Evolution of the Population Aging Index in Brazil (1991–2022): temporal analysis and sociodemographic determinants

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Abstract

Objective: To analyze the evolution of the Population Aging Index (PAI) in Brazil from 1991 to 2022 and to evaluate its association with selected demographic and socioeconomic indicators. *Methods:* This is an ecological time-series study using data from the Brazilian Demographic Censuses and intercensal estimates from the Brazilian Institute of Geography and Statistics (IBGE). The PAI was calculated as the number of individuals aged ≥60 per 100 aged 0–14. Annual percent change (APC) in PAI was estimated through Prais-Winsten regression. Selected variables included sex ratio, population density, population growth rate, life expectancy, fertility, infant mortality, urbanization, Palma ratio, Gini index, gross domestic product and Human Development Index. *Results:* The PAI increased from 16.7 in 1991 to 68.4 in 2022, constituting a 300% rise over 30 years. Higher values were concentrated in the South and Southeast, and lower values in the North. The fertility rate and Gini index were negatively associated with PAI-APC in the final model, while GDP showed a positive association. These factors explained 84% of PAI variation across states. *Conclusion:* Population aging in Brazil has rapidly and unevenly advanced, with faster growth in more developed states. The findings should be interpreted considering that some of the analyzed indicators constitute direct demographic determinants of population aging. Nevertheless, the results highlight the need for intersectoral and regionally tailored public policies to address the challenges posed by accelerated and unequal population aging.

Keywords: Aging. Population Dynamics. Socioeconomic Factors. Health Inequality Indicators. Brazil.

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INTRODUCTION

Population aging is a demographic phenomenon characterized by an increase in the proportion of older adults in relation to younger age groups in the population's age structure[1]. This process has intensified particularly rapidly in recent decades in Brazil. The older adult population increased from approximately three million people in 1960 to about 20 million in 2008, corresponding to a growth of almost 700% in less than 50 years[2]. This movement occurred in line with the demographic transition, characterized by replacement of a regime of high fertility and mortality rates with another marked by the sustained reduction of these indicators[1,2]. From this perspective, the Brazilian demographic transition stood out for its speed and scope when compared to that observed in high-income countries[2], contributing to imbalances in the dynamics of the country's social and economic institutions.

This aging process reflects social and economic transformations that occurred throughout the 20th century, including the greater insertion of women into the labor market, associated with a reduction in fertility rates; an expansion of education, with increased average schooling and access to higher education; and advances in public health and technology, which improved living conditions and raised life expectancy at birth[3,4]. Together, these factors have shaped the country's current demographic profile characterized by low population growth and greater longevity, posing significant challenges to social and economic development.

The analysis of population aging can be operationalized through the Population Aging Index (PAI), defined as the ratio between the number of people aged 60 or older and the number of individuals aged between zero and 14 years. This indicator allows us to synthesize changes in the age structure and compare aging patterns between regions and over time, being particularly useful for territorial analyses in contexts of accelerated demographic transition.

Population aging in Brazil poses challenges to economic and social systems, with repercussions on the labor market, social security, consumption patterns, and the organization of health systems[3,5–8]. However, these impacts manifest themselves unevenly among the regions of the country, reflecting differences in demographic and socioeconomic profiles. In this sense, investigating the evolution of the PAI and its association with demographic and socioeconomic indicators allows us to understand how these inequalities are expressed in the dynamics of Brazilian population aging. Given this context, it becomes relevant to analyze the temporal evolution of the Population Aging Index in Brazil and its association with selected demographic and socioeconomic indicators in an integrated way considering the regional heterogeneity of the country. Despite the relevance of the topic, studies that explore these associations over extended periods, especially at the state level, are still limited.

Thus, the objective of this study was to analyze the evolution of the Population Aging Index in Brazil between 1991 and 2022 and to evaluate its association with selected demographic and socioeconomic indicators.

METHODS

This is an ecological time-series study. The data source was the Brazilian Institute of Geography and Statistics (*IBGE* – https://www.ibge.gov.br/en/home-eng.html). We collected data from the Brazilian Demographic Censuses conducted in the years 1991, 2000, 2010, and 2022, and from estimates for their intervals (1996, 2006, 2016).

The PAI in Brazil is measured as the number of older adults aged 60 or older per 100 children and adolescents aged 0 to 14. We calculated the PAI for each of the 27 Brazilian states for these seven years mentioned (1991, 1996, 2000, 2006, 2010, 2016, and 2022). Next, we used Prais-Winsten regression to estimate the variation in the PAI between 1991 and 2022 (32 years) considering the autocorrelation of the residuals. This analysis generates an annual percentage variation coefficient (APC) with its respective 95% confidence interval (95%CI). When the 95%CI does not include the value zero, it means that the APC is increasing (if positive) or decreasing (if negative); when the 95%CI includes the value zero, it means that the APC is stable during this period.

The contextual factors (covariates) included in the analysis were: sex ratio (number of men divided by the number of women); population density (number of inhabitants per square kilometer); geometric population growth rate (constant rate at which a population changes from one period to the next); life expectancy at birth (average number of years a newborn can expect to live); fertility rate (number of children per woman); infant mortality rate (number of deaths before one year of age divided by the total number of live births); urbanization index (percentage of the population living in urban areas); Palma ratio (ratio of income of the richest 10% to the poorest 40%); Gini coefficient (a statistical measure of dispersion designed to represent income inequality, wealth inequality, or consumption inequality); Gross Domestic Product (GDP – a standard measure of the value added created through the production of goods and services); and Human Development Index (HDI – a statistical index composed of indicators of life expectancy, education, and per capita income).

These covariates were analyzed for the most recent year for which they were available. Most were extracted from the latest *IBGE* Demographic Census (*IBGE*, 2022). Otherwise, if the variable was not available in the latest Census, it was extracted from the year 2016 (namely: life expectancy at birth, infant mortality rate, urbanization index, and Palma index).

The analyses were performed in the first half of 2025. Simple and multiple regressions were performed to test the association between each covariate and the variation in the PAI. We categorized each covariate into tertiles for analysis purposes and tested them in both forms (continuous and categorical). Next, we present only the significant association for the variables in tertiles in the Results section, as these explained the greatest variability (R^2 coefficient) of the outcome. Variables with a p-value less than 0.20 were kept in the final model, and those with a p-value less than 0.05 had statistical significance. Linear trend tests were also performed.

The study used exclusively secondary, aggregated, and publicly accessible data, without the possibility of individual identification. Therefore, it is exempt from review by a Research Ethics Committee, in accordance with Resolution No. 510 of the National Health Council, of April 7, 2016.

DATA AVAILABILITY

The entire dataset supporting the results of this study is available upon request from the corresponding author, Samuel C. Dumith.

RESULTS

The PAI in Brazil changed from 16.7 in 1991 (ranging from 8.5 in Roraima to 32.5 in Rio de Janeiro) to 68.4 in 2022 (ranging from 27.1 in Roraima to 115.4 in Rio Grande do Sul). This represents an absolute increase of 51.7 percentage points (pp) or a relative increase of 300% over 30 years (Table 1). Among the 27 Brazilian states, the average annual percentage change (APC) for the PAI from 1991 to 2022 was 1.8 (95%CI 1.6 to 2.1), ranging from 0.7 (in Roraima) to 3.2 (in Rio Grande do Sul).

Considering the Brazilian regions, the APC-PAI ranged from an average of 1.1 (SD=0.4) in the North region to 2.8 (SD=0.4) in the South region (Figure 1). It increased almost fourfold between 1991 and 2022 for all five regions, rising from 10 to 40 in the North region, and from 24 and 23 to 96 and 97 for the Southeast and South regions, respectively. This means that there is virtually one older adult (60 years or older) for every child or young person under 15 years old in the Southeast and South regions, as based on the last Census (2022). However, considering the North region (lowest PAI in Brazil), there are approximately two individuals under 15 years old for every individual 60 years or older.

Table 1. Description of the population aging index (PAI) and the annual percentage change (APC) for each Brazilian state (n=27), 1991 to 2022.

State	PAI _1991	PAI _1996	PAI _2000	PAI _2006	PAI _2010	PAI _2016	PAI _2022	APC (pp)	APC (95%CI)
Rondônia	9.4	12.1	15.2	20.3	26.6	35.3	56.4	1.7	0.8; 2.5
Acre	10.8	12.7	14.1	15.0	19.0	22.6	35.3	0.8	0.3; 1.3
Amazonas	9.6	11.4	12.5	15.0	18.2	22.8	33.3	0.8	0.4; 1.3
Roraima	8.5	9.3	10.5	13.1	16.6	21.7	27.1	0.7	0.4; 1.0
Pará	11.5	13.6	15.5	18.4	22.7	29.3	44.1	1.2	0.5; 1.9
Amapá	8.6	9.4	10.4	12.0	15.5	19.7	31.1	0.8	0.3; 1.4
Tocantins	13.5	16.3	19.3	23.5	29.5	37.7	53.9	1.5	0.7; 2.2
Maranhão	13.7	16.8	19.3	23.1	28.0	34.7	49.8	1.3	0.6; 1.9
Piauí	16.2	20.6	24.8	31.3	40.0	49.3	72.6	1.9	1.2; 2.7
Ceará	19.9	23.0	26.4	32.8	41.6	52.3	71.7	1.9	1.1; 2.8
Rio Grande do Norte	22.1	25.0	28.5	34.7	43.6	52.9	76.3	1.9	1.1; 2.8
Paraíba	23.9	27.8	32.4	38.6	47.4	57.1	74.5	1.8	1.2; 2.5
Pernambuco	21.3	25.1	28.6	33.8	41.6	50.3	70.3	1.7	0.9; 2.5
Alagoas	15.9	18.3	20.6	24.4	30.4	39.7	57.5	1.5	0.6; 2.4
Sergipe	17.3	19.7	22.0	26.9	33.4	42.9	62.7	1.7	0.7; 2.6
Bahia	17.3	21.5	25.8	32.3	40.4	52.2	75.7	2.1	1.1; 3.1
Minas Gerais	22.3	27.3	32.0	41.0	52.6	71.9	98.3	2.8	1.4; 4.2
Espírito Santo	19.3	23.8	29.1	35.3	44.9	58.9	85.5	2.4	1.2; 3.6
Rio de Janeiro	32.5	38.2	42.6	50.0	61.5	79.3	105.6	2.7	1.3; 4.1
São Paulo	25.1	29.6	34.0	42.5	53.9	68.1	95.6	2.6	1.4; 3.8
Paraná	20.5	24.9	29.5	38.0	49.0	65.5	85.9	2.4	1.4; 3.5
Santa Catarina	20.4	24.3	28.5	37.2	48.2	66.5	89.8	2.6	1.4; 3.9
Rio Grande do Sul	29.7	34.8	40.1	50.8	65.5	87.4	115.4	3.2	1.7; 4.7
Mato Grosso do Sul	16.5	20.5	24.7	31.1	39.1	49.6	64.5	1.8	1.1; 2.4
Mato Grosso	11.5	14.7	18.1	23.8	30.7	40.1	52.0	1.5	1.0; 2.0
Goiás	16.7	20.5	24.5	31.0	39.0	49.2	67.5	1.8	1.1; 2.6
Distrito Federal	11.8	15.1	14.2	24.6	32.5	45.2	68.4	2.1	1.2; 3.0
Brasil	16.7	20.5	24.7	24.5	39.1	49.3	68.4	1.9	0.9; 2.9

pp: percentage points; 95%CI: 95% confidence interval.

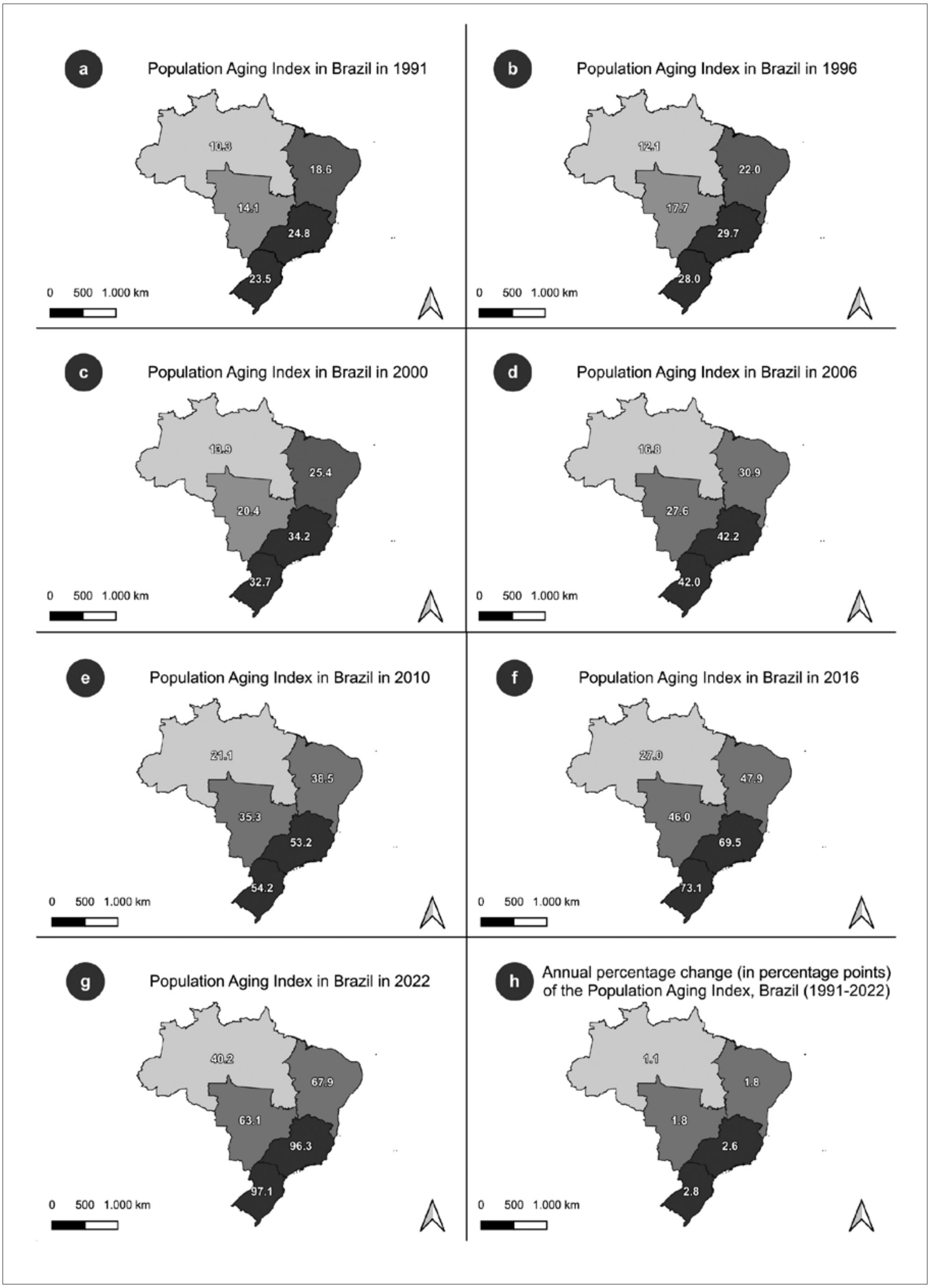

Figure 1. Description of the population aging index (PAI) according to the regional division of Brazil, 1991 to 2022.

The variables associated with the APC-PAI (Annual Percentage Change in the Population Aging Index) in the final statistical model were: fertility rate, Gini coefficient, and GDP (Table 2). We observed a negative association with the fertility rate and the Gini coefficient, meaning that an increase in their tertiles resulted in a lower APC-PAI. On the other hand, there was a positive association with GDP, meaning that each increase in its tertile resulted in a higher APC-PAI. Together, these variables explained 84% (adjusted R^2 coefficient) of the variability in the outcome (APC-PAI). The exposure variable most associated with the outcome was the fertility rate, meaning that states in the third tertile (highest fertility rate) showed an average of a 1.2 percentage point (pp) smaller increase in APC-PAI compared to the first tertile (states with the lowest fertility rate).

The other variables included in the statistical analyses (sex ratio, population density, geometric population growth rate, life expectancy at birth, infant mortality rate, urbanization index, Palma index, HDI) did not reach statistical significance (p-value >0.20) and were excluded from the final model.

Table 2. Crude and adjusted analyses of the annual percentage change (APC) in the population aging index (PAI) associated with contextual factors for the 27 federative units of Brazil – 1991 to 2022.

Contextual variables (tertiles)	Crude analysis		Adjusted analysis*	
	Beta (95%CI)	P-value**	Beta (95%CI)	P-value**
Fertility rate		<0.001		<0.001
1st (lower)	Reference (0)		Reference (0)	
2nd (intermediate)	-0.38 (-0.82; 0.07)		-0.47 (-0.77; -0.16)	
3rd (higher)	-1.14 (-1.58; -0.69)		-1.23 (-1.55; -0.92)	
Gini coefficient		0.2		<0.01
1st (lower)	Reference (0)		Reference (0)	
2nd (intermediate)	-0.87 (-1.42; -0.32)		-0.42 (-0.73; -0.11)	
3rd (higher)	-0.40 (-0.95; 0.15)		-0.56 (-0.91; -0.21)	
Gross Domestic Product (GDP)		0.01		0.01
1st (lower)	Reference (0)		Reference (0)	
2nd (intermediate)	-0.13 (-0.66; 0.40)		0.16 (-0.17; 0.49)	
3rd (higher)	0.74 (0.21; 1.27)		0.45 (0.10; 0.79)	

CI: confidence interval; * Adjusted for each of the other variables presented in this table; ** p-value for linear trend

DISCUSSION

This study provides a comprehensive analysis of trends in the PAI across all Brazilian states from 1991 to 2022, as well as its association with key contextual factors. Key findings reveal that the PAI quadrupled during this period (from 17% to 68%), reflecting an average increase of almost two percentage points (pp) per year. Furthermore, the PAI growth was inversely associated with the fertility rate and the Gini coefficient, and directly associated with GDP. Moreover, the distinct demographic stages of the states are reflected in the PAI of the state of Rio Grande do Sul (for example), which was already higher in 1991 (29.7) than the value presented in Roraima in 2022 (27.1). Taken together, these results highlight the demographic intensification of population aging in Brazil and emphasize the influence of reproductive patterns, social and economic factors on its progression. By identifying the contextual determinants of aging, this study provides evidence that can guide regional planning and formulation of equitable public policies for healthy aging.

A study[9] analyzing the period from 1970 to 2010 identified a 268% increase in PAI in Brazil, providing a different temporal perspective from our study, which also highlights the country's rapid population aging. The authors reported the highest PAI values in the South (54.9) and Southeast (54.6) regions in 2010, while the North had the lowest (21.8), with this regional pattern also being observed in the present study. Although the study did not directly examine variables associated with aging, the authors observed that more developed regions tend to have higher PAI values[9]. This was confirmed in our analysis, which found a direct relationship between PAI and GDP, and an inverse relationship with the Gini coefficient. The study also presents estimates from the United Nations Population Division, which projected that Brazil would reach a PAI of 68.3 by 2025, a threshold already surpassed in 2022 according to our data.

The fertility transition, one of the components of the demographic transition, represents the shift from a pattern of high and poorly controlled fertility levels to a scenario of birth planning, with a reduction in births and also in neonatal deaths. According to a Brazilian study[10], the fertility transition process occurred in different ways both intra- and inter-regionally, highlighting the uniqueness of the country's demographic dynamics. Some Brazilian states with greater urban and economic development, such as Rio de Janeiro, São Paulo, and Rio Grande do Sul, experienced a slow fertility transition, beginning in 1930 or earlier (given the lack of sufficient records), which is consistent with what occurred in European countries.

However, many states experienced the fertility transition phenomenon in an accelerated manner, starting in the 1960s or 1970s[10], when the reduction in the fertility rate was recorded throughout the national territory in a sustained and uninterrupted way. Furthermore, at the inter-regional level, this study[10] indicated that the state of Santa Catarina presented homogeneous variation in the fertility rate throughout its territory over the study period, while Minas Gerais was the state with the greatest heterogeneity in its municipalities, being divided into five parts. In other words, even in a socioeconomically developed state, demographic changes occur at different rates according to the microregion.

Another national study[1] which also presents an overview of the Brazilian demographic transition indicated that the national fertility rate began to decline from the end of the 1960s, reaching the replacement threshold (which produces zero population growth) in the 2000s. Furthermore, this same study[1] compared the decline in the fertility rate in Brazil with that of England: while in England it took 100 years to show a 58% decline (from 5.3 in 1870 to 2.2 in 1970), in Brazil there was a 60% reduction in 30 years (from 5.8 in 1970 to 2.3 in 2000). This study[1] reinforces how quickly this rate decreased in Brazil, a middle-income country which has seen rapid narrowing of the age pyramid compared to high-income countries, implying super-accelerated population aging.

Previous studies have shown that population aging in Brazil is more pronounced in states with higher socioeconomic development levels, which is reflected in indicators such as GDP per capita, urbanization, and access to health. In this context, a study[4] highlighted the geographically heterogeneous nature of population aging in Brazil. Based on GDP, the most economically developed regions (South and Southeast) have the highest proportions of older adults, in contrast to the lower rates observed in the North and Northeast. A study published in 2021[11] examined the relationship between income inequality and aging in Brazil. Similarly, the authors identified regional heterogeneity in sociodemographic dynamics. Furthermore, their findings revealed an inverse association between income inequality and aging indicators, reinforcing that municipalities with greater income disparities tend to have less favorable aging profiles[11].

As reported, our APC-PAI data can be explained by about 80% by the inverse relationship between the fertility rate and the Gini coefficient and positively by GDP. These findings suggest and reinforce the secondary and paradoxical effects of successful economic advancement, such as increased education and economic inclusion of women, rising cost of living, loss of value as an economic reserve for children, and greater access to birth control.[12] A global study shows that improvements in female education and access to contraceptives, strongly linked to wealth, are the main drivers of declining birth rates, accelerating the relative aging of the population.[13] Thus, this process leads to a reduction in the birth rate across all social strata in wealthier regions with less income disparity, which, combined with better sanitation, urban infrastructure, nutrition, education, and access to healthcare, pulls the age pyramid into an "age rectangle"[14-16].

Furthermore, it is important to highlight that the public policies developed in the country were essential to leverage improvement in the quality of life throughout Brazil, serving as a basis for the increase in longevity and the demographic transition. From this perspective, it is crucial to emphasize projects such as the National Immunization Program of 1973, the Unified Health System (*Sistema Único de Saúde*) and the expansion of the Family Health Strategy (*Estratégia Saúde da Família*) since 1994, as well as the expansion of access to essential medicines through the National Pharmaceutical Assistance Policy and the Popular Pharmacy Program of Brazil (*Política Nacional de Assistência Farmacêutica e do Programa Farmácia Popular do Brasil*) created in 2004, given that they constituted fundamental pillars for improving health indicators, increasing longevity and the quality of life of the Brazilian population[17,18]. Furthermore, expansion and improvement in the education system, also supported by public policies, contributed to increasing human capital, reducing inequalities, and directly influencing demographic dynamics by acting on the determinants of fertility and age structure, postponing entry into the labor market and family formation, and promoting changes in reproductive patterns[19].

Alongside population aging, social assistance policies serve as a foundation for mitigating socioeconomic inequalities in advanced ages[20], highlighting the Organic Law of Social Assistance (*Lei Orgânica da Assistência Social* (*LOAS*) – Law No. 8,742/1993), which established the Continuous Benefit Payment (*Benefício de Prestação Continuada - BPC*) as a guarantee of minimum income for older adults in vulnerable situations, regardless of social security contributions. Furthermore, the Statute of Older Adults (*Estatuto do Idoso*) established by Law No. 10,741/2003, constitutes a landmark in the institutional adaptation of the Brazilian State to population aging resulting from the demographic transition by consolidating rights and social protection mechanisms for the population aged 60 or over[20].

To our knowledge, this is the first study to quantify the magnitude of variation in the PAI in the Brazilian population over the last three decades. Our estimates included data from all Brazilian states, revealing striking differences and disparities in the population aging process among geographic regions. Furthermore, we identified the contextual factors most strongly associated with population aging in the country. The Gini coefficient was no longer significant, and the association with the fertility rate was reversed. This reversal may reflect that the states with the greatest reductions in fertility were among the poorest, while the richest states experienced slower declines.

The present study suggests that if the APC-PAI (Annual Percentage Change in the Population

Aging Index) remains constant, the number of older adults in Brazil will exceed the number of children and adolescents (0 to 14 years) within the next 15 years, which is already observed in some states. These findings emphasize the importance of anticipating demographic transitions and adapting health and social systems to the new population profile. The World Health Organization (WHO)[21] defines healthy aging as the process of maintaining functional capacity which enables well-being in old age, highlighting that health systems must be reorganized to meet the needs of aging populations. In this context, population aging not only represents a demographic change, but also a structural challenge for public health planning.

A study using data from the National Health Survey (*Pesquisa Nacional de Saúde*, 2013) showed how strongly the accumulation of chronic diseases is associated with functional dependence among older adults, reinforcing the need for integrated prevention and care strategies[22]. Similarly, regional analyses in the Americas indicate that the rapid increase in the proportion of older adults substantially contributes to the burden of non-communicable diseases and to a greater demand for long-term care[8,13].

Taken together, these findings highlight that managing population aging requires coordinated measures focused on maintaining functionality and autonomy in old age. This includes strengthening primary healthcare, expanding rehabilitation and long-term care services, and developing community environments that support active and independent living. Viewing population aging from this perspective underscores the need for strategic planning to ensure that increased longevity is accompanied by improved quality of life and system sustainability.

Some limitations of this study should be considered. We did not assess annual changes in PAI over the entire period due to the use of demographic censuses and intercensal population estimates. Thus, we selected seven points in time to ensure more reliable accuracy for trend analysis[23]. Contextual factors were assessed at a single point in time at the end of the time series (2022), except for life expectancy at birth, infant mortality rate, urbanization index, and Palma index, which were not available in the 2022 census and were obtained from the 2016 census. Furthermore, we used the age of 60 as the cut-off age for calculating PAI, while high-income countries adopt 65, which may compromise the comparability of our estimates with these countries.

CONCLUSION

The results of this study demonstrate a demographic transition process occurring heterogeneously among Brazilian states given their respective singularities in development and urbanization marked by a generalized acceleration over the last few decades. These issues converge with the findings based on the almost 300% increase in the Population Aging Index (PAI) over just three decades, in addition to the disparity in values recorded among the states, reinforcing the existence of distinct scenarios occurring simultaneously in the country. Regarding the analyzed indicators, both the fertility rate and the Gini coefficient showed an inverse association with the PAI, while the Gross Domestic Product of each state showed a positive association. Therefore, it is crucial to understand the different sociodemographic dynamics to effectively meet the specific population demands of each region, uniting public policies and studies focused on the analysis of structural factors in the fields of health, education, and social assistance as a fundamental strategy to understand and respond to the challenges posed by the rapid aging of the Brazilian population.

AUTHORSHIP

- Samuel C. Dumith: study conception, data analysis and interpretation, article writing, approval of the final manuscript version.
- Eduarda C. Policarpo: data tabulation, article writing, approval of the final manuscript version.
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- Eduarda C. Costa: critical review of the article, approval of the final manuscript version.

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