationally, stage has only been found to account for a portion of the survival disparity between indigenous and non-indigenous persons, and stage-specific ethnic disparities persist (36–38).

At the patient level, psychosocial factors including social support, stigma, and the associated delay in seeking care have been shown to be associated with socioeconomic disparities in cancer survival (29), but the effects of these on survival disparities have not to our knowledge been quantified for indigenous populations (39, 40).

The prevalence of comorbidities, quality of nutrition, and other aspects of general health (smoking, physical activity etc.) are other

**Table 4.** Age-standardized 5-year relative survival and 95% confidence intervals (CI) by sex, cancer site, and ethnicity

Site	Females		Males	
	Non-Aboriginals 5-year survival (95% CI)	First Nations 5-year survival (95% CI)	Non-Aboriginals 5-year survival (95% CI)	First Nations 5-year survival (95% CI)
Colorectal	62.6% (61.2–64.0)	50.2% (44.8–56.4)	64.1% (62.9–65.4)	50.3% (44.8–56.6)
Lung & bronchus	20.1% (19.1–21.1)	13.3% (10.5–16.9)	12.8% (12.1–13.6)	8.3% (6.20–11.1)
Prostate	—	—	93.2% (92.5–93.9)	90.6% (84.6–97.1)
Breast	87.0% (86.0–88.0)	75.3% (68.8–82.4)	—	—
Kidney	66.4% (63.1–69.8)	68.5% (58.3–80.6)	62.7% (60.1–65.4)	57.4% (48.8–67.4)
NHL	64.7% (62.4–67.1)	54.0% (41.8–69.6)	60.1% (57.9–62.4)	49.0% (35.9–66.9)
Stomach	25.6% (22.0–29.7)	19.0% (11.8–30.5)	22.0% (19.6–24.7)	16.0% (9.0–28.4)
Oral cavity & pharynx	61.3% (56.9–66.1)	50.4% (35.6–71.3)	53.6% (50.6–56.7)	37.8% (24.9–57.5)
Cervix	62.2% (57.0–67.8)	39.5% (24.3–64.3)	—	—
Corpus uteri	83.9% (82.2–85.6)	77.5% (62.3–96.3)	—	—
Pancreas	4.8% (3.6–6.5)	4.9% (1.8–13.4)	4.7% (3.6–6.3)	4.4% (1.5–12.8)
Ovary	36.1% (33.3–39.1)	15.2% (7.9–29.4)	—	—
Multiple myeloma	34.6% (30.7–39.0)	36.4% (21.9–60.3)	34.3% (30.8–38.2)	36.0% (21.9–59.1)
Leukemia	56.4% (54.3–58.7)	38.5% (24.9–59.6)	58.5% (56.3–60.7)	39.0% (25.6–59.3)
Liver	13.5% (10.8–16.8)	10.9% (4.7–25.4)	14.5% (11.8–17.9)	10.8% (4.50–25.8)

NOTE: Cases aged 45 to 90 at diagnosis, diagnosed between January 1, 2001, and December 31, 2009, excluding Quebec. Age-standardized to International Cancer Survival Standards.

Abbreviation: NHL, non-Hodgkin lymphoma.

patient level factors that are likely to mediate the association between ethnicity and survival. Comorbidities may prevent patients from being candidates for certain treatment modalities or make them less able to withstand treatment that is received. Comorbidities have been found to explain indigenous disparities in survival at least as much as treatment (34, 35, 41, 42).

Health care system-level factors include treatment and screening. Treatment-related disparities in survival between indigenous and non-indigenous people have been reported in the United States, Australia, and New Zealand (38, 41–47). These studies have reported that indigenous patients are less likely to undergo definitive surgery, and in some cases radiotherapy and chemotherapy (36, 37, 41, 42, 47, 48). Some of these differences in treatment have been attributed to poor communication between service providers and indigenous patients (49). Among Ontario breast cancer patients, however, the proportion of patients receiving appropriate treatment for age and stage did not differ between First Nations and non-Aboriginals (34, 35).

Surveys and linkage studies measuring the uptake of breast, cervical, and colorectal cancer screening among First Nations have had mixed findings (50–54). Screening could result in true differences in survival but may also exaggerate differences in survival between two populations with different screening uptake as a result of lead-time. In recent decades, prostate cancer was often diagnosed through prostate-specific antigen (PSA) "screening" and resulted in the detection of cancers that may never have presented symptomatically. From 1991 to 2001, mortality from prostate cancer among Registered First Nations within this cohort was comparable with that in the general population despite the much poorer survival, suggesting that over-detection of latent disease through higher uptake of PSA tests among non-Aboriginals could explain, at least in part, the exceptionally large survival disparity (4, 55, 56).

Increasing the uptake of screening among First Nations to meet guideline levels may improve survival and decrease cancer mortality for screen-detectable cancers. Detection of other cancers, however, will often occur through primary health care encounters and subsequent referral to specialized services (57). Each step along this cancer care continuum is an opportunity for inequalities in survival to be initiated or widened.

In summary, the disparities in cancer survival measured in this study are likely a result of differences in tumor, patient, and health care-level factors occurring across the cancer continuum. Evidence from international literature suggests that screening, stage at diagnosis, the prevalence of comorbidities, and differential treatment are interrelated and important contributors to the disparity.

### Strengths and limitations

This study makes a novel contribution to the literature. It is the first multi-province/territory study to estimate cancer survival among First Nations in Canada. The census-based cohort was sufficiently large and had sufficient follow-up to report cancer survival for 15 different cancers among First Nations, making it the first time cancer survival has been estimated among First Nations for nine of these cancers.

We took advantage of the population-based cohort to produce life tables specific to the First Nations using the same identifiers that identified First Nation cancer cases, thereby avoiding numerator-denominator bias (21, 22). This is the first North

American study we are aware in over 30 years to have estimated relative survival for an indigenous-population with indigenous-specific life tables. Using these life tables allows us to take differences in background mortality into account.

Having the census as the foundation of the study has other advantages. We were able to consider the role of rurality and individual-level income on the disparities in survival that we measured. Further, using the census allowed us to identify First Nations according to self-report. This is preferable to ethnic identifiers derived from the medical record that have been shown in the United States to markedly underestimate the number of American Indians and Alaskan Natives (58–62). Self-report tends also to be superior to geographic identifiers, which suffer from a trade-off between sensitivity and specificity, either by restricting the scope to people who live in areas densely populated with Aboriginal people (i.e., reserves) or by using a broader definition and including non-Aboriginal cases (63).

Some potential limitations to generalizability should be discussed. First, inconsistencies in registration methods between Quebec and the other Canadian provinces and territories necessitated the exclusion of Quebec from our analyses. As a result, findings from this work may not be generalizable to the Quebec population. Quebec is Canada's second largest province and home to just under 10% of the national First Nation population (2).

The representativeness of the cohort at large to the population of Canada has been discussed elsewhere and is overall considered to be good. The cohort does have an over-representation of people who are married, of higher income and/or education (10, 11). Because relative survival was used, however, and the expected mortality came from the same population from which the cancer cases were drawn, we do not expect the EMRRs from the cohort to vary significantly from those that would have been estimated based on the population at large. The mortality of cohort members is very similar to that of the Canadian Population as a whole (12).

Demographically, Registered First Nations who were eligible for the cohort (i.e., responders to the census) did not differ from those finally included in the cohort. Registered First Nations living in communities of less than 10,000 people, however, are over-represented in the cohort compared with their true share of the population because all residents of participating reserves and remote communities were administered the long-form census, rather than the one in five households that were administered the long form elsewhere (64). In exploratory analyses stratified by residence on reserve, EMRRs were similar for First Nations living on- and off-reserve suggesting that this over-representation had little impact on the results overall. There were too few cases to formally assess and report differences in survival and survival disparities between those residing on- and off-reserve and this is a limitation of the work.

With respect to completeness of the source files, we believe the Canadian Cancer Registry (CCR) to have high case ascertainment since each province and territory has a mandated responsibility for collection and reporting of cancers. Death ascertainment in the Canadian Mortality Database is, according to Statistics Canada, "virtually complete" with very few exceptions (65). By also including deaths reported in tax filings and in the Canadian Cancer Registry, death ascertainment is even higher.

With respect to the linkage, based on comparable cancer incidence patterns in the cohort at large to the general Canadian

population, linkage to the CCR appears to have been successful. Given that there are no gold standard incidence rates for First Nations, it is impossible to determine whether this was differential by ethnicity (12). If linkage to cancer records was differential by ethnicity, however, bias would only arise if linkage was also associated with cancer survival and we see no mechanism through which such a bias could arise.

As mentioned earlier, an important limitation is that while the registries currently collect information on stage at diagnosis, a key prognostic indicator, this was not the case in all provinces historically and accordingly, we were unable to explore the role of stage in the survival disparities we observed.

## Conclusions

This study demonstrated that the survival rates for the majority of cancers studied were worse for First Nation adults compared with their non-Aboriginal peers. Just as determinants of survival disparities exist at the tumor, patient, and health care levels, so must the interventions to reduce them. Across this spectrum, data and evidence for how disparities in cancer survival between First Nation and non-Aboriginal persons in Canada are initiated and sustained are sparse. Going forward research and surveillance activities that will help elucidate the best path to a reduced cancer burden are needed.

In the face of cancer incidence rates among First Nations that are rising more steeply than the general population, improving survival to match that in the general population is necessary to

reduce the burden of cancer in these populations (33, 66). The findings presented here serve as a benchmark for monitoring progress toward that end.

## Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

## Authors' Contributions

**Conception and design:** D.R. Withrow, J.D. Pole, L.D. Marrett

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**Acquisition of data (provided animals, acquired and managed patients, provided facilities, etc.):** L.D. Marrett

**Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis):** D.R. Withrow, J.D. Pole, E.D. Nishri, L.D. Marrett

**Writing, review, and/or revision of the manuscript:** D.R. Withrow, J.D. Pole, E. D. Nishri, M. Tjepkema, L.D. Marrett

**Administrative, technical, or material support (i.e., reporting or organizing data, constructing databases):** M. Tjepkema

**Study supervision:** J.D. Pole, L.D. Marrett

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