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The intersection of race/ethnicity and socioeconomic status: inequalities in breast and cervical cancer mortality in 20,665,005 adult women from the 100 Million Brazilian Cohort

Emanuelle F. Góes[a*], Joanna M. N. Guimarães[a*], Maria da Conceição C. Almeida[b], Ligia Gabrielli[c,d], Srinivasa Vittal Katikireddi[e], Ana Clara Campos[a], Sheila M. Alvim Matos[d], Ana Luísa Patrão[f], Ana Cristina de Oliveira Costa[g], Manuela Quaresma[h], Alastair H. Leyland[e], Mauricio L. Barreto[a,d], Isabel dos-Santos-Silva[h**] and Estela M. L. Aquino[d**]

[a]Centre for Data and Knowledge Integration for Health (CIDACS), Gonçalo Moniz Institute, Oswaldo Cruz Foundation, Bahia, Brazil; [b]Gonçalo Moniz Institute, Oswaldo Cruz Foundation, Salvador, Brazil; [c]Centro de Diabetes e Endocrinologia da Bahia, Secretaria de Saúde do Estado da Bahia, Bahia, Brazil; [d]Instituto de Saúde Coletiva, Universidade Federal da Bahia, Salvador, Brazil; [e]MRC/CSO Social & Public Health Sciences Unit, University of Glasgow, Glasgow, UK; [f]Center for Psychology, Faculty of Psychology and Education Science, University of Porto, Porto, Portugal; [g]Programa de Pós-graduação em Saúde Coletiva do Instituto René Rachou/FIOCRUZ Minas; [h]Faculty of Epidemiology and Population Health, London School of Hygiene & Tropical Medicine, London, UK

ABSTRACT

Objectives: There is limited evidence regarding the impact of race/racism and its intersection with socioeconomic status (SES) on breast and cervical cancer, the two most common female cancers globally. We investigated racial inequalities in breast and cervical cancer mortality and whether SES (education and household conditions) interacted with race/ethnicity.

Design: The 100 Million Brazilian Cohort data were linked to the Brazilian Mortality Database, 2004–2015 (n = 20,665,005 adult women). We analysed the association between self-reported race/ethnicity (White/'Parda'(Brown)/Black/Asian/Indigenous) and cancer mortality using Poisson regression, adjusting for age, calendar year, education, household conditions and area of residence. Additive and multiplicative interactions were assessed.

Results: Cervical cancer mortality rates were higher among Indigenous (adjusted Mortality rate ratio = 1.80, 95%CI 1.39–2.33), Asian (1.63, 1.20–2.22), 'Parda'(Brown) (1.27, 1.21–1.33) and Black (1.18, 1.09–1.28) women vs White women. Breast cancer mortality rates were higher among Black (1.10, 1.04–1.17) vs White women. Racial inequalities in cervical cancer mortality were larger among women of poor

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CONTACT Joanna M. N. Guimarães joannaguimaraes@hotmail.com Centre for Data and Knowledge Integration for Health (CIDACS), Gonçalo Moniz Institute, Oswaldo Cruz Foundation, Ed. Tecnocentro, sl 315, R Mundo 121, Trobogy, 41745-715, Salvador, Bahia, Brazil

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*These authors share the first authorship of the paper.

**These authors share the senior authorship.

household conditions, and low education (P for multiplicative interaction <0.001, and 0.02, respectively). Compared to White women living in completely adequate (3–4) household conditions, the risk of cervical cancer mortality in Black women with 3–4, 1–2, and none adequate conditions was 1.10 (1.01–1.21), 1.48 (1.28–1.71), and 2.03 (1.56–2.63), respectively (Relative excess risk due to interaction-RERI = 0.78, 0.18–1.38). Among 'Parda'(Brown) women the risk was 1.18 (1.11–1.25), 1.68 (1.56–1.81), and 1.84 (1.63–2.08), respectively (RERI = 0.52, 0.16–0.87). Compared to high-educated White women, the risk in high-, middle- and low-educated Black women was 1.14 (0.83–1.55), 1.93 (1.57–2.38) and 2.75 (2.33–3.25), respectively (RERI = 0.36, −0.05–0.77). Among 'Parda'(Brown) women the risk was 1.09 (0.91–1.31), 1.99 (1.70–2.33) and 3.03 (2.61–3.52), respectively (RERI = 0.68, 0.48–0.88). No interactions were found for breast cancer.
Conclusion: Low SES magnified racial inequalities in cervical cancer mortality. The intersection between race/ethnicity, SES and gender needs to be addressed to reduce racial health inequalities.

Introduction

Breast and cervical cancers are the two most common female cancers globally (Sung et al. 2021). Together they represent a heavy burden of disease for women and their families in low- to middle-income countries (LMICs) (Sanjose and Tsu 2019), despite being potentially preventable or curable (Ginsburg et al. 2017). Breast and cervical cancers are also emblematic of the ongoing 'cancer transition' in LMICs – i.e. a shift from a predominance of cancers with an infectious aetiology (e.g. cervical, stomach cancers) to cancers associated with lifestyle and environmental risk factors (e.g. breast and lung cancers) (Ginsburg et al. 2017).

Breast cancer incidence is higher in high-income countries and among women with more advantaged socio-economic status (SES) (Ginsburg et al. 2017). However, breast cancer mortality has increased in LMICs due to late diagnosis when the disease is already at an advanced stage and treatment is less effective (dos-Santos-Silva et al. 2019). Differences in breast cancer survival by SES, poverty, and levels of access to healthcare services and preventive care have been well documented (Coughlin 2019). Differences in breast cancer stage at diagnosis and survival by race/ethnicity have also been observed, probably as a consequence of mechanisms shaped by structural racism (Coughlin 2019; dos-Santos-Silva et al. 2019; Williams, Priest, and Anderson 2016). Racism, in its different manifestations, can contribute to delays in cancer diagnosis and treatment and, consequently, poorer survival rates (Coughlin 2019; Williams, Priest, and Anderson 2016).

Cervical cancer develops slowly, with its principal risk factor being persistent infection by the sexually transmitted human papillomavirus (HPV). Citology-based, and more recently, HPV-based screening, dramatically reduces the incidence of, and mortality from cervical cancer with further reductions expected to occur when the cohorts of young women who have been vaccinated against HPV reach the ages when cervical cancer incidence is highest (Glick et al. 2012; Pan American Health Organization 2018). Nevertheless, globally, one woman dies every two minutes from cervical cancer, with most cases and deaths occurring in LMICs (Ginsburg and Paskett 2018). A strong association has been established between cervical cancer and a low human

development index, poverty, poorer education, and gender inequalities (Dantas et al. 2020; Renna and Silva 2018). There is also evidence of cervical cancer vaccination and screening deficits by race/ethnicity (Ginsburg and Paskett 2018).

Brazil is deeply marked by racial and social inequities resulting from a harsh process of colonization that subjugated the native Indigenous populations and enslaved African Black people for over four centuries (Werneck 2016). This has affected the life and health conditions of Black, 'Parda'(Brown) and Indigenous populations through diverse expressions of racism (structural and institutional) (Werneck 2016). The intersection of race/racism with other axes of marginalization, such as SES and gender, shapes life opportunities, residential contexts and difficulty in accessing healthcare (Barber et al. 2018; Constante and Bastos 2021; Crenshaw 1989), magnifying race differences in health. Women of Black, 'Parda'(Brown) and Indigenous race/ethnicity, those with a lower education level and those living in urban peripheries and the poorest areas of the country tend to have less access to gynaecological consultations, mammography and screening tests for breast and cervical cancers (Cabral et al. 2019; dos-Santos-Silva et al. 2019; Renna and Silva 2018). Nevertheless, data are scarce on the role of race/racism in Brazil and its interrelation with SES on mortality rates from breast and cervical cancers.

We used race as a social, not a biological construct. Studies on racial inequality in the health-disease process uncover the history of oppression and racial hierarchies experienced by the Black population and Indigenous peoples over many years, as well as the systematic racial discrimination they have endured. Therefore, race can be understood as a proxy for racism and its manifestations (Araújo et al. 2020; Lett et al. 2022; Williams, Lawrence, and Davis 2019).

In this study, we used data from a large-scale population-based cohort (the 100 Million Brazilian Cohort) (Barreto et al. 2021), to examine racial/ethnic inequalities in breast and cervical cancer mortality as well as the interaction between race/ethnicity and SES. This cohort was assembled through linkage of several administrative databases and benefits from a very large sample size, which is crucial when investigating rare events such as deaths from site-specific cancers, and a wealth of data on social determinants, which allow consideration of multiple and intersecting social dimensions.

Materials and methods

Study design and participants

This is a longitudinal study based on the 100 Million (100M) Brazilian Cohort, a population-based cohort built from the Brazilian Government's Unified Register for Social Programmes (CadUnico), which includes data from over 114 million low-income Brazilians (nearly 55% of the country's population) for the 2001–2015 period (Barreto et al. 2021). For the present study, the 100M Brazilian Cohort baseline dataset was probabilistically linked to the Brazilian Mortality Database to identify women in the cohort who had died from breast or cervical cancer during follow-up. Detailed linkage procedures can be found elsewhere (Barreto et al. 2021).

For the present study, all women enrolled in CadUnico between January 1, 2004 (as levels of data missingness were high for those enrolled in previous years) and December

31, 2015 (the last year for which mortality data were available), and who were aged between 18 and 100 years at enrollment, were potentially eligible to participate. Women whose date of death was earlier than their date of enrollment into the cohort (probable due to linkage errors) and those with missing data on race/ethnicity were subsequently excluded, leaving 20,665,005 women for analysis (Figure 1).

We considered race/ethnicity as a fundamentally social construct, i.e. the perceived effect of life experiences of racism (Araújo et al. 2020; Lett et al. 2022). Data on self-reported race/ethnicity were collected at the time of enrollment in CadUnico via face-to-face interviews using the classification officially adopted by the Brazilian Institute of Geography and Statistics census (Bashir et al. 2023; Lett et al. 2022; Petruccelli, Saboia, and Instituto Brasileiro de Geografia e Estatística 2013), with five response options: White, 'Parda'(or Brown, a proxy for people of mixed White and Black race/ethnicity), Black, Yellow (Asian or people of Asian descent), or Indigenous (Brazilian indigenous) people.

Information on the occurrence of deaths during follow-up, including their underlying cause coded according to the International Classification of Diseases (ICD-10), was obtained through linkage to the national Mortality Database. Breast and cervical cancer-specific deaths, the outcomes of interest, were those with an underlying cause coded as ICD-10 C50 and C53, respectively.

Data on covariates were also collected at enrollment into CadUnico including information on age, education level (categorized as ≤5, 6–9, > 9 years of schooling) and household conditions (categorized as '3 or 4', '2 or 1' or 'none' of adequate availability of water

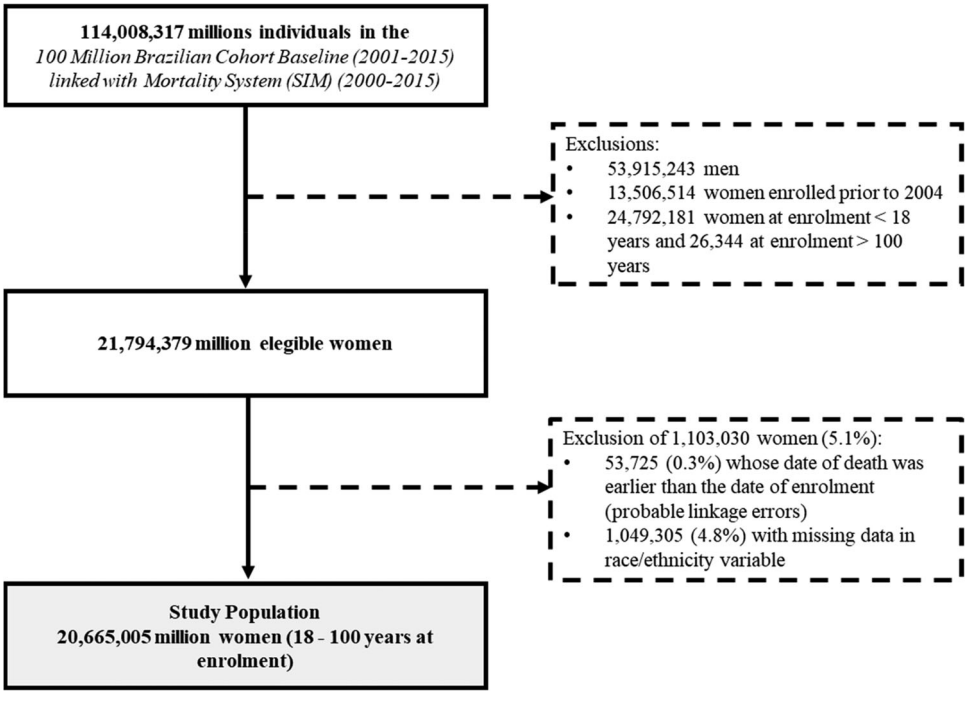

Figure 1. Flowchart of study participants' selection.

supply, sewage disposal, waste disposal/garbage collection, and electricity supply) (Supplemental material 1), and area of residence (rural vs urban). For descriptive purposes, we used: geographical region of residence, being a recipient of the Brazilian conditional cash transfer program (*Bolsa Família* Program), and at the municipality level, Family Health Strategy (*ESF-Estratégia de Saúde da Família*) coverage, a primary healthcare component of the Brazilian National Health System (SUS), and the Brazilian Deprivation Index (BDI) (Allik et al. 2020), an area-based composite score, which combines data on income, literacy and housing characteristics.

Statistical analysis

The sample characteristics were described by race/ethnic group. Breast and cervical cancer-specific mortality rates, expressed per 100,000 women-years, were obtained by dividing the number of deaths due to breast or cervical cancer, by the total women-years at risk during the follow-up. Time at risk was calculated from the time a woman was enrolled into CadUnico to the time of her death from cervical or breast cancer, death from another cause, or the end of follow-up for the present analysis (i.e. December 31, 2015), whichever occurred first. Poisson regression models, with Lexis expansion to account for the time-dependent nature of the variables age and calendar year, were used to estimate mortality rate ratios (MRR) and 95% confidence intervals (95%CI). Associations of race/ethnicity with cancer mortality were estimated after adjustments for age and calendar year (model 1). Then, we added to model 1 the variables education and household conditions to account for race/ethnic differences in individual SES, and area of residence to account for race/ethnic differences in area SES (model 2).

Educational level and household conditions were investigated as potential effect modifiers of racial/ethnic differences in the risk of dying from breast and cervical cancer, on both multiplicative and additive scales (VanderWeele and Knol 2014). For the former, multiplicative interaction terms between race/ethnicity and education, and between race/ethnicity and household conditions, were added to model 2, separately for each effect modifier and each outcome. If the interaction term was significant ($p < 0.05$) based on likelihood ratio test, stratified effects were obtained by calculating the MRR for race/ethnicity within strata of the effect modifier (education or household conditions). For the latter, joint effects were obtained by calculating the MRR for each stratum of race/ethnicity and the effect modifier (education or household conditions) combined, taking White women with high education or White women with all adequate household conditions as the reference category (i.e. the stratum with the lowest risk for the outcome). The relative risk due to interaction (RERI), and its 95% CI, which represents the combined effects based on an additive scale, was calculated to indicate the presence of additive interaction from risk ratio estimates.(VanderWeele and Knol 2014) A value of RERI > 0 indicates the presence of a positive additive interaction whilst values < 0 or = 0 corresponds to the presence of a negative, or absence of additive interaction, respectively.(VanderWeele and Knol 2014) Asian and Indigenous women were excluded from the interaction analyses, due to the small number of deaths in these subgroups.

In sensitivity analysis, to assess the extent to which the observed effect of race/ethnicity on mortality might reflect poorer quality of the data, i.e. misclassification of cervical

cancer, or underreporting of mortality among the poorest for both cancers, we restricted analysis to: (i) women aged <45 years, among whom uterine corpus cancer is very rare and hence virtually all unspecified cases can be assumed to be cervical cancer, and compared findings from analyses in which the outcome was defined as 'cervical cancer (ICD-10 C53)' with those from analyses in which the outcome was defined as either 'cervical cancer (C53)' or 'uterus cancer, part unspecified (C55)', and (ii) Brazilian municipalities known to have high death registration coverage (≥95%).

All statistical analyses were performed in Stata, version 15.1.

Results

Of the 20,665,005 participants, 34.5% self-reported as White, 56% as 'Parda'(Brown), 8.6% as Black, 0.5% as Asian, and 0.5% as Indigenous women. 'Parda'(Brown), Black and Indigenous women were more likely to be younger, lower educated, and a recipient of the conditional cash transfer program, compared to White and Asian women. 'Parda'(Brown) and Indigenous women were more likely to live in households with less-than-adequate conditions, in municipalities with higher FHS coverage and in more deprived and rural areas (Table 1).

Mortality in the whole study population was lower for cervical cancer than for breast cancer (age-standardised rates: 5.38 and 8.15 per 100,000 women-years, respectively). There were, however, marked racial/ethnic differences in mortality rates. For cervical cancer, age-standardised rates were highest for Indigenous women and lowest for White women. For breast cancer, age-standardised rates were highest for Black women and lowest for Indigenous women (Supplemental material 2).

Relative to White women – and after adjustments for age, calendar year, educational level, household conditions and area of residence (Table 2, model 2) – mortality from cervical cancer was 80% (MRR = 1.80, 95%CI 1.39–2.33) higher among Indigenous, 63% (1.63, 1.20–2.22) higher among Asian, 27% (1.27, 1.21–1.33) higher among 'Parda'(Brown), and 18% (1.18, 1.09–1.28) higher among Black women. Black women had 10% (1.10, 1.04–1.17) higher mortality from breast cancer than their White counterparts whilst 'Parda'(Brown) and Indigenous women had, respectively, 14% (0.86, 0.82–0.89) and 37% (0.63, 0.44–0.91) lower risk. Education level was negatively associated with cervical cancer mortality with the lowest-educated women being 2.6 times more likely to die from this cancer relative to the highest-educated women (P for linear trend (Pt) < 0.001, Table 2). No association was observed between educational level and breast cancer mortality (Pt = 0.84, Table 2). Women with no adequate household conditions were at increased risk of dying from cervical cancer but decreased risk of dying from breast cancer, compared to those with 3–4 adequate conditions (MRR (95% CI) = 1.53 (1.38–1.70) and 0.75 (0.67–0.84) respectively, (Pt < 0.001 for both), Table 2).

Stratified analysis by household conditions showed that racial differences in cervical cancer mortality were greater among women living in poorer household conditions (P for multiplicative interaction <0.001, Figure 2A). In contrast, there was no evidence that the risk of dying from breast cancer was modified by household conditions on a multiplicative scale (P for multiplicative interaction = 0.97, Figure 2B). Stratification by educational level showed that racial differentials in cervical cancer mortality were greater among less-educated women (P for multiplicative interaction = 0.02, Figure 2C). There

Table 1. Baseline characteristics of the study sample, by race/ethnicity. 100 Million Brazilian Cohort (2004–2015), N = 20,665,005 women aged 18–100 years.

	Race/Ethnicity				
Variables	White N = 7,122,396 (34.5%)	'Parda'(Brown) N = 11,565,543 (56.0%)	Black N = 1,776,498 (8.6%)	Asian descent N = 96,198 (0.5%)	Indigenous N = 104,370 (0.5%)
Age (years), mean (SD)	38.0 (16.2)	35.0 (14.9)	36.5(15.1)	37.3 (16.2)	32.6 (14.0)
Education level (years), %					
>9 years	29.7	27.2	24.1	35.3	14.7
6–9	28.0	28.3	28.5	24.1	22.3
<=5	42.3	44.5	47.4	40.6	63.0
Adequate household conditions*, %					
3 or 4	79.2	66.9	72.8	72.8	28.6
1 or 2	9.5	14.0	12.1	11.9	14.8
None	11.3	19.1	15.1	15.3	56.6
Area of residence, %					
Urban	83.8	77.8	83.2	80.5	34.4
Rural	16.2	22.2	16.8	19.5	65.6
Region of residence, %					
Southeast	45.7	28.3	46.1	32.4	9.5
South	25.1	3.0	7.1	5.9	7.1
Central-west	6.8	8.3	6.1	14.4	19.7
Northeast	19.0	46.0	35.0	33.1	24.8
North	3.4	14.4	5.7	10.1	38.9
Conditional cash transfer, %					
Yes	65.0	76.8	78.1	63.6	90.9
No	35.0	23.2	21.9	36.4	9.1
FHS coverage of area of residence‡, %					
High (>70%)	36.0	45.2	36.1	43.6	50.5
Medium (50–70%)	14.2	14.3	13.3	13.7	16.5
Low (<50%)	49.8	40.4	50.6	42.7	33.0
Deprivation of área of residence, %¶					
Very low / Low	38.4	16.7	29.7	22.5	5.6
Medium	22.6	17.6	23.7	20.5	8.1
Very high / High	39.0	65.7	46.6	57.0	86.3

*Availability of adequate facilities for water supply, sewage disposal, waste disposal/garbage collection, and electricity supply (see Methods section and Supplemental material 1).

‡Percentage of the population covered by primary healthcare provided by the FHS-Family Health Strategy (*ESF-Estratégia de Saúde da Família*), a component of the Brazilian National Health System (SUS).

¶Based on the Brazilian Deprivation Index, an area-based composite score, which combines data on income, literacy and housing characteristics.

was no evidence that the magnitude of the racial/ethnic differences in breast cancer mortality was modified, on a multiplicative scale, by a woman's education level (P for multiplicative interaction = 0.71, Figure 2D).

Figure 3 shows the joint effects of race/ethnicity and each effect modifier on cancer mortality. Relative to White women living in households with 3–4 adequate conditions, Black and 'Parda'(Brown) women living in households with similar conditions had only a 10% (MMR = 1.10, 95%CI 1.01–1.21) and a 18% (1.18, 1.11–1.25) higher risk of dying from cervical cancer, respectively, whilst Black and 'Parda'(Brown) women living in households with no adequate conditions had much higher risks – 100% (MRR = 2.03, 1.56–2.63) and 84% (1.84, 1.63–2.08), respectively. These estimates translated into a RERI for none adequate household conditions of 0.78 (95%CI 0.18–1.38) and 0.52 (0.16–0.87) for Black and 'Parda'(Brown) women, respectively, indicating a positive additive interaction between poor household conditions and race/ethnicity (Figure 3A). Regarding breast cancer, the poorer the household conditions the lower the mortality risks, with little evidence of additive interaction (RERI for none adequate household

Table 2. Mortality rate ratios from cervical and breast cancer associated with race/ethnicity. 100 Million Brazilian Cohort (2004-2015), N = 20,665,005 women aged 18–100 years.

	Cervical cancer – MRR (95%CI)		Breast cancer - MRR (95%CI)	
Variables	Model 1	Model 2	Model 1	Model 2
Race/ethnicity				
White	1.00	1.00	1.00	1.00
'Parda'(Brown)	1.31 (1.25–1.38)	1.27 (1.21–1.33)	0.83 (0.80–0.87)	0.86 (0.82–0.89)
Black	1.22 (1.13–1.32)	1.18 (1.09–1.28)	1.09 (1.03–1.15)	1.10 (1.04–1.17)
Asian descent	1.58 (1.17–2.14)	1.63 (1.20–2.22)	0.75 (0.55–1.03)	0.77 (0.55–1.08)
Indigenous	1.99 (1.56–2.54)	1.80 (1.39–2.33)	0.49 (0.35–0.70)	0.63 (0.44–0.91)
Education level (years)				
>9 years		1.00		1.00
6–9		1.80 (1.63–1.98)		0.98 (0.92–1.05)
<=5		2.57 (2.34–2.81)		0.99 (0.93–1.05)
P-for linear trend		<0.001		0.843
Adequate household conditions*				
3 or 4		1.00		1.00
1 or 2		1.33 (1.25–1.41)		0.81 (0.76–0.85)
None		1.53 (1.38–1.70)		0.75 (0.67–0.84)
P-for linear trend		<0.001		<0.001

Abbreviations: MRR, Mortality rate ratio; CI, Confidence interval.
*Availability of adequate facilities for water supply, sewage disposal, waste disposal/garbage collection, and electricity supply (see Methods section and Supplemental material 1).
Model 1: adjusted for age and calendar year.
Model 2: Model 1 + education level, household conditions and area of residence (rural vs urban).

conditions: −0.11 (95%CI −0.40–0.18) and 0.02 (−0.17–0.21), for Black and 'Parda'(Brown) women, respectively) (Figure 3B). Relative to White women with highest education, Black and 'Parda'(Brown) women with similar education level had a 14% (MMR = 1.14, 95%CI 0.83–1.55) and 9% (1.09, 0.91–1.31) higher risk of cervical cancer mortality, respectively, whilst Black and 'Parda'(Brown) women with lowest education level had a risk nearly 300% higher (MRR = 2.75, 95%CI 2.33–3.25 and 3.03, 2.61–3.52, respectively), reflecting a RERI for lowest education of 0.68 (95%CI 0.48–0.88) and 0.36 (−0.05–0.77) for 'Parda'(Brown) and Black women, respectively, indicating a positive additive interaction between lower education and race/ethnicity (Figure 3C). The risk of breast cancer mortality was higher for Black and lower for 'Parda'(Brown) women, irrespective of their education level, with little evidence of additive interaction (RERI for lowest education: −0.08 (95%CI −0.30–0.14) and 0.001 (−0.11–0.11) for Black and 'Parda'(Brown) women, respectively) (Figure 3D).

Sensitivity analyses restricted to women aged <45 years who died from cervical cancer or from an unspecified cancer of the uterus (ICD-10, C55) yielded similar results (Supplemental material 3). Similarly, analyses restricted to Brazilian municipalities with high (≥95%) death registration coverage yielded similar overall findings albeit, for cervical cancer, the MRR for Indigenous vs. White women increased slightly from 1.80 to 1.92 whilst the MRR for Asian vs. White women decreased from 1.63 to 1.30 and was no longer statistically significant (Supplemental material 4).

Discussion

This cohort study of over 20 million Brazilian women provided an unprecedented opportunity to investigate racial inequalities in breast and cervical cancer mortality, and their

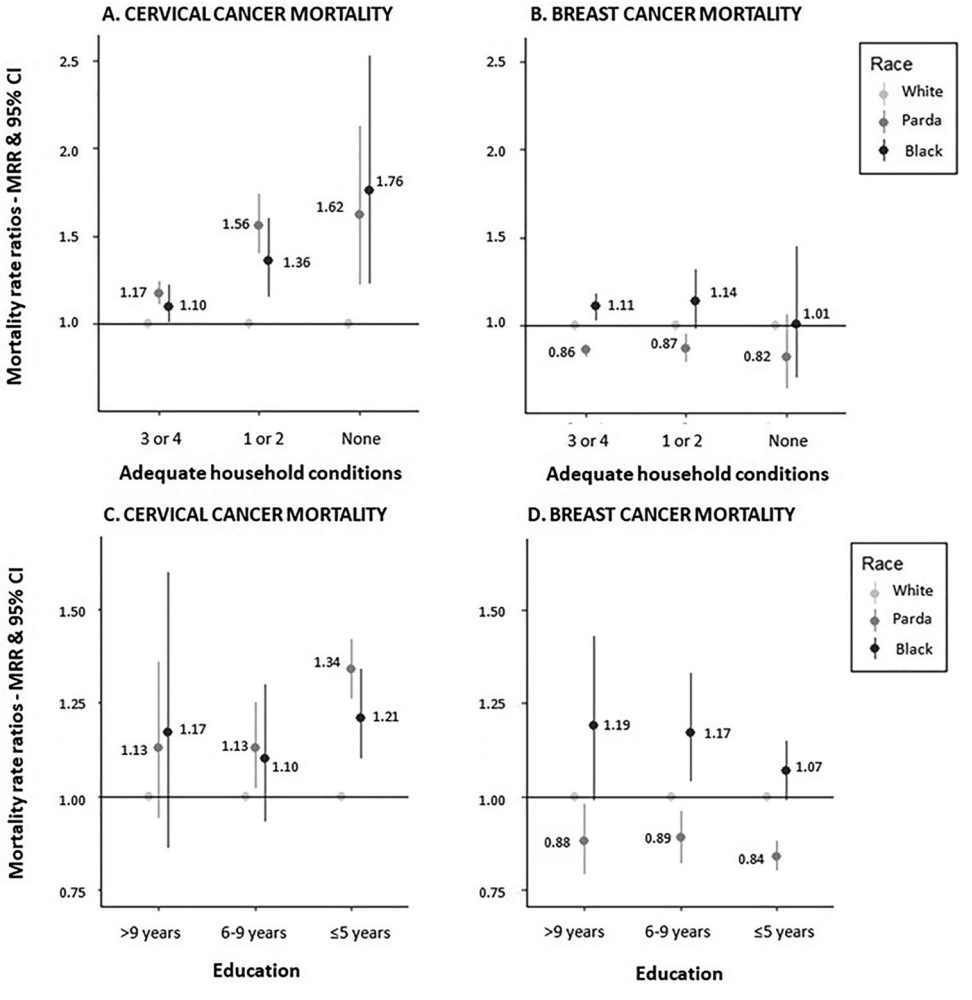

Figure 2. Breast and cervical cancer mortality associated with race/ethnicity, stratified by household conditions* (2A and 2B) and educational level** (2C and 2D). 100 Million Brazilian Cohort (2004–2015), N = 20,464,437 women aged 18–100 years. Abbreviations: MRR, Mortality rate ratio; CI, Confidence interval. *Adjusted for age, calendar year, education, area of residence and interaction term between race and household conditions.**Adjusted for age, calendar year, household conditions, area of residence and interaction term between race and education. Figure 2A. P for multiplicative interaction <0·001; Figure 2B: P for multiplicative interaction = 0·97; Figure 2C: P for multiplicative interaction = 0·02; Figure 2D: P for multiplicative interaction = 0·71. Note: Asian and Indigenous woman were excluded due to small N of deaths. Stratified effect was obtained by estimating mortality rate ratios (MRR) with 95%CI for race/ethnicity within strata of the effect modifier (household conditions or educational level).

intersection with SES, in a multi-ethnic LMIC. The findings revealed marked racial/ethnic differences in the risk of dying from both cervical and breast cancers. Using an intersectional approach, the study also showed an interaction, on both additive and multiplicative scales, between race/ethnicity and education and between race/ethnicity and household conditions, such that racial inequalities in cervical cancer mortality were stronger among women of low-educational level and those living in inadequate

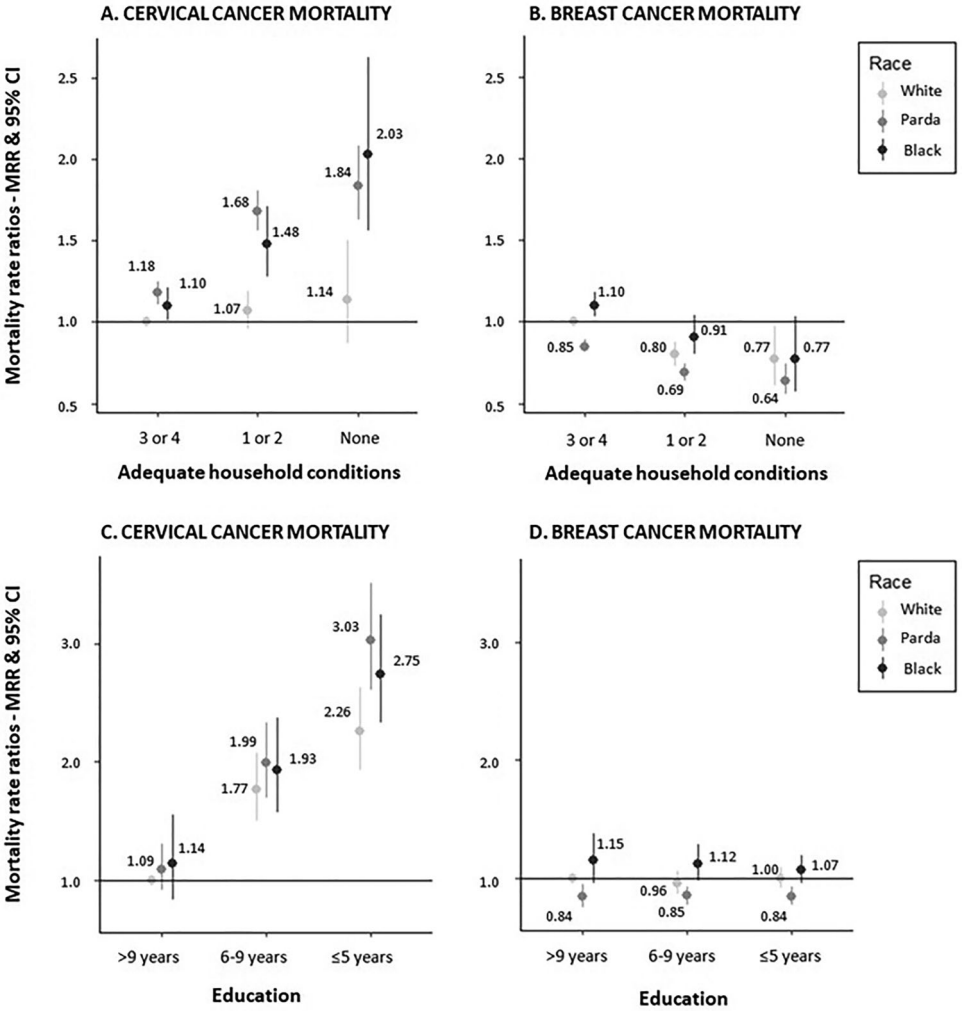

Figure 3. Joint effects of race/ethnicity combined with household conditions* (3A and 3B), and of race/ethnicity combined with educational level** (3C and 3D), on cervical and breast cancer mortality. 100 Million Brazilian Cohort (2004-2015), N = 20,564,437 women aged 18–100 years. Abbreviations: MRR, Mortality rate ratio; CI, Confidence interval; RERI, Relative excess risk due to interaction. *Adjusted for age, calendar year, education and area of residence. **Adjusted for age, calendar year, household conditions and area of residence. Figure 3A. RERI for None adequate (Parda) = 0·52 (95%CI 0·16,0·87), (Black) = 0·78 (0·18,1·38), RERI for 1 or 2 adequate (Parda) = 0·43 (95%CI 0·29,0·58), (Black) = 0·30 (0·06,0·55); Figure 3B: RERI for None adequate (Parda) = 0·02 (95%CI −0·17,0·21), (Black) = −0·11 (−0·40,0·18), RERI for 1 or 2 adequate (Parda) = 0·04 (95%CI −0·05,0·12), (Black) = 0·005 (−0·14,0·15); Figure 3C: RERI for ≤5 years (Parda) = 0·68 (95%CI 0·48,0·88), (Black) = 0·36 (−0·05,0·77), RERI for 6–9 years (Parda) = 0·13 (95%CI −0·12,0·39), (Black) = 0·03 (−0·44,0·50); Figure 3D: RERI for ≤5 years (Parda) = 0·001 (95%CI −0·11,0·11), (Black) = −0·08 (−0·30,0·14), RERI for 6–9 years (Parda) = 0·04 (95%CI −0·08,0·17), (Black) = 0·02 (−0·23,0·26).

households. In contrast, there was no evidence that the effect of race/racism on breast cancer mortality was modified by a woman's educational level or her household conditions.

Relative to White women the risk of dying from cervical cancer was highest in all other racial/ethnic groups, particularly among Indigenous women. Indigenous women have a high prevalence of infection with oncogenic human papilloma viruses (HPV) and a high incidence of cervical cancer, partly reflecting their cultural practices (e.g. early sexual exposure, multiple sexual partners, multiparity), as well as their geographic isolation and consequent lower uptake of screening and treatment of pre-malignant/malignant lesions (Fonseca et al. 2015). These behavioral and cultural issues are likely to be underpinned by structural disadvantages. Prior and present findings show that more than 60% of the Indigenous population live in the north and northeast of the country (Bastos et al. 2017), areas characterized by the greatest poverty and geographical barriers to healthcare (Renna and Silva 2018). Added to these factors is the socioeconomic precariousness of the Indigenous peoples, reflecting their historical trajectory of discrimination and invisibility linked to structural racism. Our study corroborates previous research in that most Brazilian Indigenous women have little education, live in households lacking infrastructure and in rural areas with high deprivation rates (Bastos et al. 2017; Fonseca et al. 2015), making them the most vulnerable racial/ethnic group in Brazil and in precarious health conditions (Rebouças et al. 2022).

'Parda'(Brown) and Black women in our study were also more likely to die from cervical cancer relative to White women, possibly through exposure to mechanisms of racism. 'Parda'(Brown), Black and Indigenous women should be prioritized for HPV vaccination, cervical cancer screening and pre-cancer treatment (Pan American Health Organization 2018). Asian women also showed greater risk of cervical cancer mortality, 63% higher than White women. This finding, however, should be interpreted with caution as self-reported race/ethnicity in this group (in Portuguese, *Amarela* or Yellow) might be subject to misclassification. Indeed, in representative samples of the Brazilian population, cervical cancer mortality rates in Asian women are closer to those of White women (Dantas et al. 2020). In addition, sensitivity analysis restricting our study population to municipalities with better quality mortality data attenuated the magnitude of the association between Asian race/ethnicity and cervical cancer mortality.

Relative to White women, mortality from breast cancer was lower among all groups except for a 10% higher risk among Black women. The latter is consistent with previous data showing that the prevalence of late-stage breast cancer at diagnosis was highest in Brazilian Black or 'Parda'(Brown) women (dos-Santos-Silva et al. 2019; Renna Junior et al. 2021), and in US African-American women (Hardy and Du 2021), compared to their White counterparts. Furthermore, the interval between breast cancer diagnosis and treatment onset is longer for Brazilian Black women thus increasing their risk of dying from the disease (Cabral et al. 2019). Biological differences may also contribute to racial disparities in breast cancer mortality, particularly as the triple-negative receptor subtype, which is associated with poorer prognosis, is more common in Black women (Howard and Olopade 2021; Yedjou et al. 2019). However, emerging evidence shows that pregnancy and higher parity were positively associated with this type of cancer while breastfeeding counteracted this effect (Shinde et al. 2010). Brazilian Black women, despite still having slightly higher fertility rates than White women, have followed the historical decline of this indicator in the country in recent decades and have higher exclusive breastfeeding rates than White

women (Federal University of Rio de Janeiro 2021). There is no clear evidence on the frequency of the breast cancer receptor subtypes by race/ethnicity in Brazil, however, the triple-negative subtype is more prevalent in the North Region (Carvalho et al. 2014). Therefore, barriers to accessing healthcare arising from social inequalities and structural racism may better explain our results, consistent with empirical (Cabral et al. 2019; Renna Junior et al. 2021) and review studies (Coughlin 2019; Simon et al. 2021; Williams, Lawrence, and Davis 2019; Williams, Priest, and Anderson 2016). These studies highlight how the manifestations of racism cross the health-disease process, putting Black, 'Parda'(Brown) and Indigenous women at a social disadvantage and, consequently, in more precarious living conditions. In addition, institutional racism can compromise prevention, diagnosis and treatment, whether due to geographic inequalities in the provision of health services, or due to discrimination when accessing health services.

Our findings supported our hypothesis that the intersection of race/ethnicity with SES magnified racial inequalities in cervical cancer mortality. This highlights the importance of using an intersectional lens in our study as, for instance, being a poor, Black woman is the result of the convergence of systems of oppression along class, race, and gender axes that interact and mutually reinforce each other (Constante and Bastos 2021; Crenshaw 1989; Hogan et al. 2018; Werneck 2016). Such gender, race and class axes of marginalization deprive Black and 'Parda'(Brown) women with poor SES of opportunities and socially acquired rights such as health and access to services.(Crenshaw 1989; Goes et al. 2021; Hogan et al. 2018) Poor Black and 'Parda'(Brown) Brazilian women are subjected to multiple expressions of discrimination (e.g. racism and sexism), reducing their opportunities for education, income and employment (Hogan et al. 2018), leading them to live in households with poor conditions and in segregated areas where health services are sparse and of poorer quality (Barber et al. 2018). In Brazil, studies (Constante and Bastos 2021; Goes et al. 2021) show that these intersectional groups (low SES Black women) are more likely to report longer intervals between medical appointments and discrimination from healthcare workers, despite the universal access offered within the Brazilian National Health Service.

Our strengths include the large sample size of over 20 million women, the richness of socioeconomic data and its longitudinal design, with linkage to nationwide mortality data. This allowed a rare outcome such as cancer mortality to be investigated, as well as its variation by race/ethnicity (even among racial/ethnic minorities such as Indigenous and Asian women) and SES, including examination of possible interactions. Moreover, sensitivity analyses restricted to areas with high death registration coverage yielded similar findings. The study also had some weaknesses. Generalization of its results should consider that the 100 million Brazilian cohort comprises the poorest 55% of the Brazilian population. However, it could be expected that our associations may be even larger in the general population, as White women from more advantaged socioeconomic backgrounds were under-represented in our study. The study lacks data on reproductive behavior, family history of disease, cancer stage at diagnosis, comorbidities, and health behaviors, which could have allowed a better understanding of the pathways linking race/ethnicity to cancer mortality. Future investigations should explore to what extent racial differences in cancer mortality could be explained by race/ethnic inequalities in healthcare access. Notwithstanding, robust existing evidence supports this link (Cabral

et al. 2019; Constante and Bastos 2021; Goes et al. 2021; Hogan et al. 2018; Renna Junior et al. 2021; Renna and Silva 2018).

Conclusion

Our study reveals the greatest vulnerability of the understudied population of Brazilian Indigenous women on the risk of cervical cancer death, and the high risk of Black women for both cervical and breast cancer deaths. These findings draw attention to the potential importance of racism as a structural determinant of health inequalities and point to a need for more in-depth research on this matter in Brazil and other LMICs. Our research also demonstrated that poorer SES amplified racial inequalities in cervical cancer mortality, highlighting the importance of using an intersectional lens to address racial inequalities in health. Political actions are required to decrease racial inequalities in the access to social (e.g. education and housing) and health resources.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Contributors

EFG e JMNG participated in the study conception, statistical analysis, data interpretation, and wrote the first draft of the manuscript. MCCA and LG participated in the statistical analysis and data interpretation, and helped writing the manuscript. ACC e MQ contributed to the statistical analysis. ACOC, SMAM, ALP, SVK, AHL and MLB participated in data interpretation and critical review of the paper. ISS and EMLA participated in study conception, contributed to the planning of data analysis and interpretation, and critical review of the paper. EMLA coordinated the research team. All the authors have read and approved the final manuscript.

Ethics approval

This study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee from Instituto Gonçalo Moniz – Oswaldo Cruz Foundation (1 612 302 in 2016 and 4 243 677 in 2020).

Data availability statement

All data supporting this study were obtained from the Center for Data and Knowledge Integration for Health (CIDACS). Data will be shared upon reasonable request to CIDACS and approval from the Ethics Committee.

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