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The negative impact of the COVID-19 pandemic on breast cancer care in Brazil: a time series study in regions with different human development indices

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Abstract

Background The impact of the COVID-19 pandemic on breast cancer care across Brazilian regions with varying Human Development Index (HDI) levels remains unclear. This study evaluates the pandemic's effects on screening mammograms, tumor staging at diagnosis, and treatment initiation in the Brazilian Public Health System between 2017 and 2022, focusing on regions with different HDI levels.

Methods This ecological time series study uses an inflection point regression model and monthly percentage change (MPC) to analyze an open-access Brazilian Public Healthcare System dataset. The study focuses on trends and variations in these variables among women aged 50–69 in three state groups classified by HDI: Group A (very high), Group B (medium), and Group C (high).

Results The average monthly rate of screening mammograms was highest in Group A (10.70) and lowest in Group B (8.38). At the onset of the COVID-19 pandemic, screening rates dropped significantly, with the most significant decline in Group B (58.6% decrease) and the smallest in Group A (45.7% decrease), lasting for three months. Subsequently, this variable recovered until December 2022 but was insufficient to restore the total series MPC to pre-pandemic levels. Group B had the lowest average rate of early-stage (0-II) diagnoses (2.88), while Group C had the highest (3.68). Early-stage diagnoses declined in the first three months of the pandemic, followed by a partial recovery that was insufficient to restore the pre-pandemic MPC levels. The proportion of advanced-stage diagnoses was highest in Group B (49.02%) and lowest in Group A (45.97%). The pandemic maintained the upward trend of advanced-stage (III-IV) diagnoses across all groups in the total time series. The average proportion of treatments initiated after 60 days of diagnosis was above 60% across all groups, with Group B at 64.50%. This variable began to rise 3 to 4 months after the pandemic and continued increasing until December 2022, with a greater intensity than the pre-pandemic period across all groups.

Conclusion The COVID-19 pandemic reduced breast cancer screening and early diagnosis in Brazil, leading to more advanced cases and treatment delays across all regions, with varying impacts according to regional HDI levels.

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Keywords Breast neoplasms, Public health administration, Health Status disparities, Development indicators, COVID-19

Background

Breast cancer is one of the most common cancers among women worldwide, with an estimated 2.26 million new cases in 2020, representing 24.5% of all female cancers [1]. In Brazil, breast cancer accounted for 30.3% of all cancers in women, with 88.5 thousand new cases in 2020 [1, 2]. By 2040, new breast cancer cases will rise by 40.8% globally and by 47.5% in Brazil [1]. Early diagnosis is crucial for reducing mortality (preventing seven deaths per 1,000 women screened), decreasing the incidence of late-stage cancer (by 29%), improving the five-year survival rate (98% for localized disease vs. 31% for advanced disease), and lowering healthcare costs (localized disease is less expensive to treat than advanced disease) [3].

About 83% of breast cancer cases occur in women aged 50 or older. Therefore, many countries, including Brazil, offer biennial mammography screening to women aged 50–69 [4]. The World Health Organization (WHO) recommends that at least 60% of cases be diagnosed in early stages I and II, which is considered an ideal standard in countries with robust screening programs [5]. Following a confirmed breast cancer diagnosis, it is imperative to initiate treatment without delay [5–7]. In Brazil, all patients diagnosed with malignant neoplasia have the right to receive their first treatment within 60 days of the pathology report through the public health system [7]. This treatment can include surgical, radiotherapy, or systemic therapies [7].

Socioeconomically disadvantaged populations often face worse cancer outcomes, including delayed diagnosis, lower survival rates, and higher mortality [8, 9]. According to the World Cancer Report, several factors contribute to cancer disparities, including social structures (such as sex, race, and ethnicity), as well as cultural, geographic, economic, and political factors [8]. Socioeconomic status is a critical determinant in the success of cancer prevention, early detection, and treatment initiatives. This indicator includes various elements such as education level, food security, housing conditions, and income [8, 9].

In March 2020, the World Health Organization declared COVID-19 a pandemic [10, 11]. Since then, many countries have experienced overwhelmed healthcare systems and have been struggling to meet the demands of COVID-19 patients [10, 11]. Additionally, the pandemic worsened socioeconomic inequalities, further limiting access to healthcare for disadvantaged populations [12, 13]. This negative impact extended to the prevention, diagnosis, and treatment of other diseases, including breast cancer [10, 11]. Despite this, few studies have assessed the effects of the pandemic on breast cancer care across regions with varying HDI levels in developing countries [14]. Such analysis is crucial for developing targeted strategies to address breast cancer care in areas with different HDI levels, especially during crises that strain healthcare systems. This study aims to evaluate the impact of the COVID-19 pandemic on screening mammograms, tumor staging at diagnosis, and treatment initiation in the Brazilian Public Health System between 2017 and 2022, focusing on regions with different HDI levels.

Methods

This ecological time series study utilized an open-access Brazilian Public Healthcare System dataset [15]. Brazil, the focus of the study, comprises 26 States and a Federal District and has the sixth-largest population globally [16]. As of 2022, the country's estimated population is 213.3 million, including 109.8 million women and 22.5 million people aged 50 to 69 [16]. Despite its relatively high Human Development Index (HDI) of 0.754, ranking 87th globally, Brazil ranks among the top ten countries with the highest socioeconomic inequality [17, 18]. Nearly 30% of the population lives below the poverty line, and 8.4% live in extreme poverty [17, 18]. It's important to note that all Brazilian citizens have access to the public health system, which is a significant reassurance in the face of these statistics. Approximately 25% also have private health insurance or a supplementary health plan [19, 20].

The HDI is a comprehensive measure of a country's progress based on three key factors: health, education, and standard of living [14]. Health is measured by life expectancy at birth, education by average and expected years of schooling, and standard of living by gross domestic product (GDP) per capita [14]. The HDI is widely used to compare levels of human development across countries [14]. In Brazil, the municipal Human Development Index (HDI) uses three dimensions—longevity, education, and income—to evaluate and compare the development of municipalities and regions across the country [17, 18]. This study employed the 2021 Brazilian HDI to categorize the States and the Federal District [18]. We classified the States into three groups: Group A includes São Paulo and the Federal District, with a very high HDI (0.800 to 1.000). Group B comprises Maranhão, Alagoas, Amapá, Piauí, Pará, Bahia, Paraíba, and Roraima, which have a medium HDI (0.600 to 0.699). Group C comprises the remaining States, with a high HDI (0.700 to 0.799) [18].

We obtained demographic data for the Brazilian States from the TabNet - Resident Population dataset [15]. In Brazil, women aged 50 to 69 are the target population for breast cancer screening, with recommendations for biennial mammograms [2, 4]. Therefore, this study only includes data from women in this age group. The number of bilateral screening mammograms performed, by month and year of the test and patient's residence, was obtained from the TabNet - Outpatient Production dataset [15]. We collected data on breast cancer diagnoses and the stage at presentation, according to the month and year of diagnosis and the patient's residence, from the TabNet - Oncology Panel dataset [15]. Two main categories encompass breast cancer cases: non-invasive or localized disease (stages 0 to II) and advanced or locally advanced disease (stages III and IV) [15]. Finally, we gathered the initiation time for breast cancer treatment from the TabNet – Oncology Panel dataset based on the date of diagnosis and the patient's residence [15]. In Brazil, patients should begin cancer treatment within 60 days of diagnosis [7]. To assess this indicator, we calculated the proportion of women who initiated breast cancer treatment more than 60 days after the date of diagnosis, considering only cases where information on the time of treatment initiation was available.

The independent variable in this study was time (month). The study focused on key metrics related to breast cancer in women aged 50 to 69, including the screening rate with bilateral mammography (per 1,000 women), diagnosis rates at stages 0-II and III-IV (per 100,000 women), and the proportion of women who began treatment more than 60 days after diagnosis [21]. We meticulously defined the study period between January 2017 and December 2022 to ensure sufficient data for accurate statistical analysis across different time frames. We obtained the research data in September 2024 following a rigorous data collection process.

We compared the means or medians of continuous dependent variables across the three groups of Brazilian States using the ANOVA test for normally distributed data and the Kruskal-Wallis test for non-normal distributions [22]. We have established the statistical significance threshold at 5% ($p<0.05$). When necessary, we conducted a post-hoc test to compare all possible combinations of pairs of groups to identify which ones were significantly different [22]. We utilized the Tukey test for normally distributed data and the pairwise Mann-Whitney test with Bonferroni correction ($p<0.0167$ for three comparisons) for non-normally distributed data. We utilized the Shapiro-Wilk test to evaluate the normality of the data distribution ($p<0.05$ indicates non-normal distribution). We conducted the statistical analyses of the study using Minitab® software, version 19.2020.1, developed by Minitab Inc. in Pennsylvania, USA [22].

To analyze the trend of the dependent variables in the three groups of States, we utilized the Joinpoint Regression Program (JR program), Version 5.0.2, May 2023 (Statistical Study and Applications Branch, National Cancer Institute) [23]. The JR program determines the best model to represent the time series of the dependent variable by examining if using multiple timeline segments with multiple joinpoints or inflection points better fits the trend in time compared to a single line [23, 24]. In this study, the parameters used in the JR program were: dependent variable type crude rate or proportion; independent variable type monthly interval, heteroscedasticity errors option (weighted least squares) considering homoscedasticity (constant variance); fit the model to correct for the first-order autocorrelation estimated from the data; with logarithmic transformation of data; minimum joinpoint number of zero and maximum of three; selection model Weighted Bayesian Information Criteria (BIC) method; parametric method [23, 24].

The JR program specifies the position of each inflection point. Once the model is defined, the JR program calculates each segment's monthly percentage change (MPC). This information enables us to measure, illustrate, and compare the trend of each category (stationary, increasing, or decreasing) [23, 24]. The null hypothesis (stationary trend of the segment) represents an MPC equal to zero. In other words, the trend of the variable does not change over time, considering a 95% confidence interval (95% CI) and a 5% significance level. In the total time series, the JR program identifies the straight line that best represents the variable over time (zero inflection points) [23, 24]. We compared groups and periods within the interrupted and total time series. We analyzed the MPC trend and intensity, the variation's magnitude (ΔMPC), and the overlap of MPC confidence intervals (CI 95%). We used line graphs from Joinpoint Regression to visualize the inflection points and trend changes [23, 24].

Finally, we used Microsoft Excel® (Microsoft, Redmond, WA) for Office 365 MSO to tabulate and perform descriptive statistics on the dependent variables (mean, median, standard deviation, maximum, and minimum). The Ethics Committee approved the study, and the researchers followed STROBE guidelines [25].

Results

According to Table 1, the average monthly screening mammography rate in women aged 50 to 69 was significantly higher in Group A compared to Groups B and C (10.70 vs. 8.38 and 8.41; $p<0.001$). In the pre-pandemic period, the trend for this variable was stationary across the three state groups, as shown in Fig. 1; Table 2. At the beginning of the pandemic (March 2020), there was a change in the trend of the monthly mammography rate, which decreased for three months, with a greater

Table 1 Comparison of breast cancer screening, diagnosis, and treatment patterns between 2017 and 2022

Dependent variables	Group A (Mean ± SD, 95% CI)	Group B (Mean ± SD, 95% CI)	Group C (Mean ± SD, 95% CI)	*p*-value	Post-hoc Comparisons (Group Differences)	Normal Distribution	Statistical test used
Screening mammograms rate	10.70 ± 2.48 (10.11, 11.28)	8.38 ± 3.16 (7.64, 9.13)	8.41 ± 2.51 (7.82, 9.00)	< 0.001	A ≠ B, A ≠ C	No	Kruskal-Wallis
Breast cancer diagnosis rate at stage 0-II	3.42 ± 0.37 (3.32, 3.52)	2.88 ± 0.48 (2.78, 2.98)	3.68 ± 0.41 (3,58, 3.77)	< 0.001	A ≠ B, A ≠ C, B ≠ C	Yes	ANOVA
Breast cancer diagnosis rate at stage III-IV	2.9 ± 0.49 (2.79, 3.02)	2.77 ± 0.53 (2.66, 2.88)	3.43 ± 0.42 (3.32, 3.54)	< 0.001	A ≠ C, B ≠ C	Yes	ANOVA
The proportion of women with breast cancer who started treatment more than 60 days after diagnosis	64.37 ± 5.28 (63.26, 65.48)	64.50 ± 5.09 (63.39, 65.61)	62.06 ± 3.88 (60.95, 63.17)	0.003	A ≠ C, B ≠ C	Yes	ANOVA

Note: The analysis included women aged 50 to 69 years. The variables considered were the monthly breast cancer screening rates via bilateral mammography (per 1,000 women), the monthly breast cancer diagnosis rates for stages 0-II and III-IV (per 100,000 women), and the monthly proportion of women with breast cancer who initiated treatment more than 60 days post-diagnosis. The Shapiro-Wilk test ($p < 0.05$ indicating non-normal distribution) was used to assess data distribution. To compare group means and medians, we employed ANOVA and Tukey tests for normally distributed data and the Kruskal-Wallis test with pairwise Mann-Whitney tests applying Bonferroni correction for non-normally distributed data. Statistical significance was defined as $p < 0.05$

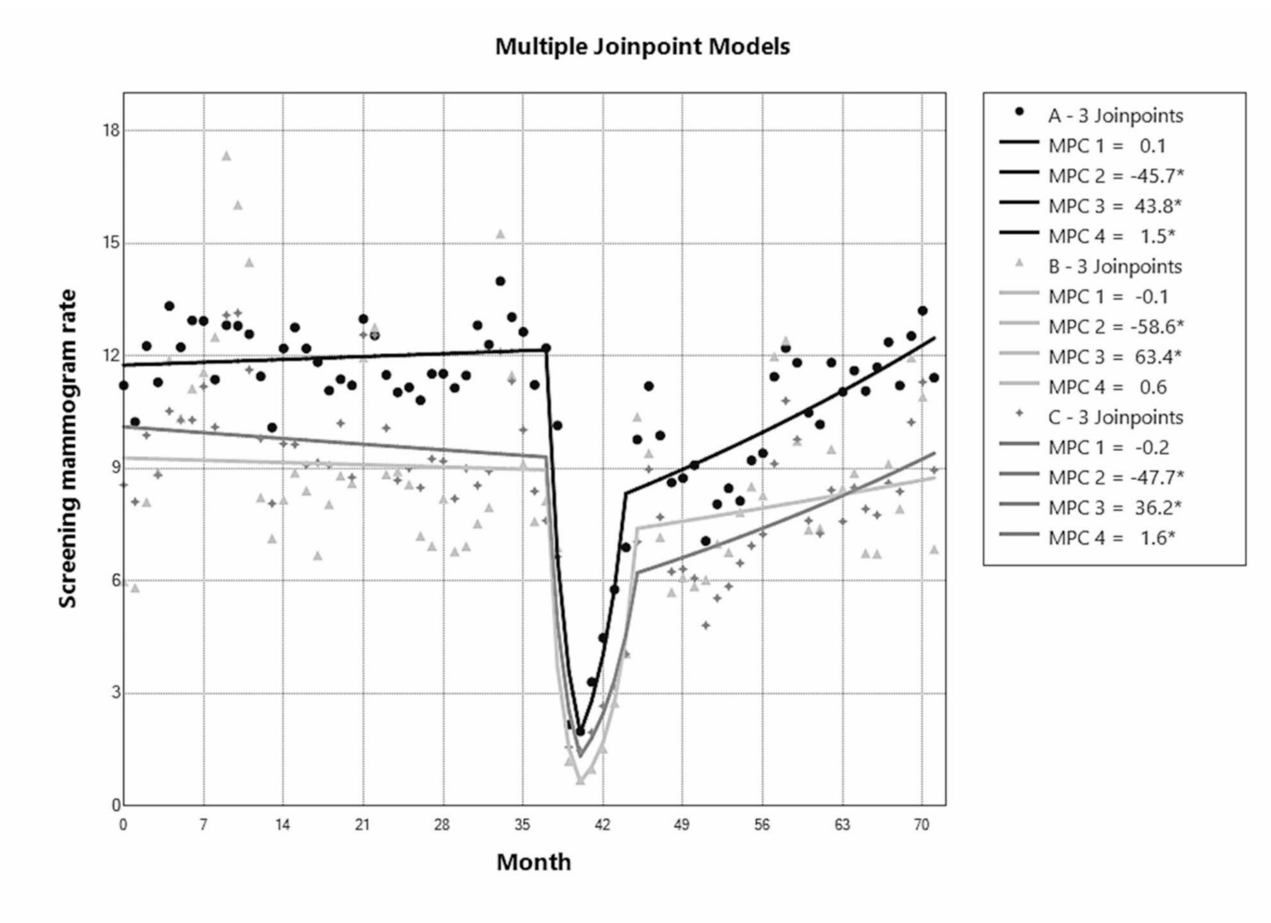

Fig. 1 Monthly trends in breast cancer screening mammogram rates by region in Brazil (2017–2022). Abbreviations: MPCn (Monthly Percentage Change by segment number), CI 95% (95% Confidence Interval), HDI (Human Development Index). Notes: The analysis includes women aged 50–69 years. The variable analyzed was the breast cancer screening rate (per 1,000 women). The COVID-19 pandemic was declared in Month 38 (March 2020). Group A represents regions with very high HDI in 2021, Group B includes regions with medium HDI in 2021, and Group C comprises regions with high HDI in 2021. *Indicates MPCn significantly differs from zero ($p < 0.05$), showing either a positive (increasing) or negative (decreasing) trend

Table 2 Monthly trends in breast cancer screening and time to treatment initiation by region in Brazil (2017–2022)

Dependent variables		Screening mammogram rate			The proportion of women treated more than 60 days after diagnosis		
Group		**A**	**B**	**C**	**A**	**B**	**C**
Segment 1	Lower Endpoint	January 2017	January 2017	January 2017	January 2017	January 2017	January 2017
	Upper Endpoint	February 2020	February 2020	February 2020	December 2019	March 2020	January 2020
	MPC	0.1	-0.1	-0.2	0.3*	0.3*	0.2*
	CI 95%	-0.2, 0.4	-1.2, 1.0	-0.8, 0.3	0.1, 0.5	0.1, 0.4	0.0, 0.3
	p-value	0.537	0.861	0.420	0.007	0.001	0.018
	Trend	Stationary	Stationary	Stationary	Increasing	Increasing	Increasing
Segment 2	Lower Endpoint	March 2020	March 2020	March 2020	January 2020	April 2020	February 2020
	Upper Endpoint	May 2020	May 2020	May 2020	April 2020	June 2020	May 2020
	MPC	-45.7*	-58.6*	-47.7*	-5.0	-10.4	-4.3
	CI 95%	-58.4, -29.2	-73.6, -35.1	-62.3, -27.6	-13.1, 4.0	-23.4, 4.8	--9.3, 1.1
	p-value	< 0.001	< 0.001	< 0.001	0.262	0.168	0.115
	Trend	Decreasing	Decreasing	Decreasing	Stationary	Stationary	Stationary
Segment 3	Lower Endpoint	June 2020	June 2020	June 2020	May 2020	July 2020	June 2020
	Upper Endpoint	September 2020	October 2020	October 2020	December 2022	September 2020	December 2022
	MPC	43.8*	63.4*	36.2*	0.8*	9.8	0.7*
	CI 95%	25.8, 64.4	35.8, 96.6	20.3, 54.2	0.5, 1.0	-6.1, 28.5	0.6, 0.9
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	0.236	< 0.001
	Trend	Increasing	Increasing	Increasing	Increasing	Stationary	Increasing
Segment 4	Lower Endpoint	October 2020	November 2020	November 2021		October 2020	
	Upper Endpoint	December 2022	December 2022	December 2022		December 2022	
	MPC	1.5*	0.6	1.6*		0.4*	
	CI 95%	1.0, 2.0	-1.1, 2.4	0.7, 2.6		0.1, 0.6	
	p-value	< 0.001	0.463	0.001		0.004	
	Trend	Increasing	Stationary	Increasing		Increasing	
Total time series	MPC	-0.3	-0.4	-0.6*	0.1	0.2*	0.0
	CI 95%	-0.7, 0.1	-1.2, 0.4	-1.1, -0.0	-0.0, 0.2	0.1, 0.2	-0.0, 0.1
	p-value	0.116	0.317	0.033	0.219	< 0.001	< 0.375
	Trend	Stationary	Stationary	Decreasing	Stationary	Increasing	Stationary

Abbreviations: MPC (Monthly Percentage Change), CI 95% (95% Confidence Interval), HDI (Human Development Index)

Notes: The analysis includes women aged 50–69 years. The variables analyzed were the breast cancer screening rate (per 1,000 women) and the proportion of women with breast cancer who initiated treatment more than 60 days after diagnosis. In March 2020, authorities declared the COVID-19 pandemic. Group A represents regions with very high HDI in 2021, Group B includes regions with medium HDI in 2021, and Group C comprises regions with high HDI in 2021. *Indicates MPC significantly differs from zero ($p<0.05$), showing either a positive (increasing) or negative (decreasing) trend

intensity in Group B (MPC −58.6%, $p<0.001$) than in Groups A (MPC −45.7%, $p<0.001$) and C (MPC −47.7%, $p<0.001$). The point of most minor reduction for this variable occurred in May 2020, being greater in Group B (-91.51%) compared to Groups A (-83.75%) and C (-80.67%) when analyzed relative to the month preceding the pandemic's onset (February 2020).

Following June 2020, there was a period of recovery in breast cancer screening rates, with an upward trend observed during the first 4 to 5 months. This increase was more pronounced in Group B (MPC 63.4%, $p<0.001$) compared to Group A (MPC 43.8%, $p<0.001$) and Group C (MPC 36.2%, $p<0.001$). Between October/November 2020 and December 2022, the growth rate of screening slowed in Groups A (MPC 1.5%, $p<0.001$) and C (MPC 1.6%, $p<0.001$), while the trend in Group B shifted to a stationary phase. Changes observed during the pandemic resulted in decreased breast cancer screening rates in the total time series compared to the pre-pandemic period. Specifically, there was a shift from a stable trend to a declining trend in Group C (MPC −0.6%, $p=0.033$). The decrease in screening rates (ΔMPC) was −0.4% in Groups A and C, and −0.3% in Group B, as shown in Table 2.

Based on Table 1, the average monthly rate of breast cancer diagnosis at stages 0-II for women aged 50 to 69 was significantly lower in Group B compared to Groups A and C (2.88 vs. 3.42 and 3.68; $p<0.001$). Before the pandemic, the trend of this variable was stable in Groups A and B and increasing in Group C (MPC 0.5%, $p<0.001$), as shown in Fig. 2; Table 3. At the onset of the COVID-19 pandemic, there was a decrease in the diagnosis rate of breast cancer at stages 0-II, with a more considerable

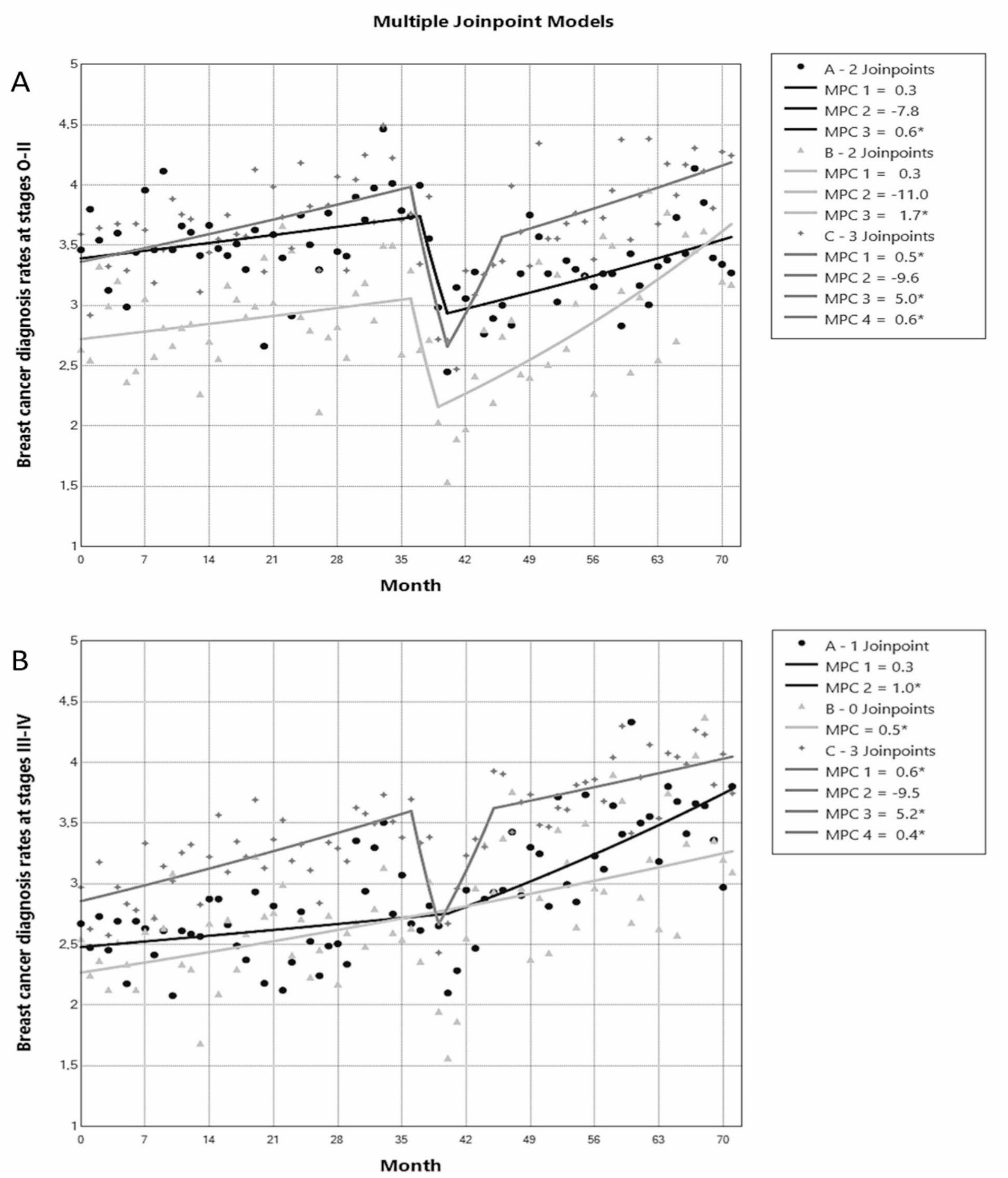

Fig. 2 Monthly trends in early and advanced-stage breast cancer diagnosis rates by region in Brazil (2017–2022). Abbreviations: MPCn (Monthly Percentage Change by segment number), CI 95% (95% Confidence Interval), HDI (Human Development Index). Notes: The analysis includes women aged 50–69 years. The variables analyzed were the breast cancer diagnosis rates at stages 0-II and III-IV (per 100,000 women). The COVID-19 pandemic was declared in Month 38 (March 2020). Group A represents regions with very high HDI in 2021, Group B includes regions with medium HDI in 2021, and Group C comprises regions with high HDI in 2021. *Indicates that MPCn significantly differs from zero ($p < 0.05$), showing either a positive (increasing) or negative (decreasing) trend

Table 3 Monthly trends in Brazil's early and advanced-stage breast cancer diagnosis rate by region (2017–2022)

Dependent variables		Breast cancer diagnosis rate at stage 0-II			Breast cancer diagnosis rate at stage III-IV		
Group		A	B	C	A	B	C
Segment 1	Lower Endpoint	January 2017	January 2017	January 2017	January 2017	January 2017	January 2017
	Upper Endpoint	February 2020	January 2020	January 2020	May 2020	December 2022	January 2020
	MPC	0.3	0.3	0.5*	0.3	0.5*	0.6*
	C I95%	-0.0, 0.5	-0.1, 0.7	0.3, 0.7	-0.0, 0.5	0.3, 0.7	0.5, 0.8
	p-value	0.057	0.113	< 0.001	0.054	< 0.001	< 0.001
	Trend	Stationary	Stationary	Increasing	Stationary	Increasing	Increasing
Segment 2	Lower Endpoint	March 2020	February 2020	February 2020	June 2020		February 2020
	Upper Endpoint	May 2020	April 2020	May 2020	December 2022		April 2020
	MPC	-7.8	-11.0	-9.6	1.0*		-9.5
	CI 95%	-28.0, 18.2	-42.8, 38.5	-18.5, 0.2	0.6, 1.4		-25.9, 10.5
	p-value	< 0.517	0.602	0.054	< 0.001		0.322
	Trend	Stationary	Stationary	Stationary	Increasing		Stationary
Segment 3	Lower Endpoint	June 2020	May 2020	June 2020			May 2020
	Upper Endpoint	December 2022	December 2020	November 2020			October 2020
	MPC	0.6*	1.7*	5.0*			5.2*
	CI 95%	0.3, 1.0	1.2, 2.2	0.8, 9.4			1.4, 9.2
	p-value	0.001	< 0.001	0.020			0.008
	Trend	Increasing	Increasing	Increasing			Increasing
Segment 4	Lower Endpoint			December 2020			November 2020
	Upper Endpoint			December 2022			December 2022
	MPC			0.6*			0.4*
	CI 95%			0.3, 1.0			0.1, 0.7
	p-value			< 0.001			0.004
	Trend			Increasing			Stationary
Total time series	MPC	-0.1	-0.1	0.2*	0.6*	0.5*	0.5*
	CI 95%	-0.2, 0.0	-0.0, 0.3	0.1, 0.3	0.4, 0.7	0.3, 0.7	0.4, 0.5
	p-value	0.096	0.109	0.004	< 0.001	< 0.001	< 0.001
	Trend	Stationary	Stationary	Increasing	Increasing	Increasing	Increasing

Abbreviations: MPC (Monthly Percentage Change), CI 95% (95% Confidence Interval), HDI (Human Development Index)

Notes: The analysis includes women aged 50–69 years. The variables analyzed were the breast cancer diagnosis rates at stages 0-II and III-IV (per 100,000 women). In March 2020, authorities declared the COVID-19 pandemic. Group A represents regions with very high HDI in 2021, Group B includes regions with medium HDI in 2021, and Group C comprises regions with high HDI in 2021. *Indicates MPC significantly differs from zero ($p<0.05$), showing either a positive (increasing) or negative (decreasing) trend

reduction in Group B (MPC −11.0%, $p=0.602$) compared to Groups A (MPC −7.8%, $p=0.517$) and C (MPC −9.6%, $p=0.054$), lasting for 3 to 4 months. Later, a recovery period was observed in all three groups, with an upward trend continuing until December 2022. Changes in the diagnosis rate of stage 0-II breast cancer during the pandemic resulted in a reduction in the overall intensity of the MPC across all groups in the total time series compared to the pre-pandemic period, with a ΔMPC of -0.4% in Groups A and B, and −0.3% in Group C.

The average monthly rate of breast cancer diagnosis at stages III-IV for women aged 50 to 69 was significantly higher in Group C compared to Groups A and B (3.43 vs. 2.90 and 2.77; $p<0.001$), as shown in Table 1. Between 2017 and 2022, the average proportion of advanced-stage breast cancer diagnoses was highest in Group B (49.02%) and lower in Groups C (48.24%) and A (45.97%). Before the pandemic, the trend in the diagnosis rate of breast cancer at stages III-IV was stable in Group A and increasing in Groups B (MPC 0.5%, $p<0.001$) and C (MPC 0.6%, $p<0.001$), as depicted in Fig. 2; Table 3. During the pandemic, this variable shifted to an upward trend in Group A (MPC 1.0%, $p<0.001$) and remained at the same intensity in Group B. In Group C, the upward trend started in June 2020 and continued until December 2022. Changes in the diagnosis rate of advanced-stage breast cancer during the pandemic resulted in an overall upward trend in the total time series across all groups compared to the pre-pandemic period, with a ΔMPC of 0.3% in Group A, 0% in Group B, and −0.1% in Group C.

The average proportion of breast cancer treatments initiated more than 60 days after diagnosis exceeded 60% in all groups, with the highest proportion in Group B (64.50%), as shown in Table 1. Before the pandemic, this variable showed an increasing trend across all groups, with a monthly percentage change (MPC) of 0.3% in

Groups A and B, and 0.2% in Group C, as indicated in Fig. 3; Table 2. At the onset of the COVID-19 pandemic, there was a decrease in the proportion of treatments initiated after 60 days, which lasted for 3 to 4 months, followed by a shift to a stable trend. Subsequently, the trend returned upward until December 2022, with a higher MPC than the pre-pandemic period.

Discussion

This study revealed that the COVID-19 pandemic in Brazil's public health system caused a decrease in breast cancer screening and early-stage diagnoses. It also led to increased advanced-stage diagnoses and delays in treatment initiation across all regions, with varying impacts on regional HDI levels. At the onset of the COVID-19 pandemic, there was a significant drop in the screening rate trend across the three groups of states, lasting for three months and being more intense in Group B. Subsequently, this variable recovered until December 2022, but it did not fully return to pre-pandemic levels across all groups. Early-stage diagnoses also declined during the first three months of the pandemic across all groups, with the sharpest decrease in Group B. There was a partial recovery, but it did not reach pre-pandemic levels. The pandemic sustained the upward trend of advanced-stage (III-IV) diagnoses in all groups. The average proportion of treatments initiated more than 60 days after diagnosis began to increase 3 to 4 months after the onset of the pandemic and continued to rise until December 2022, with greater intensity compared to the pre-pandemic period across all groups.

The COVID-19 pandemic has had a significant impact on breast cancer screening in different locations [10, 11]. Similar to our study, most countries experienced changes in mammogram trends in March 2020, coinciding with the World Health Organization's declaration of

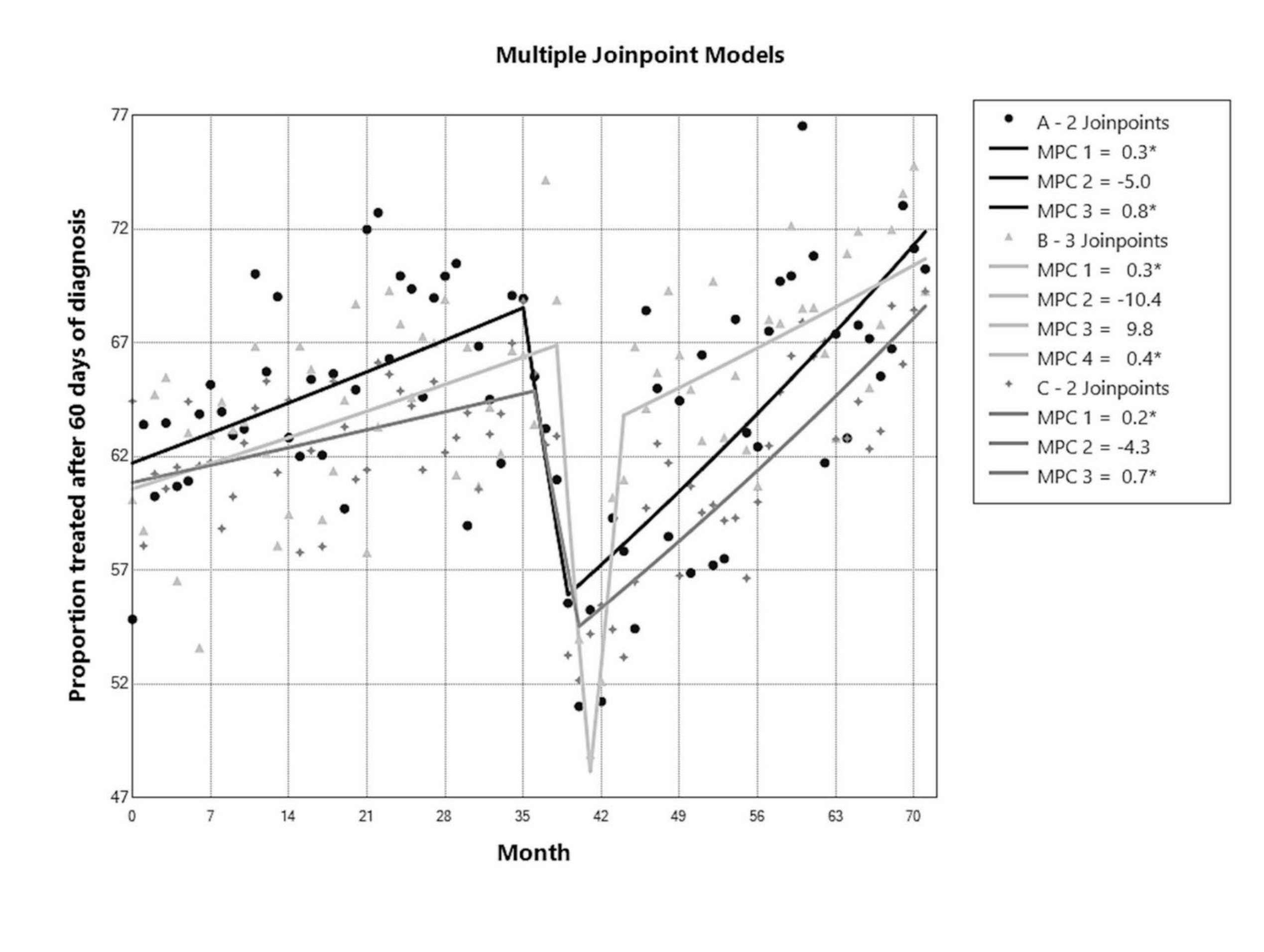

Fig. 3 Monthly trends in the proportion of women treated more than 60 days after breast cancer diagnosis by region in Brazil (2017–2022). Abbreviations: MPCn (Monthly Percentage Change by segment number), CI 95% (95% Confidence Interval), HDI (Human Development Index). Notes: The analysis includes women aged 50–69 years. The variable analyzed was the proportion of women with breast cancer who initiated treatment more than 60 days after diagnosis. The COVID-19 pandemic was declared in Month 38 (March 2020). Group A represents regions with very high HDI in 2021, Group B includes regions with medium HDI in 2021, and Group C comprises regions with high HDI in 2021. *Indicates that MPCn significantly differs from zero ($p < 0.05$), showing either a positive (increasing) or negative (decreasing) trend

the pandemic [26, 27]. Since then, breast cancer screening has been reduced or interrupted in several regions for periods ranging from 1 to 6 months [26]. Our study revealed that the average breast cancer screening rate varied significantly according to the regional HDI levels. The pandemic did not halt but significantly reduced the screening rate across all groups for three months, with the most intense decline observed in Group B. A study in a very high-HDI country, utilizing an interrupted time series, demonstrated that the most significant reduction in screening mammograms occurred in March, with a decrease of -85.1% [27]. In our study, the month with the most significant decrease in screening mammograms was May 2020 across all groups, with the most pronounced decline in states with medium HDI (-91.5%).

The healthcare system's ability to resume breast cancer screening is directly related to the subsequent recovery of the mammogram rate to pre-pandemic levels [26, 27]. For example, a study conducted in a very high-HDI country showed that in September 2020, about six months after the most significant reduction in the number of mammograms, the number of exams reached the expected levels for that month had the pandemic not occurred [27]. Our study indicated a more intense recovery period in the mammogram rate starting in June 2020, lasting for 4 to 5 months, followed by a slowdown in the growth of this variable until the end of the study across all groups. Compared to the pre-pandemic period, the recovery of the mammogram rate during the pandemic was insufficient to maintain the same trend or intensity of the MPC throughout the total time series across all analyzed groups.

The decrease in breast cancer screening rates at the onset of the COVID-19 pandemic, the insufficient recovery period, and the regional disparities based on the HDI stem from a variety of factors [13, 26–28]. The temporary suspension of non-essential health services and the prioritization of pandemic-related cases led to decreased availability of elective tests [10, 11, 28]. The fear of contracting COVID-19 also discouraged people from seeking healthcare services [10, 11, 28]. The interruption of awareness campaigns, public health initiatives, and changes in health behaviors contributed to a sustained decrease in demand for preventive tests, which was insufficient to return to pre-pandemic levels. Regions with lower HDI often face structural challenges such as inadequate health infrastructure, limited availability of tests, lower health education, difficulties in accessing primary care, and a shortage of healthcare professionals, particularly in remote and socioeconomically disadvantaged areas, which can limit women's access to screening tests [12, 13, 28]. These disparities in healthcare resources and access to services can lead to unequal health outcomes, highlighting the need for targeted public policies to address these regional disparities and ensure equitable access to cancer care, even in times of crisis.

The reduction in the number of breast cancer screening mammograms during the COVID-19 pandemic is a critical factor that may lead to an increase in advanced-stage diagnoses and, consequently, higher breast cancer mortality rates [11, 29]. Studies suggest that a six-month interruption in screening could double the number of stage III-IV cancer cases at diagnosis and increase mortality by 22.3% over five years [29]. A systematic review indicates that many high-HDI countries experienced a decrease in early-stage cancer diagnoses alongside an increase in advanced-stage cases during the pandemic [11]. Similarly, our study indicated a decline in the rate of stage 0-II breast cancer diagnoses at the onset of the pandemic, which persisted for three months, followed by a recovery period that was insufficient to restore the intensity observed during the pre-pandemic phase across the total time series. The impairment of breast cancer screening during the pandemic likely caused the decline in early-stage diagnoses. On the other hand, the upward trend in advanced-stage diagnoses suggests that many women, unable to access preventive testing, sought medical attention only when symptoms became more severe, resulting in a more significant number of late-stage diagnoses [11, 28, 29]. This shift in detection dynamics may reflect the direct impact of the pandemic on the distribution of disease stages at the time of diagnosis, with a higher proportion of patients being diagnosed at later, more advanced stages, which often have poorer prognoses and require more aggressive treatment.

The time interval between diagnosis and treatment initiation is a crucial indicator of the healthcare system's capacity to meet the needs of cancer patients, as delays can compromise prognosis and reduce survival rates [5–7]. In Brazil, Law No. 12.732/2012 mandates that cancer patients must begin treatment within 60 days after diagnosis is confirmed by the Public Health System [7]. Nonetheless, our study demonstrated that more than 60% of patients initiate therapy beyond this timeframe. Even before the pandemic, delays in initiating breast cancer treatment were already a problem, with a growing trend across all three groups. The suspension of elective services, the reprogramming of surgical treatments, and the prioritization of care for COVID-19 cases resulted in significant reductions or interruptions in the initiation of cancer treatment in many countries [28]. This may explain the increase in the proportion of women experiencing delays in treatment initiation, which began 3 to 4 months after the onset of the pandemic and continued until December 2022 across all groups. Thus, the pandemic not only delayed the detection of cancer in its early stages but also hindered the ability to initiate treatment promptly within the optimal timeframe, leading to an increase in the proportion of treatments initiated after the 60-day threshold as a result of the reorganization of services and patient care pathways. These delays in treatment initiation can have profound implications for patient outcomes, including increased disease progression and reduced survival rates [5, 6].

While the Human Development Index (HDI) has some limitations, it remains an important and globally recognized indicator, providing an overview of human development and living conditions. The HDI helps identify priority areas and plan equitable and effective public health policies [14]. Generally, countries or regions with solid socioeconomic development achieve higher HDI scores due to increased investments in education, healthcare, and income per capita, collectively improving living standards [14]. However, because the HDI relies on aggregated data, it can obscure critical information necessary for public policy planning, such as regional and sectoral disparities, infrastructure, and the subjective quality of life. Additionally, the HDI may not accurately reflect rapid economic changes (temporal limitation) and may overlook local differences among population groups, including inequalities related to gender, race, or social class. It can also underestimate the development of regions with prevalent informal or subsistence rural economies [14]. Nevertheless, our study showed that there may be differences in breast cancer care indicators among regions with varying HDI levels, even during the pandemic. This knowledge is essential because it can contribute to the planning of targeted public policies according to the needs of each region, aiming to ensure equity in cancer care, even in times of crisis. Therefore, while the HDI is valuable for global analyses, further research should incorporate complementary analyses that address regional inequalities, infrastructure, and cultural factors to enable more detailed and effective planning, particularly in a diverse country like Brazil.

Our study has some limitations that need to be acknowledged. The results only apply to women between the ages of 50 and 69. The study analyzes only screening mammograms, excluding those intended for other purposes, such as diagnostic, pre-surgical, and post-treatment follow-up. The dataset we utilized contains information from the public health system, which serves most of the population, but does not include data from the private system, which caters to approximately 25% of the population. Furthermore, there may be inaccuracies or delays in recording information in this database and the possibility of patients moving between states with different levels of HDI for tests or treatments. However, our method of collecting data from the dataset considered the date of the test or treatment (rather than the date the information became available) and the patient's residence (instead of the location where the test or treatment took place. This approach was crucial for minimizing bias. It's important to note that there might be delays of up to six months in recording tests and treatments in the dataset. However, the time gap between the end of the study period (December 2022) and the data collection (September 2024) significantly helps to address this issue.

Conclusion

The COVID-19 pandemic significantly impacted Brazil's public health system, leading to a reduction in breast cancer screening and early-stage diagnoses. Simultaneously, there was an increase in advanced-stage (III-IV) diagnoses and delays in the initiation of treatments across all regions, with varying impacts according to regional HDI levels. These findings are significant because they highlight regional inequalities in the pandemic's effect on breast cancer care in Brazil, particularly in regions with different HDI levels. Understanding these effects is essential to guide the planning of public policies that ensure the equitable resumption of health services, focusing on reducing delays in diagnosis and treatment. This knowledge can contribute to developing more robust strategies to face future crises, ensuring that cancer care is not compromised and that health equity is preserved, even during a pandemic.

Abbreviations

BIC	Bayesian Information Criteria
COVID-19	Novel Coronavirus disease
GDP	Gross Domestic Product
HDI	Human Development Index
JR	Joinpoint Regression Program
MPC	Monthly Percent Change
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

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Author contributions

Study conception and design: A.H., E.S.M.C. and S.C.K.; analysis planning, data collection, verification, and data analysis: A.H., E.S.M.C. and S.C.K.; data interpretation, drafting and critical revision of the article and approved the final submitted version: A.H., E.S.M.C. and S.C.K.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The Ethics Committee of the Health Sciences Sector at the Federal University of Paraná (SCS/UFPR) waived the requirement for informed consent under registration number CAAE 51438521.2.0000.0102. This study exclusively utilized a publicly accessible dataset and did not involve human participants or experimental animals. We conducted all procedures following the applicable guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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