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EPIDEMIOLOGY

Analysis of incidence, mortality trends, and geographic distribution of breast cancer patients in Canada

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Abstract

Background/purpose Breast cancer is the malignancy with the highest incidence rate excluding non-melanoma skin cancers, and the second leading cause of cancer-related deaths among Canadian women. Many modifiable risk factors have been linked to the pathogenesis of this disease. The purpose of this study is to analyze the epidemiology of breast cancer in Canada and to examine its geographic distribution to help identify new risk factors for this disease.

Methods Three independent population-based cancer registries were used to retrospectively analyze demographic data from Canadian women diagnosed with invasive breast cancer across all provinces and territories between 1992 and 2010. The incidence and mortality rates were assessed at the provincial, city, and forward sortation area (FSA) postal code levels.

Results The overall age-adjusted incidence rate was 114.4 cases per 100,000 females per year. Six provinces and several groups of FSAs had significantly higher incidence rates. There was a significant increase in incidence and decrease in mortality rates between 1992 and 2010. The overall mortality rate was 31.5 deaths per 100,000 females per year. However, three provinces had significantly higher mortality rates.

Conclusion By identifying high-incidence areas for breast cancer, our study will help identify patient populations that are at higher risk for this malignancy. It will also act as a foundation for future studies to establish novel risk factors for this disease.

Keywords Cancer · Breast · Epidemiology · Incidence · Mortality · Environmental risk factors

Introduction

Breast cancer is the malignancy with the highest incidence rate -excluding non-melanoma skin cancers- and the second leading cause of cancer-related deaths among Canadian women [1]. In fact, breast cancer represented 25% of all new cancer cases in 2017 and 13% of cancer-related deaths in Canadian women during the same time period [1]. It has been estimated that 1 in 8 Canadian women will develop breast cancer throughout their lifetime [1]. The temporal trends for breast cancer show that Canadian incidence rates increased between 1969 and 1999, decreased in the early 2000s, and have stabilized since 2004 [1, 2]. Moreover, the overall Canadian mortality rates show a 25% decline since the mid 1980s [1, 2].

There are many established modifiable risk factors for developing breast cancer, including increased age at first full-term pregnancy, low parity, increased body mass index, active and passive smoking, alcohol consumption, use of hormone therapies (estrogen and progesterone), exposure to ionizing radiation, and physical inactivity [3–14]. In fact, it has been estimated that 25–33% of breast cancers are attributable to modifiable risk factors [15, 16]. In addition, migration studies show that women who move from low-incidence countries to high-incidence countries develop similar breast

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cancer incidence rates as the women from high-incidence countries [17]. This further suggests that lifestyle and environmental risk factors may play an important role in the pathogenesis of this disease. An extensive list of modifiable and non-modifiable risk factors are summarized in Supplementary Table 1 [6, 7, 10–12, 14, 16, 18–20].

This study was conducted to help identify areas of geographic clustering for this malignancy. The identification of these geographic clusters may help determine the relevant risk factors for Canada. To our knowledge, no research has attempted to map the incidence and mortality rates of breast cancer at the municipal and forward sortation area (FSA) postal code levels in Canada.

Methods

This study was conducted in accordance with the CISS-RDC-668035 protocol approved by the Social Sciences and Humanities Research Council of Canada (SSHRC) as well as the 13-SSH-MCG-3749-S001 protocol approved by the Quebec Inter-University Centre for Social Statistics (QICSS). Furthermore, the Research Ethics Board Review of McGill University exempted this project in accordance with their policy.

Data collection

Data on incidence and mortality rates of invasive breast cancer in Canada between 1992 and 2010 were collected from three different population-based cancer registries. The Canadian Cancer Registry (CCR) and Le Registre Québécois du Cancer (LRQC) databases were used to collect data on incidence, as previously reported [21–32]. Only invasive breast cancers were included in the analysis since benign tumors are not recorded in these registries. The CCR provides information on Canadian residents from all provinces and territories outside of Quebec with a primary malignant tumor diagnosis between 1992 and 2015. For Quebec, the LRQC provides information on residents with a primary malignant tumor diagnosis between 1992 and 2010. These databases provide demographic information including: the patient's sex, year of diagnosis, age at the time of diagnosis, forward sortation area (FSA; first 3 entries of postal code—smallest geographical unit that is permitted for analysis as per SSHRC/QICSS regulations), city, and province of residence, laterality of the malignancy, as well as the ICD-O-3 code of the neoplasm. For consistency purposes, we chose to analyze incidence rates from 1992 to 2010 given that the data from the LRQC were only available until 2010. The Canadian Vital Statistics (CVS) database was used to collect the mortality data. This database provided demographic information on patients including: sex, year deceased, age at the time of death, FSA of residence, and the International Statistical Classification of Diseases and Related Health Problems (cause-of-death) code for the malignancy. To be consistent with the breast cancer incidence data, we analyzed mortality rates from 1992 to 2010. This study only included invasive cancers since the databases did not include data on in situ cancers.

The codes for the tumor's primary site (topography) were used to collect incidence data from the CCR and LRQC (C50.0 denoting a malignant neoplasm of the nipple, C50.1 for a malignant neoplasm of the central portion of breast, C50.2 for a malignant neoplasm of the upper-inner quadrant of breast, C50.3 for a malignant neoplasm of the lower-inner quadrant of breast, C50.4 for a malignant neoplasm of the upper-outer quadrant of breast, C50.5 for a malignant neoplasm of the lower-outer quadrant of breast, C50.6 for a malignant neoplasm of the axillary tail of breast, C50.8 for malignant neoplasm of breast with overlapping lesion of breast, and C50.9 for malignant neoplasm of the breast NOS). The International Classification of Diseases for Oncology ICD-O-3 codes for all breast cancer subtypes were also used. The ICD-O-3 codes and breast cancer subtypes that were included in the analysis are listed in Table 1. The International Statistical Classification of Diseases and Related Health Problems, ninth revision (ICD-9) was used to assess mortality by breast cancer between the years 1992 and 1999. The corresponding tenth revision (ICD-10) was used for deaths by breast cancer between the years 2000 and 2010. Population counts for the country, provinces, cities, and forward sortation areas (FSAs) were used to calculate incidence and mortality rates. These counts were obtained from Statistics Canada's Census of Population for 1996, 2001, 2006, and 2011. Cities and FSAs that had a female population < 5000 were not included in the analysis to avoid artificially inflated incidence and mortality rates.

Data on visible minorities and socioeconomic status (SES) were obtained from the Canadian Census of Population from 2001 and 2006 for each FSA. The median household income was used to represent SES. Each FSA was categorized into a quintile based on its average median income. The FSAs with the lowest SES were in the first quintile ($Q1_{SES}$) and the FSAs with the highest SES were in the fifth ($Q5_{SES}$). FSAs were categorized in a similar way based on the percentage of its population that is not a visible minority (i.e., Caucasian). FSAs with the lowest percentage of Caucasian individuals were in the first quintile ($Q1_{\%Caucasian}$) and FSAs with the highest percentage of Caucasian individuals were placed in the fifth quintile ($Q5_{\%Caucasian}$). Quintiles were compared using incidence rate ratios (IRR) and their corresponding 95% confidence intervals (95% CI).

Table 1 List of malignancies included in this study along with their corresponding ICD-O-3 codes, the number of cases reported in Canada between the years 1992 and 2010, and the mean age at the time of diagnosis

ICD-O3 code	Neoplasm	Number of cases[a]	% of total	Mean age at diagnosis (95% CI)
8200	Adenoid cystic carcinoma	235	0.1	60.53 (58.95–62.11)
	Bronchial adenoma, cylindroid			
8201	Cribriform carcinoma NOS	705	0.2	61.54 (60.52–62.56)
8211	Tubular adenocarcinoma	3760	1.1	60.13 (59.77–60.50)
8246	Neuroendocrine carcinoma NOS	150	0.0	66.19 (64.01–68.38)
8401	Apocrine adenocarcinoma	475	0.1	63.52 (62.24–64.81)
8480	Mucinous adenocarcinoma	5900	1.8	68.40 (68.04–68.75)
	Pseudomyxoma peritonei with unknown primary site			
8500	Invading ductal carcinoma NOS	248,965	74.9	60.54 (60.49–60.60)
8501	Comedocarcinoma, NOS	3610	1.1	56.62 (56.19–57.04)
8503	Intraductal papillary adenocarcinoma with invasion	1300	0.4	65.05 (64.27–65.83)
	invasive papillary carcinoma			
8504	Noninfiltrating intracystic carcinoma (2)	505	0.2	68.25 (67.13–69.36)
8507	Invasive micropapillary carcinoma	425	0.1	60.92 (59.59–62.26)
8510	Medullary carcinoma NOS	675	0.2	53.52 (52.46–54.57)
	Medullary adenocarcinoma			
8520	Lobular carcinoma	27,670	8.3	64.16 (64.00–64.31)
8521	Infiltrating ductal carcinoma	7785	2.3	60.48 (60.18–60.78)
8522	Infiltrating duct and lobular carcinoma	17,050	5.1	61.36 (61.16–61.56)
8523	Infiltrating duct mixed with other types of carcinoma	6200	1.9	62.41 (62.07–62.76)
8524	Infiltrating lobular mixed with other types of carcinoma	790	0.2	63.97 (63.08–64.86)
8530	Inflammatory carcinoma	2335	0.7	56.81 (56.25–57.38)
8540	Paget disease, mammary	640	0.2	66.18 (65.04–67.33)
8541	Paget disease and infiltrating duct carcinoma of breast	1525	0.5	62.59 (61.83–63.36)
8543	Paget disease and intraductal carcinoma of breast	1030	0.3	63.62 (62.74–64.49)
8550	Acinar cell carcinoma	30	0.0	60.44 (55.25–65.63)
8560	Adenosquamous carcinoma	130	0.0	62.33 (60.03–64.64)
8572	Adenocarcinoma with spindle cell metaplasia	30	0.0	64.14 (58.47–69.80)
8575	Metaplastic carcinoma NOS	665	0.2	61.66 (60.53–62.80)
	Mixed epithelial/mesenchymal metaplastic carcinoma			
–	Total	332,585	100.0	61.05 (61.00–61.10)

The same ICD-O3 code can be used to represent more than one breast cancer subtype

[a]Number of cases was rounded to a multiple of 5 as per SSHRC regulations

Mandatory data rounding

A number of confidentiality rules must be respected before the publication of the data obtained from the CCR, LQRC, and CVS registries. For this reason, researchers working at the SSHRC and Statistics Canada are required to round each frequency count to a multiple of 5 (lower or higher) via a random rounding scheme. In addition, as per the SSHRC rules, frequency counts cannot be released if they are ≥ 1 and ≤ 5 to protect patient confidentiality. However, we were able to search for communities, where zero cases/deaths were documented.

Data analysis

This study analyzed the complete data on all breast cancer cases in Canada from 1992 to 2010. Incidence and mortality rates as well as their 95% confidence intervals were calculated and are presented per 100,000 females per year. They are reported by age group, by year of diagnosis, and by specific region (province, city, FSA). Exact Poisson distributions were used to calculate the 95% confidence intervals. Regression models were used to assess trends over time. The ArcMap software was used for geographic

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analysis. Incidence and mortality rates were mapped by province, city, and FSA.

Results

Demographic characteristics of patients diagnosed with breast cancer in Canada between 1992 and 2010

Approximately 332,590 Canadian women were diagnosed with one of the subtypes of invasive breast cancer listed in Table 1 between the years 1992 and 2010. Cases predominantly represented invading ductal carcinoma NOS (75%), followed by lobular carcinoma (8%), and infiltrating ductal and lobular carcinoma (5%). Details on the tumors primary site are presented in Supplementary Table 2. There were no reported cases of ductal carcinoma in situ or lobar carcinoma in situ, since the databases only provided information on invasive breast cancers. Between 1992 and 2010, there were 1395 cases (< 1%) of breast cancer in patients ≤ 29 years of age; 16,050 cases (5%) in patients between ages 30 and 39; 139,015 cases (42%) in patients between ages 40 and 59; 141,380 cases (43%) in patients between age 61 and 79; and 34,750 cases (10%) in women ≥ 80 years of age (Table 2). The average age at diagnosis was 61.051 (95% CI 61.0038–61.10).

Incidence of breast cancer cases in Canada between 1992 and 2010 and their geographic distribution

The national age-adjusted incidence rate of all cases from 1992 to 2010 was 114.41 cases per 100,000 women per year (95% CI 114.022–114.79). The annual incidence rates for 1992 to 2010 years are displayed in Fig. 1a. There was an overall increase in breast cancer incidence with an annual increase of 1.57 ± 0.11 cases per 100,000 females between 1992 and 2010 (coefficient of determination [R^2] = 0.93; $p < 0.0001$). If the incidence rate for 1992 persisted for the period 1992–2010, there would be 4810 fewer cases of

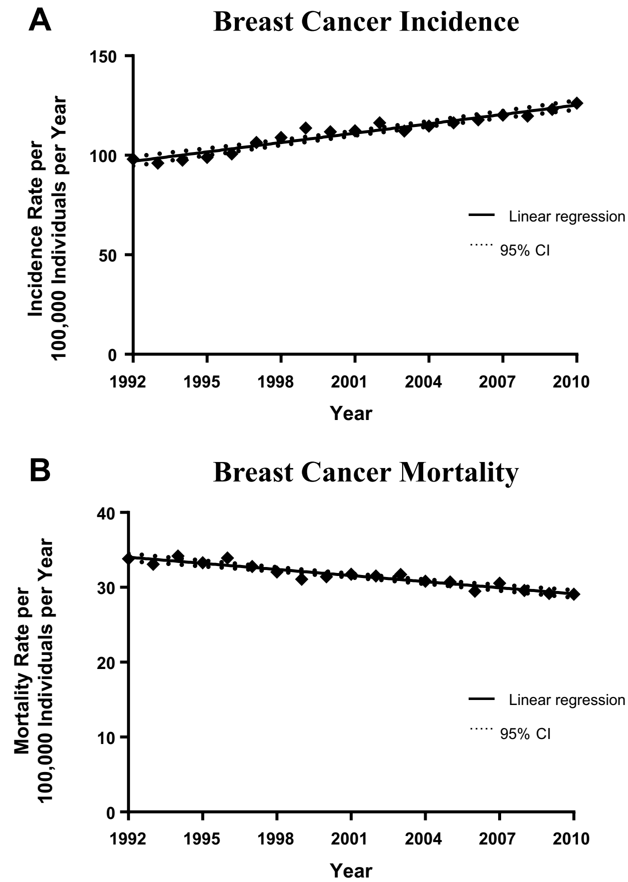

Fig. 1 Age-standardized incidence and mortality rates (cases per 100,000 females per year) for all cases of breast cancer between 1992 and 2010 with the line of best fit, and linear regression analysis of the incidence rate over time. **a** Incidence trends (coefficient of determination [R^2] = 0.93; $p < 0.0001$; CI = confidence intervals). The slope of the line was 1.57 ± 0.11 cases per 100,000 females per year. The average age-standardized incidence rate of this malignancy in Canada from 1992 to 2010 was 114.41 cases per 100,000 females per year. **b** Mortality trends [R^2] = 0.89; $p < 0.0001$. The slope of the line was − 0.27 ± 0.023 cases per 100,000 females per year. The average age-standardized mortality rate of this malignancy in Canada from 1992 to 2010 was 31.58 deaths per 100,000 females per year

Table 2 Breast cancer incidence rates by age group for the years 1992–2010

Age group	Number of cases[a]	Female population (rounded to 1000)	Incidence per 100,000 women (95% CI)
0–29	1395	5829,000	1.26 (1.19–1.33)
30–39	16,050	2,312,000	36.54 (35.97–37.11)
40–59	139,015	4,347,000	168.32 (167.44–169.21)
60–79	141,380	2,264,000	328.63 (326.92–330.34)
> 80	34,750	614,000	297.96 (294.83–301.11)

Age-adjusted incidence rates are expressed per 100,000 women per year

[a]Number of cases was rounded to a multiple of 5 as per SSHRC/Statistics Canada regulations

breast cancer in 2010 (22% decrease). Interestingly, these trends differ when examining ductal and lobular breast cancers separately. For ductal breast cancer, there was also an overall significant increase with an annual increase of 0.88 ± 0.11 cases per 100,000 women per year (coefficient of determination [R^2] = 0.79; $p < 0.0001$) and an average incidence rate of 93.97 cases per 100,000 women per year in Canada from 1992 to 2010 (Fig. 2a). On the other hand, for lobular breast cancer, there was an annual decrease of 0.27 ± 0.023 cases per 100,000 women per year (coefficient of determination [R^2] = 0.89; $p < 0.0001$) and an average overall incidence rate of 31.58 cases per 100,000 women per year (Fig. 2b).

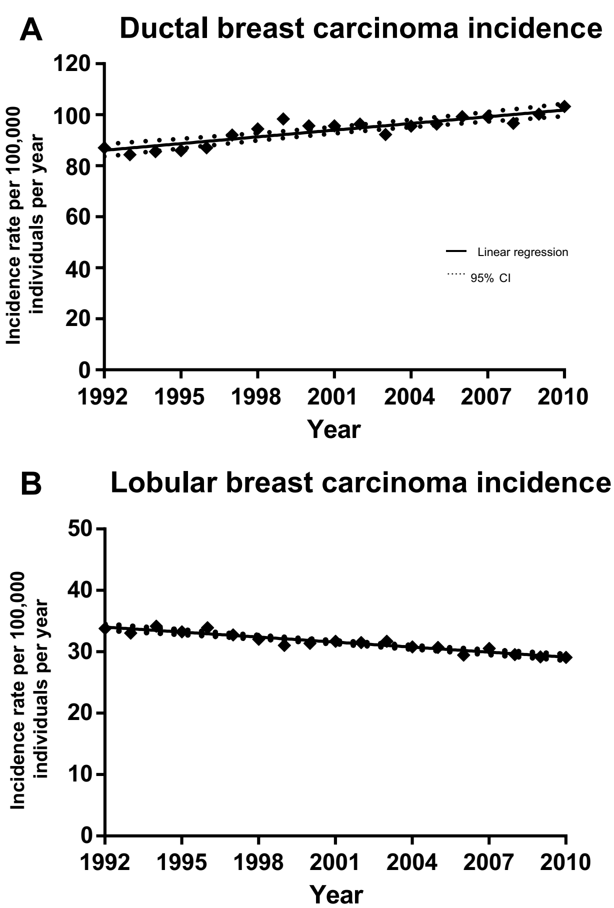

Fig. 2 Incidence rates (cases per 100,000 women per year) of all cases of ductal and lobular breast cancer between 1992 and 2010. The figure includes the line of best fit, and linear regression analysis of the incidence rate over time. **a** Ductal breast cancer incidence rates between 1992 and 2010 (coefficient of determination [R^2] = 0.79; $p < 0.0001$; CI = confidence intervals). The slope of the line was 0.88 ± 0.11 cases per 100,000 women per year. The average incidence rate of this malignancy in Canada from 1992 to 2010 was 93.97 cases per 100,000 women per year. **b** Lobular breast cancer incidence rates between 1992 and 2010 (coefficient of determination [R^2] = 0.89; $p < 0.0001$; CI = confidence intervals). The slope of the line was − 0.27 ± 0.023 cases per 100,000 women per year. The average incidence rate of this malignancy in Canada from 1992 to 2010 was 31.58 cases per 100,000 women per year

Six provinces had statistically significantly higher incidence rates than the national average: Nova Scotia (123.67; 95% CI 121.39–125.99), New Brunswick (119.29; 95% CI 116.78–121.84), Prince Edward Island (118.42; 95% CI 112.64–124.42), Manitoba (118.20; 95% CI 116.18–120.24), British Columbia (115.96; 95% CI 114.88–117.034), and Quebec (115.57; 95% CI 114.78–116.36) (Table 3, Supplementary Fig. 1A). Six provinces and territories had statistically significantly lower incidence rates than the national average: Ontario (109.12; 95% CI 108.51–109.73), Alberta (101.031; 95% CI 99.88–102.19), Newfoundland and Labrador (100.59; 95% CI 97.86–103.37), Yukon (87.72; 95% CI 77.18–99.29), Northwest Territories (68.42; 95% CI 60.36–77.26), and Nunavut (24.29; 95% CI 18.54–31.27) (Table 3). Additional incidence analyses were conducted at the city and FSA postal code levels (Supplementary Tables 3–6 and Supplementary Figs. 2–4).

The average age of residents in the high-incidence FSAs was 42.55, whereas it was 35.65 in the low-incidence FSAs. This difference was statistically significant ($p < 0.001$). In addition, there was an average of 2.79 nursing care facilities and 3.17 continuing care retirement centers per high-incidence FSA, and an average of 1.92 nursing care facilities and 2.081 continuing care retirement centers per low-incidence FSAs. These differences were significant with both p values < 0.001. Hence, the geographic differences in breast cancer incidence could be in part explained by older women, who might be relocating to these FSAs due to the availability of retirement and nursing care facilities.

There was a significant positive relationship between the provincial incidence rates and the percentage of the population that is above the age of 65 ($R^2 = 0.63$, $p = 0.0064$). However, there was no significant relationships between the provincial incidence rates and the percentage of the population that smokes ($R^2 = 0.065$, $p = 0.48$) or with obesity prevalence ($R = 0.14$, $p = 0.28$). There was an association between incidence rates of breast cancer by FSA and socioeconomic status (SES) quintiles, as well as between breast cancer incidence rates by FSA and ethnicity. Incidence rates for this malignancy were significantly lower in the highest SES quintile compared to the lowest quintile ($IRR_{SES\ Q5\ vs.\ Q1} = 0.91$; 95% CI 0.90–0.91). However, incidence rates were significantly higher in the second ($IRR_{SES\ Q4\ vs.\ Q1} = 1.038$; 95% CI 1.026–1.050) and third highest SES quintile $IRR_{SES\ Q3\ vs.\ Q1} = 1.11$; 95% CI 1.094–1.12) compared to the lowest quintile. Additionally, our data demonstrated that breast cancer incidence was significantly higher in the quintiles with the highest percentage of Caucasian individuals compared to the quintile with the lowest percentage of Caucasian individuals ($IRR_{\%Caucasian\ Q5\ vs.\ Q1} = 1.25$, 95% CI 1.24–1.26).

Table 3 Overall breast cancer incidence rates by province between 1992 and 2010

Province/Territory	Number of cases[a]	Female Population (rounded to 1000)	Incidence per 100,000 women (95% CI)
Nova Scotia	11,185	476,000	123.67 (121.39–125.99)
New Brunswick	8,590	379,000	119.29 (116.78–121.84)
Prince Edward Island	1575	70,000	118.42 (112.64–124.42)
Manitoba	13,115	584,000	118.20 (116.18–120.24)
British Columbia	44,790	2,033,000	115.96 (114.88–117.03)
Quebec	82,780	3,770,000	115.57 (114.78–116.36)
Saskatchewan	10,635	508,000	110.18 (108.10–112.30)
Ontario	124,705	6,015,000	109.12 (108.51–109.72)
Alberta	29,485	1,536,000	101.03 (99.88–102.19)
Newfoundland and Labrador	5160	270,000	100.58 (97.86–103.37)
Yukon	250	15,000	87.72 (77.18–99.29)
Northwest Territories	260	20,000	68.42 (60.36–77.26)
Nunavut	60	13,000	24.29 (18.54–31.27)

Incidence rates are expressed per 100,000 women per year

[a]Number of cases was rounded to a multiple of 5 as per SSHRC/Statistics Canada regulations

Mortality rates and geographical distribution of deaths for breast cancer in Canada between 1992 and 2010

In total, approximately 93,890 Canadian women died from breast cancer between 1992 and 2010. The overall national age-standardized mortality rate was 31.50 (95% CI 31.30–31.70) deaths per 100,000 women per year and the average age at the time of death was 67.19 (95% CI 67.050–67.33). All age-standardized mortality rates per 100,000 women by age group are presented in Table 4. The annual mortality rates for 1992–2010 are displayed in Fig. 1b. There was an overall significant decrease in the mortality rate between 1992 and 2010 with a yearly decrease of 0.27 ± 0.023 deaths per 100,000 females per year ($R^2 = 0.89$, $p < 0.0001$). If the mortality rate for 1992 persisted for 1992–2010, there would be 810 more deaths from breast cancer in 2010 (16% increase).

The overall provincial mortality rates are listed in Table 5. Three provinces had statistically significantly higher mortality rates than the national average: Nova Scotia (36.60; 95% CI 35.36–37.87), Quebec (34.66; 95% CI 34.23–35.10), and Manitoba (34.066; 95% CI 32.99–35.17) (Supplementary Fig. 1B). Two provinces and three territories had statistically significantly lower mortality rates than the national average: British Columbia (28.52; 95% CI 27.99–29.054), Alberta (25.065; 95% CI 24.49–25.65), Yukon (17.54; 95% CI 13.020–23.19), Northwest Territories (13.16; 95% CI 9.77–17.39), and Nunavut (4.049; 95% CI 1.94–7.63). Additional analyses on breast cancer mortality were conducted at the FSA level and this information is presented in Supplementary Tables 7 and 8.

Discussion

In this study, we present a comprehensive analysis of the epidemiology of breast cancer in Canada between 1992 and 2010. To our knowledge, this is the first Canadian study to geographically analyze incidence and mortality rates at the

Table 4 Breast cancer mortality rates by age group for the years 1992–2010

Age Group	Number of cases[a]	Female population (rounded to 1000)	Mortality rate per 100,000 women (95% CI)
0–29	150	5,829,000	0.13 (0.11–0.16)
30–39	2690	2,312,000	6.12 (5.89–6.36)
40–59	25,960	4,347,000	31.43 (31.05–31.82)
60–79	40,645	2,264,000	94.48 (93.56–95.40)
80+	24,435	614,000	209.51 (206.90–212.16)

Mortality rates are expressed per 100,000 women per year

[a]Number of cases was rounded to a multiple of 5 as per SSHRC/Statistics Canada regulations

Table 5 Overall breast cancer mortality rates by province between 1992 and 2010

Province/Territory	Cases[a]	Female population (rounded to 1000)	Incidence per 100,000 women (95% CI)
Nova Scotia	3310	476,000	36.60 (35.36–37.87)
Quebec	24,830	3,770,000	34.66 (34.23–35.10)
Manitoba	3780	584,000	34.07 (32.99–35.17)
Prince Edward Island	440	70,000	33.08 (30.06–36.33)
New Brunswick	2365	379,000	32.84 (31.53–34.19)
Newfoundland and Labrador	1640	270,000	31.97 (30.44–33.55)
Saskatchewan	3045	508,000	31.55 (30.44–32.69)
Ontario	35,935	6,015,000	31.44 (31.12–31.77)
British Columbia	11,015	2,033,000	28.52 (27.99–29.05)
Alberta	7,315	1,536,000	25.07 (24.49–25.65)
Yukon	50	15,000	17.54 (13.02–23.19)
Northwest Territories	50	20,000	13.16 (9.77–17.39)
Nunavut	10	13,000	4.05 (1.94–7.63)

Mortality rates are expressed per 100,000 women per year

[a]Number of cases was rounded to a multiple of 5 as per SSHRC/Statistics Canada regulations

city and FSA levels. Our results are consistent with those found in the literature. To illustrate, an American study by DeSantis et al. [8] found that between 2006 and 2010 the national incidence rate was 127.3 cases per 100,000 females per year and the national mortality rate was 22.7 deaths per 100,000 females per year. It is important to note that, in that study, ductal and lobular and mixed breast cancer subtypes were not analyzed separately [33].

Breast cancer incidence rates increased significantly between 1992 and 2010 by 1.57 ± 0.11 cases per 100,000 females per year ($p < 0.0001$). In a cohort study by Clavel-Chapelon et al. [6], the age of menarche decreased from 13.3 to 12.7 on average in the 1930 and 1950 birth cohorts, respectively. This 6-month decrease in age of menarche over a 20 year period is hypothesized to have contributed to the increase in incidence [6]. In addition, the increase seen in the late 1990s has been hypothesized to be caused by increased screening via mammography, increased use of hormone replacement therapy (HRT) in postmenopausal women, and increased obesity rates [14, 34]. In Canada, mammography screening programs existed in every province by 1998 [35]. This resulted in breast cancer being diagnosed 1–3 years sooner, which could in part explain the increase in incidence rates [34]. According to a study by Statistics Canada, 40% of women aged 50–69 reported that they had a mammogram in the last 2 years [35]. This percentage increased to 72% in the year 2000 and remained stable until the end of the study in 2008 [35]. The long-term increase in incidence rates is likely due to delayed childbearing and decreased number of births and the overall aging of the Canadian population [14, 34]. Interestingly, incidence of lobular carcinoma of the breast shows the opposite: a decreasing trend. A study by Dossus and Benusiglio [36] also reports a similar decline in lobular breast cancer incidence since 1999. It is known that lobular breast cancer incidence is more strongly related to endogenous and exogenous female hormones [36]. Therefore, it is hypothesized that this decline is most likely due to the decreasing use of postmenopausal hormone therapy [36].

Mortality rates for breast cancer decreased significantly between 1992 and 2010 by -0.27 ± 0.023 deaths per 100,000 females per year ($p < 0.0001$), which represents a 29% decline in 19 years. An American study found similar results with breast cancer mortality rate dropping from 33.0 deaths per 100,000 per year in 1990 to 21.3 deaths per 100,000 per year in 2010 [37]. Some studies suggest that this decline is likely due to earlier detection by mammography and treatment improvements [1, 14, 34]. Some studies have also hypothesized the introduction of more effective drugs, such as adjuvant chemotherapy, in the 1970s are responsible for the decline in mortality rates [37]. A timeline outlining the advances in breast cancer treatment and screening methods in Canada is presented in Supplementary Table 9 [38–40].

This study was able to identify high-incidence FSAs that were adjacent or in close proximity to one another. Most of these geographic clusters were found in cities and other urban areas, and very few were in rural areas. Studies by Hystad et al. [7] and Crouse et al. [10] found that breast cancer incidence rates were higher in areas with higher levels of air traffic pollution, notably in urban areas. In addition, urban areas have higher SES and density of primary care providers that contribute to higher breast cancer detection rates [41]. Also, our analysis highlighted that high incidence of breast cancer correlated with the overall older population living in these areas and availability of retirement and nursing facilities. While realizing that some geographic differences are due to external risk factors, random variation could also be responsible for part of these differences.

Many large population-based studies have been shown to possess inherent limitations, including missing data and a risk of misclassification of patients. These limitations are discussed in more detail in an article by Sanders et al. [42]. In particular, the databases used in this study do not provide information on the patients' race, socioeconomic status, lifestyle habits, and occupation, which could act as confounding factors. In addition, the databases did not provide information on the stage of the breast cancer.

In conclusion, through this study, many Canadian geographic clusters for breast cancer have been identified. This is the first Canadian study that analyzes the incidence and mortality rates for this malignancy at the city and forward sortation area levels. Our results demonstrate that new external risk factors may be involved in the pathogenesis of breast cancer and will act as a foundation for future studies that will seek to identify new risk factors and etiologic agents for this malignancy.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflicts of interest to disclose.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was conducted in accordance with the CISS-RDC-668035 protocol approved by the Social Sciences and Humanities Research Council of Canada (SSHRC) as well as the 13-SSH-MCG-3749-S001 protocol approved by the Quebec Inter-University Centre for Social Statistics (QICSS). Furthermore, the Research Ethics Board Review of McGill University exempted this project in accordance with their policy.

Informed consent Not applicable.

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