Preventive Medicine Reports 37 (2024) 102578

Contents lists available at ScienceDirect

Preventive Medicine Reports

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

COVID-19 pandemic impact on the potential exacerbation of screening mammography disparities: A population-based study in Ontario, Canada

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ARTICLE INFO

Keywords:
COVID-19
Pandemic
Breast cancer screening
Mammography
Cancer screening
Early detection of cancer
Healthcare disparity
Socioeconomic factors

ABSTRACT

Strategies to ramp up breast cancer screening after COVID-19 require data on the influence of the pandemic on groups of women with historically low screening uptake. Using data from Ontario, Canada, our objectives were to 1) quantify the overall pandemic impact on weekly bilateral screening mammography rates (per 100,000) of average-risk women aged 50–74 and 2) examine if COVID-19 has shifted any mammography inequalities according to age, immigration status, rurality, and access to material resources. Using a segmented negative binomial regression model, we estimated the mean change in rate at the start of the pandemic (the week of March 15, 2020) and changes in weekly trend of rates during the pandemic period (March 15—December 26, 2020) compared to the pre-pandemic period (January 3, 2016—March 14, 2020) for all women and for each subgroup. A 3-way interaction term (COVID-19*week*subgroup variable) was added to the model to detect any pandemic impact on screening disparities. Of the 3,481,283 mammograms, 8.6 % (n = 300,064) occurred during the pandemic period. Overall, the mean weekly rate dropped by 93.4 % (95 % CI 91.7 % – 94.8 %) at the beginning of COVID-19, followed by a weekly increase of 8.4 % (95 % CI 7.4 % – 9.4 %) until December 26, 2020. The pandemic did not shift any disparities (all interactions $p > 0.05$) and that women who were under 60 or over 70, immigrants, or with a limited access to material resources had persistently low screening rate in both periods. Interventions should proactively target these underserved populations with the goals of reducing advanced-stage breast cancer presentations and mortality.

1. Introduction

With nearly 2.3 million new cases, female breast cancer was the most commonly diagnosed cancer type globally in 2020. (Sung et al., 2021) Despite having the world's third highest age-standardized incidence rate (89.4 per 100,000 population), North America has relatively low breast cancer mortality (12.1 per 100,000 population), in part due to the widespread uptake of organized and opportunistic screening mammography. (Thun et al., 2017) For most women, screening mammograms are the best way to find and treat breast cancer early to reduce mortality. (Nelson et al., 2016).

Being the most populous province of Canada (14.6 million, including 7.4 million women), Ontario screens women for breast cancer under an organized, population-based, publicly funded program (Ontario Breast Screening Program; OBSP) that had its genesis in 1990; high-risk women receive screening under a dedicated program (High Risk OBSP), which was launched in 2006. (Walker et al., 2021; Chiarelli et al., 2021) Ontario Health (previously Cancer Care Ontario), the provincial cancer

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https://doi.org/10.1016/j.pmedr.2023.102578
Received 29 August 2023; Received in revised form 20 December 2023; Accepted 23 December 2023
Available online 25 December 2023

agency, mails letters to eligible average-risk women 50–74 years to invite them to book an appointment directly with an OBSP site without needing a requisition from the primary care physician. (Walker et al., 2021) OBSP participation among screen-eligible women was 61 % – 66 % from 2000 to 2018. Ontario Health (Cancer Care Ontario), (2021) Mammograms are universally accessible under a single-payer health insurance system, Ontario Health Insurance Plan (OHIP). (OHIP, 2022).

Because more than 90% of screening mammograms are performed within the OBSP, Ontario can provide data to answer a range of research questions pertaining to the population-level impact of COVID-19 on breast cancer screening. Ontario reported the country's first case of COVID-19 on January 25, 2020. On March 15, 2020, all hospitals were advised by the province's Chief Medical Officer of Health to cancel nonemergent and elective procedures. (Ministry of Health, 2020) Following the government's declaration of provincial state of emergency on March 17, 2020, Ontario Health recommended that all cancer screening be suspended on March 23, 2020. (Chief Medical Officer of Health, 2023) Screening services were allowed to resume under a prioritization framework in late-May 2020. (Chiarelli et al., 2021) Average-risk OBSP was assigned the lowest priority (Priority III) after diagnostic mammography for breast assessment (Priority I) and High Risk OBSP screening mammography (Priority II). Correspondence between Ontario Health and screen-eligible women was resumed in January 2021. (Chiarelli et al., 2021).

There have been several Ontario studies that examined the pandemic impact on monthly volumes of screening mammography. (Walker et al., 2021; Chiarelli et al., 2021; Walker et al., 2022) Unsurprisingly, all studies concluded an immediate halt (>99 %) of screening participation between April-May 2020. Two months after the directed resumption of cancer screening, in July 2020, the monthly volume of High Risk OBSP was reported to already exceed its 2019 level, while the monthly volume of average-risk OBSP only reached 80 % of its 2019 level as of December 2020. (Walker et al., 2021) Comparing age and socioeconomic characteristics (neighborhood income, rurality, and approximated Indigenous status using postal codes) of OBSP attendees during the first 6 months of the pandemic (March-December 2020) versus those in the same period of 2019 did not yield any significant difference. (Walker et al., 2021).

While there appears to be no profile difference of OBSP participants in Ontario, the international literature has suggested that certain subgroups of women to experience a sharper decrease in screening mammography during the pandemic (Appendix I). In the US, women who were non-White, considered low-risk, or residing in rural areas were more negatively impacted by COVID-19. (Amornsiripanitch et al., 2021; Amram et al., 2021; Becker et al., 2021; DeGroff et al., 2021; Fasano et al., 2022; Labaki et al., 2021; Marcondes et al., 2021; Monsivais et al., 2022; Nyante et al., 2021; Patt et al., 2022) Findings regarding other factors are mixed. For instance, while most studies identified older age to be associated with less screening during COVID-19 (Amornsiripanitch et al., 2021; Monsivais et al., 2022; Chen et al., 2021; Lee et al., 2022), one study found younger women to miss their appointments more. (Becker et al., 2021) Similar conflicting results were reached for socioeconomic status. (Amornsiripanitch et al., 2021; Amram et al., 2021; Fasano et al., 2022; Labaki et al., 2021; Monsivais et al., 2022; Patt et al., 2022; Chen et al., 2021; Lee et al., 2022; Du et al., 2022).

Perhaps a more important inquiry; has the pandemic widened any pre-pandemic mammography disparities? This is fundamentally different from identifying the subgroups with a particularly low use of mammography during the pandemic or a very large percentage decrease in use compared to pre-pandemic. To our best knowledge, there were very few statistical investigations on this topic. Among the available data, racially based disparities were reported to have been accentuated. (Labaki et al., 2021; Marcondes et al., 2021; Monsivais et al., 2022) Mixed evidence was drawn for socioeconomic status, while stable, unchanged disparities were concluded for age and rurality. (Fasano et al., 2022; Monsivais et al., 2022; Chen et al., 2021) These scarce and unclear findings call for analyses to demonstrate if the pandemic has indeed made some subgroups of women worse off; if so, post-pandemic interventions targeting these underserved women need to go beyond the magnitude of the pre-pandemic levels to ensure these women meet the standard of care.

The objectives of this study were to 1) quantify the overall pandemic impact on weekly bilateral screening mammography rates of average-risk women aged 50–74 and 2) examine if COVID-19 has accentuated (or ameliorated) any mammography inequalities according to age, immigration status, rurality, and access to material resources.

2. Methods

2.1. Study design

We conducted this retrospective population-based cohort study at ICES, a non-profit research institute legalized by section 45 of Ontario's Personal Health Information Protection Act to collect and analyze health care data for health system analysis, evaluation and decision support. The use of the data in this study is authorized under section 45 and approved by ICES' Privacy and Legal Office, and therefore, does not require review by a Research Ethics Board.

2.2. Study cohort

At the beginning of each week between January 3, 2016 and December 26, 2020, we identified OHIP-eligible women who were average-risk according to the OBSP guideline (Cancer Care Ontario. Ontario Breast Screening Program (OBSP) (2022)) using a validated algorithm (Sutradhar et al., 2016): those with no prior diagnosis of breast cancer, without a history of prior mastectomy or breast implants, and who were aged between 50 and 74 years. We also required women to have a valid Ontario postal code at the start of that week to calculate neighborhood rurality and access to material resources. The accrual end date (December 26, 2020) represents the last reliable data from the OBSP at the time of this analysis (April 2022). These weekly cohorts of average-risk women were aggregated to form the study cohort.

2.3. Data sources

Datasets (Appendix II) were linked using unique encoded identifiers and analyzed at ICES. The OHIP physician claims database and the OBSP database both hold mammogram records, where the OHIP additionally captures mammograms delivered outside of the OBSP (i.e., opportunistic screening with a physician referral). (Sutradhar et al., 2016) The Ontario Cancer Registry (OCR) identifies the population with a cancer diagnosis. (Jensen et al., 1991; Robles et al., 1988) The Canadian Institute for Health Information's Discharge Abstract Database stores hospitalization records. Client Agency Program Enrollment (CAPE) identifies family physicians practicing under one of the three primary health care models and their rostered (formally registered) patients. (Steele et al., 2013; College, 2012) The Registered Persons Database (RPDB) maintains the demographic information of individuals covered by OHIP. Statistics Canada's Postal Code Conversion File (PCCF) was used to obtain neighborhood rurality status. (du Plessis et al., 2001) The Immigration, Refugees and Citizenship Canada (IRCC) Permanent Resident Database (with data from January 1985 to May 2017) includes records of individuals who immigrated to Ontario during this period. The Ontario Marginalization Index (ON-MARG) database reports material resources, a composite measure that captures the proportion of residents of a neighborhood that is without a high school degree, single-parent families, receiving government transfer payments, unemployed, low-income, or living in dwellings in need of a major repair. (Matheson et al., 2022).

2.4. Exposure

Our primary binary exposure variable indicated the start of the COVID-19 pandemic in Ontario, March 15, 2020. (Eskander et al., 2021; Eskander et al., 2022a; Fu et al., 2022a; Fu et al., 2022b; Fu et al., 2022c; Eskander et al., 2022b; Fu et al., 2022d; Fu et al., 2023b; Fu et al., 2022e; Fu et al., 2023c) As such, in this study, January 3, 2016—March 14, 2020 was termed the 'pre-pandemic period' while March 15, 2020—December 26, 2020 was the 'pandemic period'.

2.5. Outcome

We examined crude weekly mammography rates, defined as the weekly volume of bilateral mammograms per 100,000 average-risk women. To ensure a comprehensive identification of screening mammograms regardless of physician referral status, we included any bilateral mammogram that could be identified using a physician billing in the OHIP claims database (X172, X178 and X185) or a screening record in the OBSP database. (Toronto Public Health, 2022) For women receiving multiple mammograms over the study period including those who received two or more mammograms during the same week (0.11 % of all mammograms), we included all records and conducted all analyses at the mammogram level.

2.6. Covariates

At the beginning of each week, we measured the following characteristics of the identified bilateral mammograms. The age of women was obtained from the RPDB. Rural living was defined as living in a rural area or small town with a population of less than 10,000. (du Plessis et al., 2001) Immigrant status was determined from the IRCC Permanent Resident Database. Access to material resources from the ON-MARG was reported in quintiles. Comorbidity, measured by the Elixhauser Comorbidity Index, was based on hospitalization records in the past 5 years. (Elixhauser et al., 1998) Five comorbidity groups were created for women scoring 0, 1, 2, 3+ on the Index and for those who were not hospitalized. A woman was rostered (formally registered) with a primary care physician if she was enlisted as a patient under that physician in the CAPE database. For non-rostered women, we identified their most-responsible primary care physician according to the maximum dollar value of 18 comprehensive primary care billing codes during the preceding year. (Aggarwal, 2009) If there were no such claims, this woman was "not rostered", and if there were, she was "virtually rostered" if her most-responsible physician was practicing under a primary health care model or "not enrolled" if the physician was not in any enrollment group.

2.7. Statistical analysis

Descriptive analyses were performed to compare the distributions of characteristics of bilateral mammograms in average-risk women in pre-pandemic and pandemic periods. A standardized difference greater than 0.1 was used to identify an imbalance in characteristics. (Austin, 2009).

To quantify the overall COVID-19 pandemic impact on crude weekly mammography rates, we used a segmented negative binomial regression model (Appendix III) to estimate three parameters: the pre-pandemic weekly trend in rates (slope), mean change in rates during the first week of COVID-19 (relative change in intercept), and further change in the weekly trend of rates in pandemic compared to pre-pandemic (relative change in slope) periods. This modeling technique has been used by our group to assess other outcomes impacted by COVID-19. (Eskander et al., 2022a; Fu et al., 2022a; Fu et al., 2022d; Fu et al., 2022e; Fu et al., 2023c).

Then, for mammography disparities, we performed a two-step analysis on four pre-specified variables: age (50–54, 55–59, 60–64, 65–69, and 70–74), type of living community (rural/urban), immigration status (immigrants/non-immigrants), and access to material resources (quintiles). For each variable, we first repeated the segmented regression analysis stratified by each characteristic. Then, we tested the significance of each variable as an independent covariate (main effect, denoting overall mammography disparity) and of a 3-way interaction term (COVID-19*week*subgroup variable) within the segmented regression model, following the published studies. (Marcondes et al., 2021; Monsivais et al., 2022) If significant, the interaction term would imply that the magnitude and/or the direction of the disparity had shifted after the start of the pandemic. All regression analyses were two-sided using a p-value < 0.05 to indicate statistical significance. Analyses were performed on SAS Enterprise Guide 7.15 (SAS Institute).

3. Results

Between January 3, 2016 and December 26, 2020, 3,481,283 bilateral mammograms were performed in average-risk women aged 50–74 in Ontario. Of those, 91.4 % (n = 3,181,219) took place in the pre-pandemic period and 8.6 % (n = 300,064) during the pandemic period. Over the entire study period, the mean weekly mammography rate was 605 per 100,000 average-risk women. In the pre-pandemic period, the mean rate was 658 per 100,000 average-risk women, which then dropped by 51.4 % to a mean of 320 per 100,000 average-risk women in the pandemic period. No differences in sociodemographic and clinical characteristics were found for mammograms that occurred in the pandemic period to those before (Table 1).

For the general average-risk women population, stable crude weekly mammography rates were observed during the pre-pandemic period (rate ratio [RR]: 1.000, 95 % confidence interval [CI]: 0.999–1.001, Fig. 1). Over the first week of the pandemic, the mean weekly rate dropped by 93.4 % compared to the week prior (RR: 0.066, 95 % CI: 0.052–0.083). Then, the rate rose by 8.4 % each week (RR: 1.084, 95 % CI: 1.074–1.094), and during the week of November 1–7, 2020, returned to the pre-pandemic weekly utilization level. For each stratum of average-risk women, their weekly mammography rate returned to the pre-pandemic level by November 21, 2020 (Fig. 2, Appendix IV).

Over the entire study period, there were significant mammography disparities by age, immigration status, and material resources (all main-effect p-value < 0.01, Appendix V). Specifically, when compared to average-risk women in the youngest age group (50–54), the weekly mammography use of women in their 60 s was significantly higher while the use of women aged 55–59 or 70–74 was not statistically different; immigrants had a lower weekly mammography use than non-immigrants; as did those who had a limited access to material resources. No disparity was detected between rural- and urban-living women during the entire study period (main-effect p-value = 0.95). Because none of the 3-way interaction terms (COVID-19*week*-subgroup) were significant, we conclude the COVID-19 pandemic neither accentuated nor ameliorated the pre-pandemic mammography disparities according to these variables.

4. Discussion

For average-risk women in Ontario, mammography use decreased by 93.4 % in the first week of COVID-19, but the weekly rate returned to pre-pandemic levels within 7 months. The pandemic did not further shift any pre-pandemic mammography disparities, and as such, women who were under 60 or over 70, immigrants, and those with a limited access to material resources had lower rates of mammography in both pre-pandemic and pandemic periods.

During the first week of COVID-19 in Ontario, there was a nearly complete halt (93.4 %) in screening mammography participation. We provide three explanations for the very small number of observed women who still attended their appointment: first, while Ontario Health recommended the suspension of cancer screening on March 23, 2020,

Table 1
Characteristics of average-risk women receiving a bilateral mammogram between January 3, 2016 and December 26, 2020 in Ontario, Canada.

Characteristics	Mammograms delivered in pre-pandemic (N = 3,181,219, 91.4 %)	Mammograms delivered during the pandemic (N = 300,064, 8.6 %)	Standardized difference
Age, year			
Mean ± SD	60.64 ± 6.83	60.82 ± 6.91	0.03
50–54	749,548 (23.6 %)	68,412 (22.8 %)	0.02
55–59	745,154 (23.4 %)	69,314 (23.1 %)	0.01
60–64	680,892 (21.4 %)	64,641 (21.5 %)	0
65–69	590,785 (18.6 %)	55,651 (18.5 %)	0
70–74	414,840 (13.0 %)	42,046 (14.0 %)	0.03
Type of living community			
Rural	361,006 (11.3 %)	36,109 (12.0 %)	0.02
Urban	2,820,213 (88.7 %)	263,955 (88.0 %)	0.02
Immigrants			
All immigrants	529,069 (16.6 %)	49,057 (16.3 %)	0.01
Landing ≤ 5 years	32,552 (1.0 %)	964 (0.3 %)	0.09
Landing 5–10 years	51,166 (1.6 %)	3,960 (1.3 %)	0.02
Landing > 10 years	445,351 (14.0 %)	44,133 (14.7 %)	0.02
Material resources quintile[1]			
First, least deprived	763,877 (24.0 %)	76,101 (25.4 %)	0.03
Second	707,278 (22.2 %)	68,299 (22.8 %)	0.01
Third	627,840 (19.7 %)	58,343 (19.4 %)	0.01
Fourth	573,927 (18.0 %)	51,946 (17.3 %)	0.02
Fifth, most deprived	508,297 (16.0 %)	45,375 (15.1 %)	0.02
Region			
Central	1,011,041 (31.8 %)	91,311 (30.4 %)	0.03
East	841,769 (26.5 %)	79,485 (26.5 %)	0
North	188,771 (5.9 %)	20,702 (6.9 %)	0.04
Toronto	250,387 (7.9 %)	24,434 (8.1 %)	0.01
West	889,251 (28.0 %)	84,132 (28.0 %)	0
Elixhauser grouping[2]			
0	244,210 (7.7 %)	23,483 (7.8 %)	0.01
1	134,719 (4.2 %)	12,540 (4.2 %)	0
2	70,060 (2.2 %)	6,234 (2.1 %)	0.01
≥3	59,769 (1.9 %)	5,114 (1.7 %)	0.01
No hospitalization	2,672,461 (84.0 %)	252,693 (84.2 %)	0.01
Status of primary care provider[3]			
Rostered	2,821,298 (88.7 %)	265,013 (88.3 %)	0.01
Virtually rostered	190,050 (6.0 %)	18.785 (6.3 %)	0.01
Physician not enrolled	97,491 (3.1 %)	8,250 (2.7 %)	0.02
Not rostered	72,380 (2.3 %)	8,016 (2.7 %)	0.03

All variables were measured at the beginning of each week. We reported the characteristics for each instance of bilateral mammogram. We defined the pre-pandemic period to be from January 3, 2016 to March 14, 2020, and the pandemic period from March 15, 2020 to December 26, 2020. We used 0.1 as a threshold for the standardized difference to identify a significant difference between the two groups.
[1]Access to material resources is a measure of socioeconomic status that considers the proportion of a geographic region that is without a high school degree, families that are single parent, receiving government transfer payments, unemployed, low-income, and living in dwellings needing a major repair.
[2]The Elixhauser comorbidity grouping was computed using a 5-year look-back window from the beginning of that week.
[3]Women who were formally registered with a primary care practice were considered 'rostered'. For non-rostered women, we identified their most-responsible physician according to the maximum dollar value of 18 comprehensive primary care billing codes during the preceding year. If there were no such claims, this woman was "not rostered". Otherwise, she was "virtually rostered" if her most-responsible physician was practising under one of the three primary health care models.
Abbreviations: SD, standard deviation.

we used an earlier date (March 15), when hospitals were advised to cancel elective procedures, to mark the start of COVID-19. This decision was made to be consistent with our prior publications (Fu et al., 2023a; Eskander et al., 2022a; Fu et al., 2022a; Fu et al., 2022b; Fu et al., 2022c; Fu et al., 2022d; Fu et al., 2023b; Fu et al., 2022e; Fu et al., 2023c) and to account for the fact that many OBSP sites had already been fully or partially closed at that time. (Chiarelli et al., 2021) Second, we captured mammograms through both the OBSP database and from physician billings (OHIP), meaning that women who attended screening after receiving a physician referral (outside of the OBSP) were also included in our analysis. These women may be more reluctant than other average-risk women to cancel their mammography appointment during early pandemic. Finally, unlike previous studies that conducted monthly analyses (Walker et al., 2021; Chiarelli et al., 2021; Walker et al., 2022), we used week as the analytical unit for more nuanced results. This implies the 93.4 % sharp decrease occurred just within the first week of COVID-19. It took 7 months for weekly utilization of average-risk screening mammography to return to the pre-pandemic level. This relatively speedy recovery reflects the effectiveness of policies in inviting women back to screening. However, despite the directed efforts, the backlog remains substantial; in fact, a full year after the onset of COVID-19 (March 2021), 340,000 average-risk mammograms were not

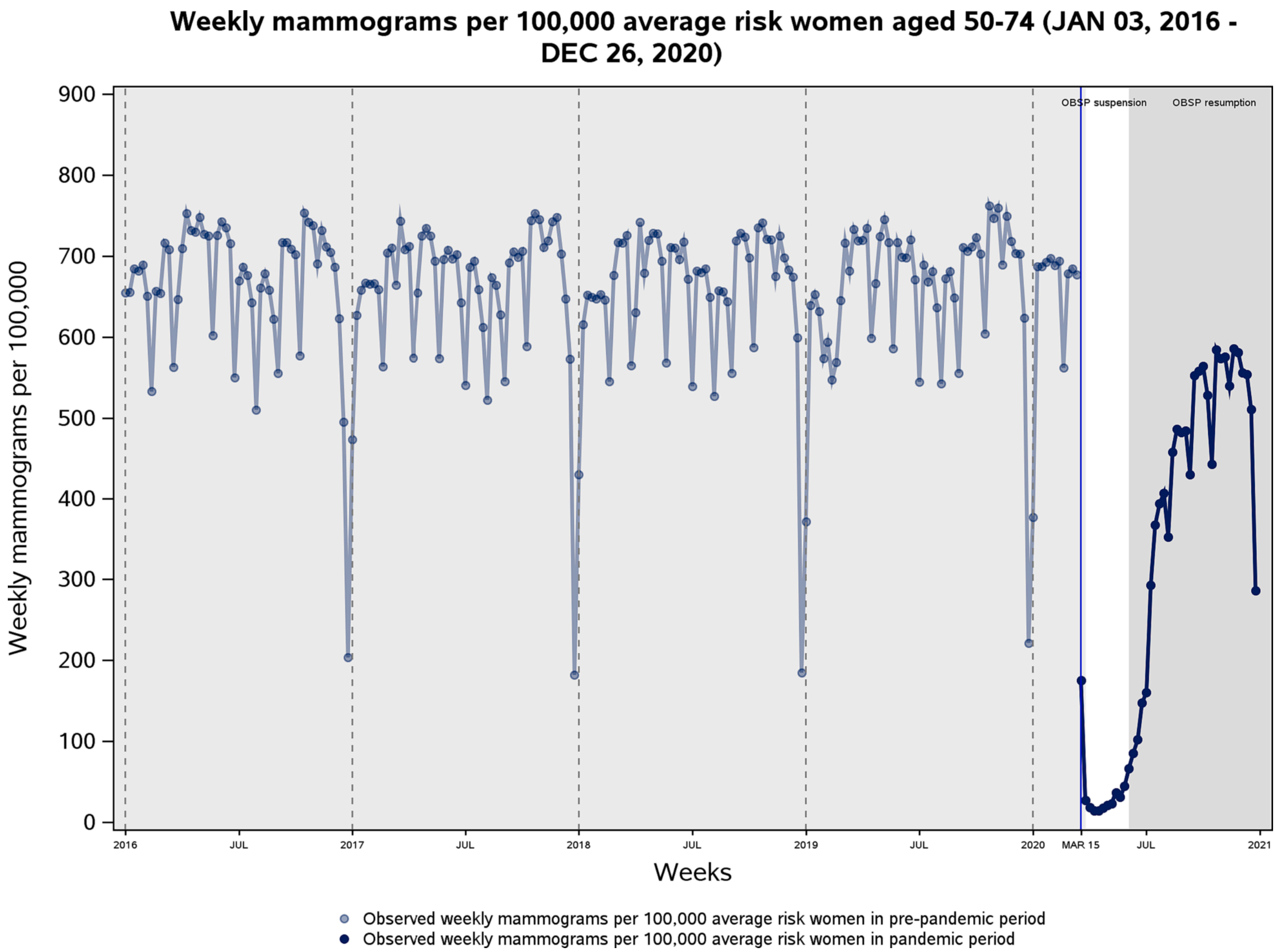

Fig. 1. Weekly average-risk mammography rates in Ontario, Canada between January 3, 2016 and December 26, 2020. We used March 15, 2020 (blue vertical line) to represent the start of the COVID-19 pandemic in Ontario, Canada. The Ontario Breast Screening Program (OBSP) was suspended for two months from March 23, 2020 to May 31, 2020 (the OBSP suspension period). OBSP services were allowed to resume under a prioritization framework starting from June 1, 2020 (the OBSP resumption period). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

performed, (Chiarelli et al., 2021) raising concerns of increased presentations of advanced-stage breast cancer and even more deaths in the next decade. (Yong et al., 2021; Maringe et al., 2020).

We found that average-risk women who were under 60 or over 70, women who were immigrants, and women who experienced limited access to material resources all had low use of screening mammography in both the pre-pandemic and pandemic periods. This means that the health benefits of Ontario's breast cancer screening program, including reducing deaths from breast cancer through early detection, are limited for these women. An early Canadian study observed that while women were encouraged to begin screening at age 50, many did not have their first screen until late 50 s. (Volesky and Villeneuve, 2017) For older screen-eligible women in their 70 s, mobility impairment and anxiety due to potential false-positive mammograms may be associated with their low use. (Walter and Schonberg, 2014) Understanding these experiences could guide interventions to mitigate the age disparity. For immigrants, our results echoed rich literature that shows immigrant women are a group associated with low breast screening utilization. (Dumky et al., 2023; Vahabi et al., 2021; Vahabi et al., 2015; Vahabi et al., 2016) Particularly, Canadian women who are new immigrants, of South Asian origin, or have a refugee status have been repeatedly shown to have extremely low screening use. Increasing these women's interactions with the primary care system, especially through a female family doctor, may be an effective way to enhance their adherence to routine screening. (Vahabi et al., 2015; Vahabi et al., 2016) Finally, we found weekly mammography rates to decrease with increased obstacles in accessing material resources. These results directly corroborated a US study that observed mammography use to decline with higher Area Deprivation Index, a similar measure to Material Resources. (Labaki et al., 2021) Interestingly, high socioeconomic status was found to be associated with a steeper decrease in screening rate in 2020 relative to 2019 on several occasions. (Amornsiripanitch et al., 2021; Chen et al., 2021; Lee et al., 2022) These observations may imply that women with high socioeconomic status reacted more swiftly to early social distancing measures. Despite this, these women were able to quickly catch up on the missed appointment. Indeed, in our analysis, use of screening among women in the least materially deprived quintile resumed to the pre-pandemic levels during the last week of October 2020, one week ahead of women in the third, fourth and fifth quintiles. These detailed data generated by our subgroup analyses could be used to support simulation studies aimed at predicting the excess breast cancer mortality due to the COVID-related screening deficit in these populations.

In our interaction effect analysis, we found the pandemic has neither widened nor narrowed the mammography disparities by age, rural living, immigration status, and access to material resources. Three US studies have drawn similar conclusions (Fasano et al., 2022; Marcondes et al., 2021; Monsivais et al., 2022). Another two US studies revealed that racial disparities, which we did not assess due to lack of race data in our dataset, to be accentuated in the pandemic, particularly among Asian and Hispanic women. (Labaki et al., 2021; Monsivais et al., 2022)

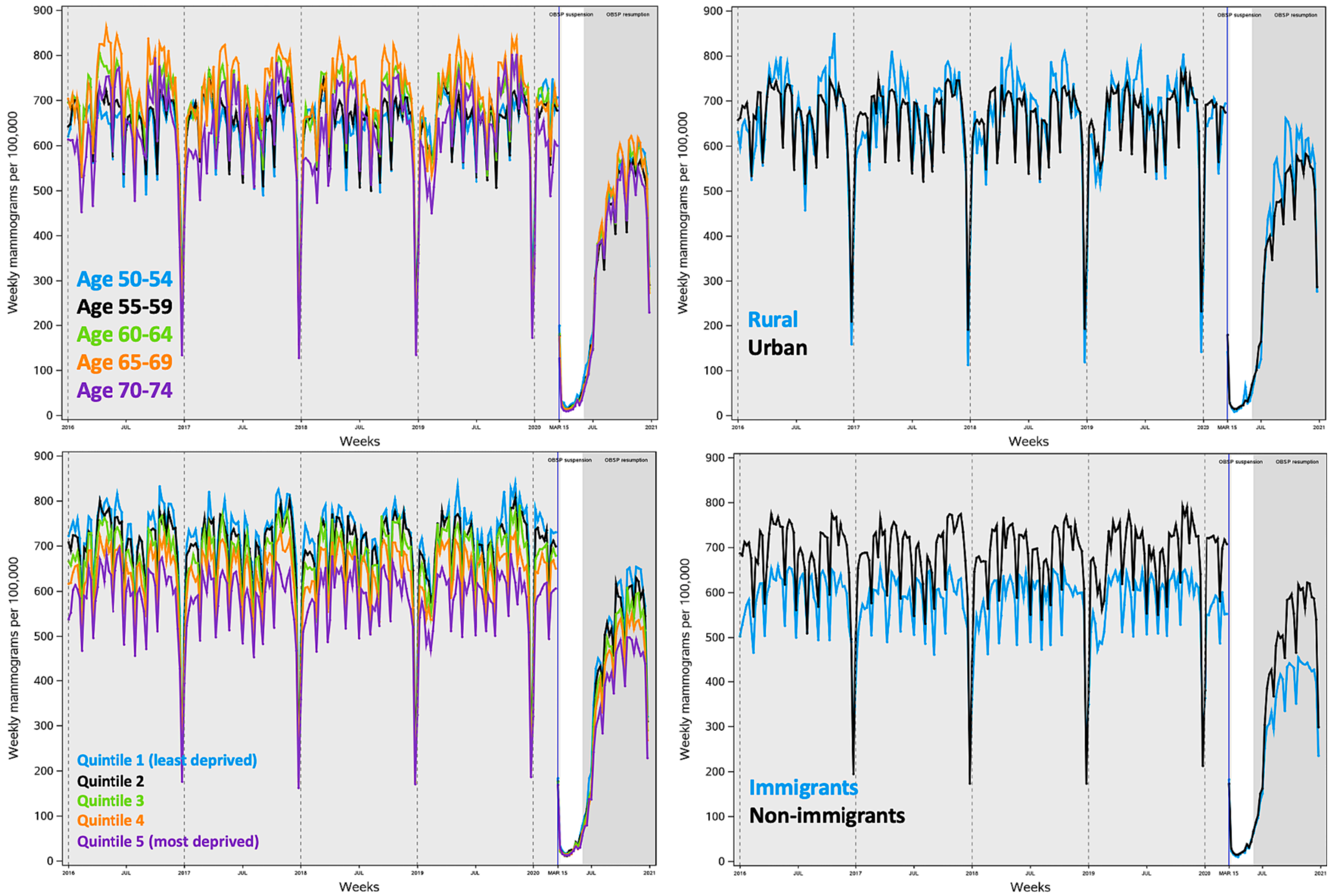

Fig. 2. Weekly average-risk mammography rates stratified by age group, rural living, immigration status and material resources quintile in Ontario, Canada between January 3, 2016 and December 26, 2020. For each variable, we repeated the segmented regression analysis on each level. We reported the regression results in **Appendix IV**.

There was also evidence of a widened screening gap between Medicaid and Medicare beneficiaries (Monsivais et al., 2022). However, another large study involving 60 million commercially insured Americans found the socioeconomic status-based disparity to have been narrowed by the pandemic, citing the use of telehealth as a potential mediating factor. (Chen et al., 2021) Similar to many US states, Ontario swiftly expanded the use of telemedicine soon after the start of COVID-19 by introducing temporary fee codes that physicians can claim for conducting a virtual (including an au. dio-only phone) visit. (Fu et al., 2022a; Fu et al., 2022d) The role of telemedicine in promoting access to cancer screening warrants additional research.

Our study results yield new insights for policies to inform decisions to ramp up screening mammography in the aftermath of COVID-19. As we rebuild the overall capacity for average-risk breast cancer screening, we must also direct resources to address the persistently low screening participation among women not in their 60 s, immigrants, and those with limited access to material resources. Ontario has successfully increased the rollout of COVID-19 vaccine in marginalized communities by implementing strategies at both provincial and local levels; these existing models may have immediate and long-term applications for cancer screening. For example, having a primary care physician to champion the operation of pop-up and mobile clinics can reduce barriers to vaccination for rural residents. (Carter et al., 2022) Ontario currently operates mobile screening coaches in two regions; with an increased funding more women can potentially get screened with privacy and convenience. (Ontario Health (Cancer Care Ontario) (2023)) Furthermore, establishing a centralized online booking system, similar to the provincial COVID-19 vaccination portal, may be a more cost-effective way to encourage screening.

This study has limitations. Our 8-month pandemic timeframe means we cannot reliably incorporate seasonality (which typically requires at least 1 year of data (Wagner et al., 2002)) in the regression analysis. This short time window also limits the scope of our findings since Ontario has implemented more public health actions after the first peak of COVID-19. Our previous work has indeed demonstrated the second wave of COVID-19 (January 2021) to have an similarly immediate impact on cancer activities. (Fu et al., 2022e; Fu et al., 2022b) We focused on the first wave of COVID-19 in this analysis because this marked the only time when cancer screening was officially suspended by the provincial authority. Next, we did not strictly focus on women who are due for a screen or statistically account for the repeated screens of the same women; this would be better assessed in an individual-level time-to-event analysis. The unique structure of Ontario's universally accessible cancer screening program has limited the generalizability of our findings. As COVID-19 has led to significant economic hardship for many families, health jurisdictions that require women to pay out-of-pocket for breast screening may have observed an even steeper decrease in screening and slower recovery. (Lee et al., 2023) In our disparity investigation, there are other sociodemographic factors, such as race/ethnicity, that we did not consider. This means COVID-19 may have indeed exacerbated some preexisting screening disparities that we were unable to capture in this analysis. Our data on immigration status was not up to date; this limitation could be addressed in future analyses with data on new immigrants and their world of origin. We did not consider women already at risk of breast cancer; results on High Risk OBSP can be seen elsewhere. (Chiarelli et al., 2021) Our strengths include the use of a large population-based dataset and the accurate linkage of mammograms to sociodemographic and clinical factors.

5. Conclusion

We report here a 93.4 % decrease in mammography rate per 100,000 average-risk women in the first week of COVID-19, followed by a steady increase leading the weekly mammography use to fully return to the pre-pandemic levels in early November 2020. Mammography uptake was low among women under 60 or over 70, immigrants, and those with limited access to material resources. COVID-19 pandemic neither accentuated nor ameliorated the pre-pandemic mammography disparities. The persisting disparities require innovative screening promotion models that leverage the experiences garnered from the rollout of COVID-19 vaccine to ensure improvement. These strategies should aim to reduce the presentation of advanced-stage breast cancers and the associated mortality that would potentially occur due to the COVID-related screening deficit.

CRediT authorship contribution statement

Rui Fu: Writing – original draft, Writing – review & editing, Methodology, Investigation, Conceptualization. **Jill Tinmouth:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Qing Li:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anna Dare:** Writing – review & editing, Investigation, Conceptualization. **Julie Hallet:** Writing – review & editing, Investigation, Conceptualization. **Natalie Coburn:** Writing – review & editing, Investigation, Conceptualization. **Lauren Lapointe-Shaw:** Writing – review & editing, Investigation, Conceptualization. **Nicole J. Look Hong:** Writing – review & editing, Investigation, Conceptualization. **Irene Karam:** Writing – review & editing, Investigation, Conceptualization. **Linda Rabeneck:** Writing – review & editing, Investigation, Conceptualization. **Monika Krzyzanowska:** Writing – review & editing, Investigation, Conceptualization. **Rinku Sutradhar:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Antoine Eskander:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgements

This document used data adapted from the Statistics Canada Postal Code OM Conversion File version 7B (November 2018), which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health (MOH) Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada. This does not constitute an endorsement by Statistics Canada of this product. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information, the Ontario MOH, Ontario Health, and Immigration, Refugees and Citizenship Canada current to May 31, 2017. Parts of this report are based on Ontario Registrar General (ORG) information on deaths, the original source of which is ServiceOntario. The views expressed therein are those of the author and do not necessarily reflect those of ORG or the Ministry of Public and Business Service Delivery. We thank the Toronto Community Health Profiles Partnership for providing access to the Ontario Marginalization Index. The analyses, conclusions, opinions, and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred.

Disclosure of Funding and Conflicts of Interest

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care. This work was also supported by the Ontario Health Data Platform (OHDP), a Province of Ontario initiative to support Ontario's ongoing response to COVID-19 and its related impacts. This study also received funding from a Sunnybrook Research Institute and Sunnybrook Foundation COVID-19 Response Grant and a Canadian Institutes of Health Research Operating Grant #179892. The funders were not involved in any part of the study. No endorsement by the OHDP, its partners, or the Province of Ontario is intended or should be inferred.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102578.

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