Analysis of Age, Period, and Birth Cohort Effects on Suicide Mortality in Brazil and the Five Major Geographic Regions

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Research Article

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Abstract

Objective: Estimate the effects of age, period, and birth cohort on suicide mortality in Brazil and by major geographic region in the overall population and by sex.

Methods: This was a time trend ecological study. National and regional suicide mortality data from 1981 to 2015 were analyzed for the overall population and by sex. Age, period, and cohort effects were calculated with a Poisson regression model, using estimable functions with the Epi package of the R statistical program, version 3.4.3.

Results: Except for the North of Brazil and the female population in the Central-West region, the model that best fits the data was the complete model, following by the age-period model in most of the analyses.

Conclusions: Suicide mortality rates have shown an upward trend with advancing age in the Brazilian population, in both men and women. However, the behavior of the period effect and cohort has depended on the population analyzed and regional distribution.

Introduction

According to the World Health Organization (WHO), 703 thousand persons die from suicide per year and there are many more people who attempt suicide [1]. In 2019, Brazil had 13523 deaths by suicide, with a rate of 6.6 deaths per 100,000 inhabitants [2]. It is estimated an average of 24 deaths per day [3].

Brazil reported less significant suicide rates than other countries for many years [4]. Starting in the latter half of the 20th century, the Brazilian population underwent various changes, launching an important demographic transition. First, infant mortality declined, and life expectancy increased, while the birth rate and fertility rate were still high. In the mid-1960s, the latter rates began to drop, a process that intensified in the 1970s. Since then, the impact of infectious and parasitic diseases has decreased among the causes of illness and death in the Brazilian population, while external causes and chronic noncommunicable diseases have taken more victims [5]. In the wake of this phenomenon, the last five decades have witnessed a significant increase (60%) in Brazil's suicide rates [6, 7]. Although the national suicide rates were considered low for many years, starting in 2001 until 2019 they reached 5.3 to 6.6 deaths per 100,000 inhabitants, already considered a moderately high level [2, 8].

These changes in suicide rates and in the age profile of individuals that commit suicide have raised new research questions. Preliminary studies have shown directly or indirectly the effects of birth cohort, that is, generational differences in suicide risk [9]. A key objective in epidemiology is to identify influences on different factors for illness and dying over time [10], and one approach for attempting to understand suicide behavior in a society has been age-period-cohort (APC) modeling[9, 11–17].This modeling provides a descriptive tool for observing disease records and the temporal effect of an event's occurrence [18–20], highly useful for modeling incidence and mortality rates [21].

APC analysis has the unique capacity to moderately describe the entire complex of social, historical, and environmental factors that simultaneously affect individuals and populations of individuals and is widely used to address questions of lasting importance for studies on social change, disease etiology, aging, and population processes and dynamics [18]. APC modeling serves to separate the different effects of age (age effects), historical circumstances (period effects), and generational succession (birth cohort effects) [9, 18]. However, the modeling is hindered by the redundancy of linear effects of age, period, and cohort, since any two of the three dimensions fixes the third, a problem called identifiability, a widely debated fact [9, 21].

This study aimed to model the data series on suicide for Brazil as a whole and its five major geographic regions, using the APC approach, in the overall population and by sex.

Material And Methods

This was an ecological study on suicide mortality in Brazil from 1981 to 2015. Data were obtained from the death certificates recorded in the Mortality Information System (SIM), and the populations estimates were from the Brazilian Institute of Geography and Statistics (IBGE), downloaded from the website of the IT Department of the Unified Health System (DATASUS).

There were 243,694 suicides recorded during the study period. The current study included suicide deaths of individuals 20 years or older and under 80 years of age (due to the need for age brackets with regular intervals). Thus, 27,047 suicides in individuals that did not meet the eligibility criteria were removed from the sample, resulting in 216,647 suicides eligible for the proposed modeling.

The data were compiled in the R software, version 3.4.3, and the modeling was done with the Epi package, ggplot2, and gridExtra.

Crude and adjusted mortality rates were calculated for each year, with crude rates calculated as the ratio between the number of suicide deaths in individuals 5 years or older and the population with the same age, in the same geographic region and period, multiplied by 100 thousand, and the adjusted rates calculated by the direct method and using the standard population recommended by the WHO [22], to allow comparison of the rates by year.

For the age-period-cohort (APC) modeling, the number of deaths and the population at risk were grouped into 12 age brackets (20–24 years; 25–29 years; 30–34 years; 35–39 years; 40–44 years; 45–49 years; 50–54 years; 55–59 years; 60–64 years; 65–69 years; 70–74 years; and 75–79 years), for 7 periods (1981–1985; 1986–1990; 1991–1995; 1996–2000; 2001–2005; 2006–2010; 2011–2015) and 18 cohorts (1906–1910; 1911–1915; 1916–1920; 1921–1925; 1926–1930; 1931–1935; 1936–1940; 1941–1945; 1946–1950; 1951–1955; 1956–1960; 1961–1965; 1966–1970; 1971–1975; 1976–1980; 1981–1985; 1986–1990; 1991–1995). The cohorts were not furnished, since the selected function calculates the cohort based on period and age.

Age, period, and cohort effects were modeled with natural splines for each of the terms and calculated via Poisson regression, expressed as:

$$\ln\left(E\left[r_{ij}\right]\right) = \ln\left(\frac{\theta_{ij}}{N_{ij}}\right) = \mu + \alpha_i + \beta_j + \gamma_k$$

where the logarithm of the rate's expected values is a linear function of the effect of age, period, and cohort; $E\left[r_{ij}\right]$ represents the expected mortality rate at age *i* and period *j*; θ_{ij} and N_{ij} represent the number of deaths and the population at risk, respectively, at age *i* and in period *j*; μ represents the mean effect; α_i, the effect of age *i*; β_j, the effect of period *j*; and γ_k, the effect of cohort *k* [23–27].

One limitation to this modeling is the problem of identifiability. One of the resources used to mitigate this problem is the use of estimable functions in the models. Since the model for the principal effect of age provides a better distinct fit than the models of the principal effect of period and cohort, age was implemented as a mandatory component of preliminary two-factor models, and as a target factor for subsequent restrictions. Preliminary age-period (AP) and age-cohort (AC) models served to develop a complete APC model [9]. Thus, estimable functions are limited to analyzing the linear combinations and curvatures (or deviations from linearity) for age, period, and birth cohort. The curvatures can be estimated and remain constant regardless of the parametrization employed in the analysis, while the linear combinations are divided into two distinct components, the linear effect of age and the drift effect (corresponding to the linear effect of period and cohort combined). The first drift described in the model represents the linear trend of the logarithm for the age-specific rates and is equal to the sum of the period and cohort slopes ($\beta L + \gamma L$), where βL and γL are the linear period and cohort trends, respectively, while the second drift represents the longitudinal age trend and is the sum of age and the period slope ($\alpha L + \beta L$), where αL and βL are the linear age and period trends, respectively [19, 24, 25].

The model's fit was performed via deviance, defined as twice the logarithm of the complete model's likelihood function in relation to the logarithm of the estimated model's likelihood function [23, 26]. The effects' contribution was assessed by comparison of the model's deviance with the specific effect in relation to the complete model. Statistical significance of the results was set at $P < 0.05$ [26]. The model with the lowest deviance has the best fit [23]. The cohort adopted as the reference was 1946, and the reference period was the year 1998, since they were more centralized in the analysis. The measure of association generated by the APC model is relative risk (RR) [26], which is calculated automatically by the *apc.fit* function of the Epi package, together with the respective 95% confidence intervals (95%CI) [26].

Results

From 1981 to 2015, there were 216,647 suicides in individuals 20 to 80 years of age in Brazil, of which 79.2% were committed by men. The region with the largest share of suicide deaths was the Southeast (41.3%), followed by the South (27.1%), Northeast (18.5%), Central-West (8.2%), and North (5.0%) (data not tabulated).

During the period, the Brazilian population showed a standardized mean suicide rate of 4.99 deaths per 100 thousand inhabitants (varying from 4.13 to 5.76), while the mean rate in the male population was 8.08 deaths per 100 thousand inhabitants (6.43–9.35) and the mean rate in the female population was 2.14 deaths per 100 thousand inhabitants (1.76–2.54). For both the overall population and by sex, the highest rates were in the South (mean rate of 9.10, mean male rate of 14.90, and mean female rate of 3.74 deaths per 100 thousand inhabitants) and Central-West (6.12; 9.55; and 2.73 deaths per 100 thousand inhabitants). The suicide mortality rates in the Southeast, Northeast, and North regions were lower than the Brazilian rate (data not tabulated).

Suicide mortality rates have shown an upward pattern in the Brazilian population with increasing age and were considerably higher at 70 years and older, with the oldest cohorts showing the highest rates. The age brackets from 50 to 70 years have not shown a specific pattern, while the younger age brackets (from 20 to 50 years) have shown an upward pattern in the rates (Fig. 1a). In the North, suicide mortality rates among younger individuals have increased more than in the other age brackets. The pattern for the age brackets from 20 and 34 years have been largely upward, while from 35 to 69 years they have declined slightly in the last 5 years. The age brackets from 70 to 74 and from 75 to 79 years showed a distinct pattern from the others, alternating periods of decline with subsequent increases. The cohorts with the highest rates were 1991 to 1995, 1936 to 1940, and 1986 to 1990 (Fig. 1b). In Northeast Brazil, most of the rates were largely upward, except for the bracket from 30 to 59 years, which showed a slight decline at the end of the period. The cohorts with the highest rates were between 1930 and 1960 (Fig. 1c). In the Central-West region, the age brackets from 70 years upward have shown higher rates than the others. In the last 10 years of the follow-up period, the rates showed an overall decline. The highest cohorts were from 1921 to 1925 and 1931 to 1935 (Fig. 1d). In the South, with Brazil's highest rates, the pattern has been largely downward both for the period and for age brackets, with the oldest cohorts (1906 to 1930) displaying higher rates than the others (Fig. 1e). In the Southeast, the cohorts with the highest rates were from 1906 to 1925. The age brackets from 20 to 45 years displayed an upward pattern in recent periods, while the group of individuals 70 years and older increased again after an intense decline in rates (Fig. 1f).

Analysis of the likelihood ratio showed that nearly all of the analyses performed in the complete APC model displayed a better fit to the data ($p < 0.001$) that the other models, except when considering the North of Brazil, in which the best fit was with the age-drift* model (non-linear age effect) for the overall population and for men, while the best fit for the female population was the age-cohort model, and the same was true for the female population in the Central-West region. For Brazil as a whole, the study found a cohort effect with a better fit, since the second-best model was the age-cohort model for the overall population, but when analyzing by sex, the period effect was better at explaining the rates' behavior, since the second-best model was age-period. According to regions of Brazil, the Northeast displayed a period effect with a better fit to the target situations, and the same was true for the overall population and the male population in the Central-West and South and for the female population in the Southeast, while the cohort effects prevailed in the overall and male populations in the Southeast and the female population in the South (Table 1).

Table 1
Fit parameters for APC model of suicide data in Brazil and major geographic regions, 1981 to 2015, in the overall population and by sex.

Model	Brazil			North			Northeast			Central-West			South			Southeast		
	df	*RD*	p	df	*RD*	p	Df	*RD*	p	df	*RD*	p	df	*RD*	p	df	*RD*	p
Overall Population																		
Age	79	1936.7		79	476.3		79	3881.7		79	413.5		79	481.0		79	736.7	
Age-drift*	78	606.3	< 0.001	78	94.5	< 0.001	78	360.4	< 0.001	78	289.7	< 0.001	78	446.4	< 0.001	78	564.8	< 0.
Age-Cohort	75	499.1	< 0.001	75	92.8	0.637	75	321.5	< 0.001	75	274.4	0.002	75	368.0	< 0.001	75	446.9	< 0.
Age-Period-Cohort	72	417.9	< 0.001	72	89.3	0.314	72	166.6	< 0.001	72	116.4	< 0.001	72	170.0	< 0.001	72	389.3	< 0.
Age-Period	75	535.6	< 0.001	75	91.8	0.471	75	189.9	< 0.001	75	122.7	0.099	75	263.5	< 0.001	75	503.7	< 0.
Age-drift**	78	606.3	< 0.001	78	94.5	0.435	78	360.4	< 0.001	78	289.7	< 0.001	78	446.4	< 0.001	78	564.8	< 0.
Male Population																		
Age	79	2153.0		79	500.7		79	3358.1		79	444.7		79	501.8		79	683.3	
Age-drift*	78	669.2	< 0.001	78	95.2	< 0.001	78	328.2	< 0.001	78	284.1	< 0.001	78	497.6	0.038	78	446.9	< 0.
Age-Cohort	75	629.0	< 0.001	75	92.9	0.152	75	264.6	< 0.001	75	271.9	0.007	75	468.9	< 0.001	75	360.5	< 0.
Age-Period-Cohort	72	393.7	< 0.001	72	90.3	0.282	72	148.3	< 0.001	72	101.4	< 0.001	72	163.7	< 0.001	72	329.6	< 0.
Age-Period	75	453.8	< 0.001	75	97.1	0.080	75	184.3	< 0.001	75	109.3	0.048	75	207.0	< 0.001	75	417.6	< 0.
Age-drift**	78	669.2	< 0.001	78	98.2	0.588	78	328.2	< 0.001	78	284.1	< 0.001	78	497.6	< 0.001	78	446.9	< 0.
Female Population																		
Age	79	448.5		79	93.0		79	635.9		79	116.2		79	281.8		79	437.2	
Age-drift*	78	418.5	< 0.001	78	740	< 0.001	78	165.6	< 0.001	78	113.4	0.095	78	218.8	< 0.001	78	436.6	0.
Age-Cohort	75	303.8	< 0.001	75	66.0	0.045	75	156.6	0.029	75	93.315	< 0.001	75	138.2	< 0.001	75	352.6	< 0.
Age-Period-Cohort	72	169.4	< 0.001	72	62.4	0.313	72	111.7	< 0.001	72	87.481	0.119	72	115.7	< 0.001	72	150.1	< 0.
Age-Period	75	299.6	< 0.001	75	70.8	0.039	75	122.7	0.011	75	102.9	0.001	75	1937	< 0.001	75	259.0	< 0.
Age-drift**	78	418.5	< 0.001	78	74.0	0.353	78	165.6	< 0.001	78	113.4	0.015	78	218.8	< 0.001	78	436.6	< 0.

df = degrees of freedom; RD = residual deviance; * linear trend for period and cohort; ** longitudinal trend for age

In the overall population, the age model-adjusted suicide mortality rates showed an upward pattern for Brazil as a whole and especially for the Central-West, Northeast, and North. In the South of Brazil, the pattern showed that the rates increased rapidly starting in the third decade of life, with the increase slowing down in the sixth decade of life. Meanwhile, the Southeast displayed less variation in suicide mortality rates over the course of life, stabilizing from the fifth decade of life onward (Fig. 2a). The mortality risk ratio (expressed as RR) according to cohort in the Brazilian population increased starting with the 1946 cohort (reference), and the most recent cohort showed the highest associated risk, 1.54 (95%CI 1.50; 1.58), while the oldest cohort showed the lowest associated risk, 0.88 (95%CI 0.84;0.91). This phenomenon was also true for the North of Brazil (1991–1995 cohort, RR = 2.53, 95%CI 2.26;2.83; 1906–1910 cohort, RR = 0.46, 95%CI 0.38;0.55), Northeast (1991–1995 cohort, RR = 4.22, 95%CI 3.93;4.52; 1906–1910 cohort, RR = 0.24, 95%CI 0.22;0.27); and Central-West (1991–1995 cohort, RR = 1.59, 95%CI 1.45;1.74; 1906–1910 cohort, RR = 0.62, 95%CI 0.53;0.72). The majority of the cohorts in the South and Southeast had higher RR than the reference cohort. The RR was only less than or equal to 1 in individuals born from 1951 to 1965 and from 1991 to 1995 (the youngest cohort studied) in the South of Brazil and among those born from 1941 to 1945 in the Southeast. However, whereas in the South the more recent cohorts displayed lower suicide risk than the older cohorts, the distribution was the opposite in the Southeast (higher RR in the more recent cohorts), reaching 1.30 in the 1991–1995 cohort (95%CI 1.24;1.35) (Fig. 2b). As for period effect, the Brazilian population showed the highest risk in 2001–2005 (RR = 1.01, 95%CI 1.00;1.02), which also happened in the Northeast (RR = 1.12, 95%CI 1.09;1.15) and South (RR = 1.004; 95%CI 0.99; 1.01). The other periods presented a lower risk than the reference period (1996–2000) for Brazil as a whole and the South. In the North and Central-West regions, all the periods showed lower risk than the reference period, while in the Northeast in 1981–1985 and 2006–2010 the risks were higher than in the reference period. In the Southeast, the periods prior to the reference period and the latest interval studied displayed higher risk of suicide; however, interestingly, the risk began increasing again from 2011 to 2015 (RR = 1.05; 95%CI 1.03;1.07) (Fig. 2c).

Considering the male population (the principal victims of death by suicide), the suicide-adjusted mortality rates presented an upward pattern with increasing age for Brazil as a whole and all five geographic regions, with the largest increase in the Northeast (Fig. 3a). As with the overall population, the RR for the male population increased starting with the 1946 cohort (reference), and the highest risk was in the most recent cohort, or 1.67 (95%CI 1.62;1.72), while the lowest risk was in the oldest cohort, with 0.79 (95%CI 0.75;0.82), and the same was true for the North (1991–1995 cohort, RR = 3.02, 95%CI 2.66;3.43; 1906–1910 cohort, RR = 0.44, 95%CI 0.35;0.54), Northeast (1991–1995 cohort, RR = 4.35, 95%CI 4.02;4.70; 1906–1910 cohort, RR = 0.20, 95%CI 0.18;0.23); Central-West (1991–1995 cohort, RR = 1.86, 95%CI 1.67;2.07; 1906–1910 cohort, RR = 0.55, 95%CI 0.46;0.65); and Southeast (1991–1995 cohort, RR = 1.42, 95%CI 1.36;1.49; 1906–1910 cohort, RR = 1.06, 95%CI 0.99;1.14). There was another reversal in the risk behavior of individuals born in the South of Brazil, with RR of 1.06 (95%CI 1.00;1.12) for the cohort from 1991 to 1995, while the older cohorts showed RR = 1.27 (95%CI 1.17;1.38) (Fig. 3b). As for period effect, the male population presented the highest risk in 2001–2005 (RR = 1.01, 95%CI 0.99;1.02), as well as in the Northeast (RR = 1.07, 95%CI 1.05;1.09) and South (RR = 1.008; 95%CI 0.99; 1.02). The other periods showed lower risk than the reference period (1995–2000) for Brazil as a whole and the South. In the North, Central-West, and Southeast, all the periods showed lower risk than the reference period, while in the Northeast, the risks were only higher than the reference period in 2006–2010 (Fig. 3c).

For the female population in Brazil as a whole and in the Northeast, suicide-adjusted mortality rates continued to increase with age. The North showed an atypical pattern: the highest rate was from 20 to 24 years, with a decrease in the following age group and a slow increase over the course of the subsequent ages. In the Central-West, South, and Southeast, the highest rates were between 45 and 69 years of age, decreasing near the end of life (Fig. 4a). The RR for cohort in the Brazilian population was 1.07 (95%CI 0.98;1.16) in the 1906–1910 cohorts followed by decreasing risk until the reference cohort and then an increase until the 1966–1970 cohort (RR = 1.23, 95%CI 1.19; 1.28), after which there was another decrease. In the North, the risk increased over the course of the cohorts, with a peak in the 1981–1985 cohort (RR = 1.58, 95%CI 1.32;1.89), with the same behavior in the Central-West, where the peak risk was in women born from 1971 to 1975 (RR = 1.18; 95%CI 1.04; 1.33) and in the Northeast among those born from 1991 to 1995 (RR = 3.26; 95%CI 2.84;3.73). Among women in the South and Southeast, the more recent cohorts have shown lower risk in the follow-up (0.77, 95%CI 0.69; 0.87; 0.91; 95%CI 0.83; 0.99, respectively) (Fig. 4b). As for period effect, the Brazilian female population had the highest risk in 1981–1985 (RR = 1.19; 95%CI 1.15;1.23) and 2011–2015 (RR = 1.13, 95%CI 1.11;1.16), with the same happening in the North (RR = 1.00; 95%CI 0.83;1.21 and RR = 1.03, 95%CI 0.93;1.15), South (RR = 1.07; 95%CI 1.01;1.14 and RR = 1.08, 95%CI 1.03;1.14), and Southeast (RR = 1.36; 95%CI 1.30;1.42 e RR = 1.29, 95%CI 1.25;1.34). In the Northeast and Central-West regions, the period with the highest risk was 2001–2005 (RR = 1.19, 95%CI 1.13;1.26 and RR = 1.04; 95%CI 0.96;1.12, respectively) (Fig. 4c).

Discussion

The study's main findings evidenced the magnitude of the suicide problem in Brazilian society. Suicide has taken more lives in Brazil with each passing year and is frequent in all adult age brackets (starting at 20 years), but the rates have grown at particularly alarming rates in the elderly population. And although the suicide rates in women were four times lower than in men, younger Brazilian women have nevertheless increasingly died by suicide. There are also differences in the regional suicide mortality rates: while for many years the South of Brazil had the most cases and highest rates [28–31], it has shown a downward pattern in rates in the period studied and in the relative risk in the more recent cohorts. Meanwhile, Northeast Brazil has displayed alarming growth in suicide rates and the Southeast has witnessed an increasing risk of suicide in the most recent years analyzed.

This study aimed to estimate suicide trends over time in Brazilian society. The findings reinforce questions that had already been raised in other studies and shed light on possible suicide prevention strategies.

Age has always been aired as related to illness and death, and its effects have always been related to relevant health outcomes [20, 32], due to physiological changes, accumulated social experience, social role, changes in status, or a combination of the above. These changes thus reflect the biological and social process of individuals' internal aging and represent changes in life-course development [10]. Age is considered one of the main risk factors for suicide [33, 34], with the extreme age groups – the youngest adults [30, 33, 35–38] and the elderly [30, 34, 38–43] – as those most affected. Our study revealed a clear relationship between the increase in suicide rates over the course of life in practically all of the subsets tested. Only women 20–24 years of age in the North showed higher suicide rates than all the other age brackets.

We opted not to include individuals under 20 years of age, realizing that the impact on younger people (children and adolescents) has been small compared to the other age rates and that the inclusion of very extreme rates would hinder the analysis of the proposed modeling. However, women have died of suicide earlier than men, and this should be considered in any strategy to confront the problem. Suicide in young people is closely related to the life phase in which they are making choices that determine their fates and life projects [44] and that create intense economic impacts. Various factors have been listed as potential causes of suicide among young people and adolescents: unemployment, economic difficulties, family breakdown, and changes in society, such as decreased religiousness, new gender roles, increasing competition in school, increasing female presence in universities, and the shift from traditional rural society to an urban and industrialized structure [37]. From 1980 to 2000, Brazil experienced an alarming 1,900% increase in suicide rates in the young population [30], corroborating our findings, although the South of Brazil showed a clear decrease in the rates in this same age bracket.

The increase in suicide rates among the elderly, as evidenced in this study, is consistent with findings in other countries and raises a serious concern, since the world population's life expectancy is increasing, and along with it, the proportion of the elderly population in societies' composition [14]. In addition, the method used most frequently in this age group has been self-poisoning either with pesticides or medicines, and access to the latter is easier in this age bracket due to various clinical conditions that are more frequent in the elderly. Clearly, more elderly persons have shown greater risk due to two factors, age and generation. As for age, the reasons for developing suicidal ideation include the impossibility of coping with life as previously, loss of life companions, and disabilities resulting from illnesses or aging itself [45]. The reality of many elderly people is rife with chronic illnesses, which can often cause emotional changes and decreased functional capacity. In addition, retiring from the world of work, loss of contact with coworkers, and the death of loved ones result in the lack of a social place and exacerbate the impacts of chronic illness [46].

This study showed that gender and age were the most important factors for explaining suicide rates in Brazil, as in the only other study with APC modeling in Brazil [16] and in other countries [9, 11–14].

The generation effect is even more serious but has received little attention. The cohort or generation effect is the change in groups' experience in an initial event such as birth in the same year or ranges of years [20] and that undergo different exposures to socioeconomic, behavioral, and environmental risk factors in various life cycles [10]. Brazilian society is undergoing an accelerated demographic transition in which personal relations have changed greatly: fertility has decreased, even as childbearing age has started earlier (with earlier sexual maturity) and has lasted longer due to medical technology that maintains biological viability of pregnancies in older women, as well as procedures that have extended men's sexual life with medications; the nuclear family no longer has a perpetual configuration, marriage is no longer indissoluble, and relationships are quicker and less bureaucratic, without maintaining the patriarchal hierarchy of the last century; and despite social networks and the modern world's dynamics, individuals feel increasingly isolated and removed from personal relations. This process of social change together with an older population (more physically, economically, and technologically limited) aggravates processes of isolation and depression, leading to suicidal ideation much more often than in other age groups. Our findings show that for practically all the regions and for Brazil as a whole, the more recent cohorts (1991 to 1995) evidenced higher risk when evaluating the overall population. The South was the only region of Brazil with higher suicide risk in the oldest cohort (1906 a 1910).

Other studies have largely pointed to greater importance of these effects on suicide rates, especially in relation to cohorts. In Switzerland, the cohort effects were similar for the male and female populations, although in the latter the effects were less pronounced, but were determinant for understanding the behavior of suicide rates in that country [9]. A study in Spain found a period effect for the female population, while the cohort effect was more evident in the male population [12]. In South Korea, cohort effects were determinant in the changes in rates from 1984 to 2013 [14]. A study conducted in Hong Kong and Taiwan found that the age effects for both regions in both sexes were quite similar and suicide rates increased with increasing age. Regarding period effects, Hong Kong had one peak (1999–2003) and Taiwan had two peaks (1979–1983 and 2004–2008). As for cohort effects, in both Hong Kong and Taiwan, younger male cohorts showed high suicide risk; while younger female cohorts, however, showed relatively low risk [11]. In the state of Rio de Janeiro, Brazil, from 1979 to 1998, the age-adjusted rates increased, more in men than in women, while a weak period effect was seen in the increasing rates in 1983–1984 and the cohort effect showed a decrease in the rates between the oldest cohorts and the youngest [16]. However, in our study, the period effect was larger than the cohort effect on suicide rates for most of the situations analyzed. The cohort effect was only stronger for the overall Brazilian population, the overall and male populations in the Southeast, and the female populations in the North, Central-West, and South.

Period effect is the variation in the time period that affects all the groups simultaneously, representing the rate's change in successive time periods [20, 33], summarizing a complex set of historical events and environmental factors, such as world wars, economic booms and recessions, famine, infectious disease pandemics, public health interventions, and technological discoveries [10]. The literature includes reports on the association between suicide and economic crises that resulted in economic recession and unemployment in various regions of the world [14, 47, 48].

The specific Brazilian case has shown that the rates have grown over the years [42, 49–51], raising the possibility that economic status has been a strong factor for the problem, together with the trends in personal and social relations addressed above in this article. The Brazilian economy has alternated short growth cycles with economic slowdowns, generally abrupt, since the 1980s when the dictatorship came to an end and the country began its process of re-democratization. This growth pattern persisted over the early 2000s. In the year 2000, Brazil's per capita Gross Domestic Product grew 4.3%, but in the following years (2001 to 2003) the economic slowdown had a heavy impact, and the GDP grew by only 1.7% per year. This economic scenario was followed by years of abundance and growth until mid-2014, except for a short period in 2009, when Brazil suffered the impact of the global crisis [52]. Our findings showed that an increase in suicide risk in the period from 2001 to 2005 in the overall population of Brazil and in some regions suggested that this period of economic and social transition with changes in the political profile resulting in conditions of emotional instabilities that provided fertile ground for self-destructive behavior. This analysis is important, because the Brazilian economy entered another heavy and prolonged recession starting in 2015, starting with crises in the industrial and services sectors and still showing no signs of recovery [52]. One can thus infer that the suicide rates since 2015 may have been influenced by this panorama and that feasible strategies need to be designed to minimize the harms from the economic impact on the Brazilian population's mental health.

This finding on the period effect with the study in Spain showed that socioeconomic and structural changes were responsible for the increase in depression, alcoholism, and suicidal ideation in the 1980s [12]. Likewise, in Switzerland, the two World Wars and economic problems were the factors impacting suicide rates in both sexes [9]. In Russia, the Cold War, Mikail Gorbatchev's plans, and the breakup of the Soviet Union were the backdrop for the increase in suicide rates among Russians [13]. The concern with this effect's impact is due mainly to doubts as to the repercussions of this scenario on future suicide rates, since Brazil is suffering the effects of the global economic crisis and globalization of consumption, leading to cheaper costs for importation than for domestic production, alongside the unfavorable political scenario stemming from the discovery of corruption schemes in large state-owned companies, drastic government changes, and dwindling investments in social programs. This combination of factors tends to aggravate the changes in society and predict an increase in psychological suffering, depression, and other mental disorders that can trigger suicides.

Except for the North and for women in the Central-West region, the model that best fits the data is the complete model (age-period-cohort). Table 1 shows that cohort effect had a stronger influence than period effect for the overall population of Brazil and the Central-West and Southeast, the male population of the Southeast, and the female population in the South. The period effect had a stronger influence in all the other cases.

A question that cannot be overlooked is that this increase in the absolute number of suicides and in the rates may result from improvement in the quality of mortality data. Confronting the idea of death mobilizes our own sense of finitude, an aspect that increases exponentially in the case of suicide [53]. Suicide is still permeated by persistent taboos and prejudices, hindering the search for help in the presence of ideation, even though the problem is debated more widely today. Thus, part of the logical reasoning is to assume that underreporting can occur, although the official data on suicide are believed to be improving. However, admitting that a suicide has touched the individual's family, the community, or society is still not a routine and demystified step. Admitting the suicide often means admitting that the psychological suffering existed and was not adequately treated to avoid resulting in the act, and that preventive policies have been insufficient. Still, admitting the fact is actually the first step towards changing the situation, as confirmed by the change experienced in the South of Brazil. Although the South of Brazil still has high suicide rates, our study showed that the younger cohorts have lower suicide risk and that the rates have decreased over time. This change has not appeared out of nowhere: it is the result of various studies [28–31] that reported higher suicidal behavior in this population, based on which, adequate suicide prevention policies were demanded that produced these new results over time.

The APC method also allowed detecting the differential magnitude of suicide's impact between men and women. Not surprisingly, males predominated in the suicide profile, a fact that has been documented in other studies in Brazil [2, 4, 7, 8, 29, 30, 36, 49, 50, 54, 55] and elsewhere in the world [43, 56–61]. However, female suicide patterns call stand out, since women have tended to die of suicide at younger ages. Attempted suicide should also be considered, since it is more frequent in women [62–64]. The pattern may still be disguised by women's choice of less effective and less violent methods [65]. According to another theory, men generally tend to have more schooling than women, and women would thus display lower suicide rates. This difference in education has decreased over the years, but women have continued to be protected by having lower prevalence of alcohol abuse, greater religiousness, and flexibility in social skills and roles throughout life, while recognizing risk signs for depression earlier, participating more in social support networks [66–69], and seeking help for mental disorders earlier. Our findings evidenced that Brazilian women have displayed an upward pattern in suicide rates throughout adulthood, until around 50 years, when the rates decreased, except in the Northeast and Southeast regions, where they continued to increase.

Limitations

Possible limitations are the type of data used (death certificate records) and uncertainty concerning this data's quality. In addition, the study design (ecological) does not allow individualization of the findings, making it difficult to correlate the suicide event with the occurrence of depression and mental disorders in the Brazilian population and thus address possible causes of this problem.

On the issue of the method used here, APC modeling is not routine or simple to analyze. In other studies that use APC analysis of suicide data, there was no consensus on the best way to analyze the data [11–17]. The current study shares the limitations common to APC analysis. On the one hand, they are constrained by the lack of definitive real-world models, such that some ambiguity in the results cannot be ruled out. On the other, the effects of APC represent formal dimensions related to time and age, which are insignificant per se, but which provide useful tools for examining real-world variables. The analysis was also limited to the principal effects and leaves some room for more complex models, such as non-linear models or models including interaction effects.

Despite these possible limitations, age-period-cohort modeling is capable of describing suicide trends more accurately than other approaches. It obviously does not rule out the need for other epidemiological studies, but it focuses the attention where it has proven most urgent and where the interventions should begin.

Conclusions

Suicide mortality rates have shown an upward pattern with increasing age in the Brazilian population, independently of gender. However, the behavior of period effect and cohort effect has depended on the population analyzed and its regional distribution. According to our findings, the majority of Brazil's regions were more influenced by a period effect, and fluctuations in the patterns were consistent with periods of economic growth versus recession. This suggests a guideline that can be followed to promote an effective public policy in mental health.

Today, suicide prevention in Brazil is still a low-priority public policy. "Yellow September" has been celebrated in recent years as part of the prevention strategy, but precarious mental healthcare at the local level (in Brazil's municipalities) is still an obstacle to accessing this type of service. More services and more healthcare professionals are needed to treat all aspects of psychological distress, ranging from primary care to Centers for Psychosocial Support and referral hospitals for psychiatric care. It is important to eliminate deeply rooted taboos and prejudices and to understand that the process of suffering that leads from ideation to death by suicide can be interrupted, thus avoiding early loss of lives and sequelae from suicide attempts.

Declarations

Ethics approval and consent to participate

The data employed in this study are publicly available by the Brazilian Ministry of Health, without identifying participants, on the official website (DATASUS). Thus, according to Resolution No. 510/2016 of the Brazilian National Health Council, research conducted with anonymized public data does not require research ethics committee approval or informed consent because it is not possible to identify individuals. All methods were carried out in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and material

The datasets analysed during the current study are available in the Zenodo repository, https://zenodo.org/record/6547039#.YoJ-QOjMK3C

Competing interests

The authors declare that they have no competing interest.

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Authors' contributions

PVMG contributed to the conception and design of the study, the acquisition, analysis, interpretation of data and drafted the manuscript. CMFPS participated in the conception and design of the study, interpretation of data and provided critical revision of the article. All authors have read and approved the manuscript.

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References

1. WHO. Suicide. World Health Organization. 2021. https://www.who.int/news-room/fact-sheets/detail/suicide. Accessed 31 Oct 2021.
2. Brazil. Mortalidade por suicídio e notificações de lesões autoprovocadas no Brasil. Bol Epidemiológico. 2021;52:1–10.
3. Minayo MC de S, Bahia CA. Suicide, A Public Health Problem in Brazil. IntechOpen; 2021.
4. Souza ER de, Minayo MC de S, Malaquias JV. Suicide among young people in selected Brazilian State capitals. Cad Saúde Pública. 2002;18:673–83.
5. Vasconcelos AMN, Gomes MMF. Transição demográfica: a experiência brasileira. Epidemiol E Serviços Saúde. 2012;21:539–48.
6. Macente LB, Zandonade E. Spatial distribution of suicide incidence rates in municipalities in the state of Espírito Santo (Brazil), 2003-2007: spatial analysis to identify risk areas. Braz J Psychiatry. 2012;34:261–9.
7. Parente A da CM, Soares R de B, Araújo ARF, Cavalcante IS, Monteiro CF de S. Caracterização dos casos de suicídio em uma capital do Nordeste Brasileiro. Rev Bras Enferm. 2007;60:377–81.
8. Brazil. Perfil epidemiológico das tentativas e óbitos por suicídio no Brasil e a rede de atenção à saúde. Bol Epidemiológico. 2017;48:1–14.
9. Ajdacic-Gross V, Bopp M, Gostynski M, Lauber C, Gutzwiller F, Rössler W. Age-period-cohort analysis of Swiss suicide data, 1881-2000. Eur Arch Psychiatry Clin Neurosci. 2006;256:207–14.
10. Yang Y, Land KC. Age-Period-Cohort Analysis: new models, methods, and empirical applications. Boca Raton: CRC Press; 2013.
11. Chen Y-Y, Yang C-T, Pinkney E, Yip PSF. The Age-Period-Cohort trends of suicide in Hong Kong and Taiwan, 1979-2018. J Affect Disord. 2021;295:587–93.
12. Granizo JJ, Guallar E, Rodríguez-Artalejo F. Age-period-cohort analysis of suicide mortality rates in Spain, 1959-1991. Int J Epidemiol. 1996;25:814–20.
13. Jukkala T, Stickley A, Mäkinen IH, Baburin A, Sparén P. Age, period and cohort effects on suicide mortality in Russia, 1956–2005. BMC Public Health. 2017;17:235.
14. Park C, Jee YH, Jung KJ. Age–period–cohort analysis of the suicide rate in Korea. J Affect Disord. 2016;194:16–20.
15. Phillips JA. A changing epidemiology of suicide? The influence of birth cohorts on suicide rates in the United States. Soc Sci Med 1982. 2014;114:151–60.
16. Rodrigues NCP, Werneck GL. Age-period-cohort analysis of suicide rates in Rio de Janeiro, Brazil, 1979–1998. Soc Psychiatry Psychiatr. 2005;40:192–6.
17. Surtees PG, Duffy JC. Suicide in England and Wales 1946–1985: an age-period-cohort analysis. Acta Psychiatr Scand. 1989;79:216–23.
18. Carstensen B. Demography and epidemiology: Age-Period-Cohort models in the computer age. Copenhagen: Department of Biostatistics, University of Copenhagen; 2005.
19. Meira KC, Silva GA e, Silva CMFP da, Valente JG. Efeito idade-período-coorte na mortalidade por câncer do colo uterino. Rev Saúde Pública. 2013;47:274–82.
20. Yang Y, Schulhofer-Wohl S, Fu WJ, Land KC. The intrinsic estimator for Age-Period-Cohort Analysis: what it is and how to use it. Am J Sociol. 2008;113:1697–736.
21. Rutherford MJ, Lambert PC, Thompson JR. Age–period–cohort modeling. Stata J. 2010;10:606–27.
22. Ahmad OB, Boschi-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age Standardization of Rates: A new WHO Standard. GPE Discuss Pap Ser. 2001;9:14.
23. González JR, Llorca FJ, Moreno V. Algunos aspectos metodológicos sobre los modelos edad-período-cohorte: aplicación a las tendencias de mortalidad por cáncer. Gac Sanit. 2002;16:267–73.
24. Holford TR. Understanding the effects of age, period, and cohort on incidence and mortality rates. Annu Rev Public Health. 1991;12:425–57.

25. Holford TR. The estimation of age, period and cohort effects for vital rates. Biometrics. 1983;39:311–24.
26. Meira KC, Guimarães RM, Santos J dos, Cabrelli R. Análise de efeito idade-período-coorte na mortalidade por câncer de mama no Brasil e regiões. Rev Panam Salud Publica. 2015;37:402–8.
27. Robertson C, Boyle P. Age-period-cohort analysis of chronic disease rates. I: Modelling approach. Stat Med. 1998;17:1305–23.
28. Calixto Filho M, Zerbini T. Epidemiologia do suicídio no Brasil entre os anos de 2000 e 2010. Saúde Ética Justiça. 2016;21:45–51.
29. Lovisi GM, Santos SA, Legay L, Abelha L, Valencia E. Análise epidemiológica do suicídio no Brasil entre 1980 e 2006. Braz J Psychiatry. 2009;31 Supl II:S86–93.
30. Mello-Santos C de, Bertolote JM, Wang Y-P. Epidemiology of suicide in Brazil (1980 - 2000): characterization of age and gender rates of suicide. Braz J Psychiatry. 2005;27:131–4.
31. Viana GN, Zenkner F de M, Sakae TM, Escobar BT. Prevalência de suicídio no Sul do Brasil, 2001-2005. J Bras Psiquiatr. 2008;57:38–43.
32. Robertson C, Gandini S, Boyle P. Age-period-cohort models: a comparative study of available methodologies. J Clin Epidemiol. 1999;52:569–83.
33. Abasse MLF, Oliveira RC de, Silva TC, Souza ER de. Análise epidemiológica da morbimortalidade por suicídio entre adolescentes em Minas Gerais, Brasil. Ciênc Saúde Coletiva. 2009;14:407–16.
34. Carmo ÉA, Santos PHS, Ribeiro BS, Soares C de J, Santana MLAD, Bomfim E dos S, et al. Características sociodemográficas e série temporal da mortalidade por suicídio em idosos no estado da Bahia, 1996-2013. Epidemiol E Serviços Saúde. 2018;27:e20171971.
35. Cantor CH, Neulinger K. Australian suicide trends 1964-1997: youth and beyond? Med J Aust. 1999;171:137–41.
36. Meneghel SN, Victora CG, Faria NMX, Carvalho LA de, Falk JW. Características epidemiológicas do suicídio no Rio Grande do Sul. Rev Saúde Pública. 2004;38:804–10.
37. Mittendorfer-Rutz E. Trends of youth suicide in Europe during the 1980s and 1990s – gender differences and implications for prevention. J Mens Health Gend. 2006;3:250–7.
38. Vidal-Rodeiro CL, Santiago-Pérez MI, Paz-Esquete J, López-Vizcaíno ME, Cerdeira-Caramés S, Hervada-Vidal X, et al. Distribución geográfica y temporal del suicidio en Galicia (1976–1998). Gac Sanit. 2001;15:389–97.
39. Byard RW, Hanson KA, Gilbert JD. Suicide methods in the elderly in South Australia 1981-2000. J Clin Forensic Med. 2004;11:71–4.
40. Cheong K-S, Choi M-H, Cho B-M, Yoon T-H, Kim C-H, Kim Y-M, et al. Suicide rate differences by sex, age, and urbanicity, and related regional factors in Korea. J Prev Med Pub Health. 2012;45:70–7.
41. Kim M-H, Jung-Choi K, Jun H-J, Kawachi I. Socioeconomic inequalities in suicidal ideation, parasuicides, and completed suicides in South Korea. Soc Sci Med 1982. 2010;70:1254–61.
42. Minayo MC de S, Pinto LW, Assis SG de, Cavalcante FG, Mangas RM do N. Tendência da mortalidade por suicídio na população brasileira e idosa, 1980-2006. Rev Saúde Pública. 2012;46:300–9.
43. Pavia M, Nicotera G, Scaramuzza G, Angelillo IF. Suicide mortality in Southern Italy: 1998-2002. Psychiatry Res. 2005;134:275–9.
44. Dutra E. Suicídio de universitários: o vazio existencial de jovens na contemporaneidade. Estud E Pesqui Em Psicol. 2012;12:924–37.
45. Kjølseth I, Ekeberg O, Steihaug S. Why suicide? Elderly people who committed suicide and their experience of life in the period before their death. Int Psychogeriatr. 2010;22:209–18.
46. Sousa GS de, Silva RM da, Figueiredo AEB, Minayo MC de S, Vieira LJE de S. Circunstâncias que envolvem o suicídio de pessoas idosas. Interface - Comun Saúde Educ. 2014;18:389–402.
47. Hong J, Knapp M. Geographical inequalities in suicide rates and area deprivation in South Korea. J Ment Health Policy Econ. 2013;16:109–19.
48. Yoon J-H, Junger W, Kim B-W, Kim Y-J, Koh S-B. Investigating the Time Lag Effect between Economic Recession and Suicide Rates in Agriculture, Fisheries, and Forestry Workers in Korea. Saf Health Work. 2012;3:294–7.
49. Bando DH, Jorge MHP de M, Waldman EA, Volpe FM, Lester D. Secular Trends of Suicide in the City of São Paulo, 1904–2017. Crisis. 2021.
50. Machado DB, Santos DN dos. Suicídio no Brasil, de 2000 a 2012. J Bras Psiquiatr. 2015;64:45–54.
51. Pinto LW, Pires T de O, Silva CMFP da, Assis SG de. Evolução temporal da mortalidade por suicídio em pessoas com 60 anos ou mais nos estados brasileiros, 1980 a 2009. Ciênc Saúde Coletiva. 2012;17:1973–81.
52. Paula LF de, Pires M. Crise e perspectivas para a economia brasileira. Estud Av. 2017;31:125–44.
53. Barbosa F de O, Macedo PCM, Silveira RMC da. Depressão e o suícido. Rev SBPH. 2011;14:233–43.
54. Bando DH, Scrivani H, Morettin PA, Teng CT. Seasonality of suicide in the city of Sao Paulo, Brazil, 1979-2003. Braz J Psychiatry. 2009;31:101–5.
55. Rocha FF da, Sousa KCA de, Paulino N, Castro JO, Correa H. Suicídio em Belo Horizonte entre 2004 e 2006. Braz J Psychiatry. 2007;29:190–1.
56. Agerbo E, Stack S, Petersen L. Social integration and suicide: Denmark, 1906–2006. Soc Sci J. 2011;48:630–40.
57. Ajdacic-Gross V, Wang J, Bopp M, Eich D, Rössler W, Gutzwiller F. Are seasonalities in suicide dependent on suicide methods? A reappraisal. Soc Sci Med 1982. 2003;57:1173–81.
58. Alvaro-Meca A, Kneib T, Gil-Prieto R, Gil de Miguel A. Epidemiology of suicide in Spain, 1981-2008: a spatiotemporal analysis. Public Health. 2013;127:380–5.
59. Mohanty S, Sahu G, Mohanty MK, Patnaik M. Suicide in India: a four year retrospective study. J Forensic Leg Med. 2007;14:185–9.
60. Ortega PA, Manrique RD, Tovilla Zarate CA, López Jaramillo C, Cuartas JM. Clinical and Epidemiological Characteristics of Suicides Committed in Medellin, Colombia. Rev Colomb Psiquiatr. 2014;43:106–12.

61. Tamosiunas A, Reklaitiene R, Virviciute D, Sopagiene D. Trends in suicide in a Lithuanian urban population over the period 1984–2003. BMC Public Health. 2006;6:1–7.
62. Bernardes SS, Turini CA, Matsuo T. Perfil das tentativas de suicídio por sobredose intencional de medicamentos atendidas por um Centro de Controle de Intoxicações do Paraná, Brasil. Cad Saúde Pública. 2010;26:1366–72.
63. Ghafarian Shirazi HR, Hosseini M, Zoladl M, Malekzadeh M, Momeninejad M, Noorian K, et al. Suicide in the Islamic Republic of Iran: an integrated analysis from 1981 to 2007. East Mediterr Health J. 2012;18:607–13.
64. Silva LF. Saúde das mulheres: o género, determinante cultural de saúde. Arq Med. 1999;13 Suppl 5:31–4.
65. Nock MK, Borges G, Bromet EJ, Cha CB, Kessler RC, Lee S. Suicide and Suicidal Behavior. Epidemiol Rev. 2008;30:133–54.
66. Andrés AR. Income inequality, unemployment, and suicide: a panel data analysis of 15 European countries. Appl Econ. 2005;37:439–51.
67. Koo J, Cox WM. An Economic Interpretation of Suicide Cycles in Japan. Contemp Econ Policy. 2008;26:162–74.
68. Rodriguez A. Inequality and Suicide Mortality: A Cross-Country Study. Working Paper. Development Research Working Paper Series; 2006.
69. Stack S. Suicide: a 15-year review of the sociological literature. Part II: modernization and social integration perspectives. Suicide Life Threat Behav. 2000;30:163–76.

Figures

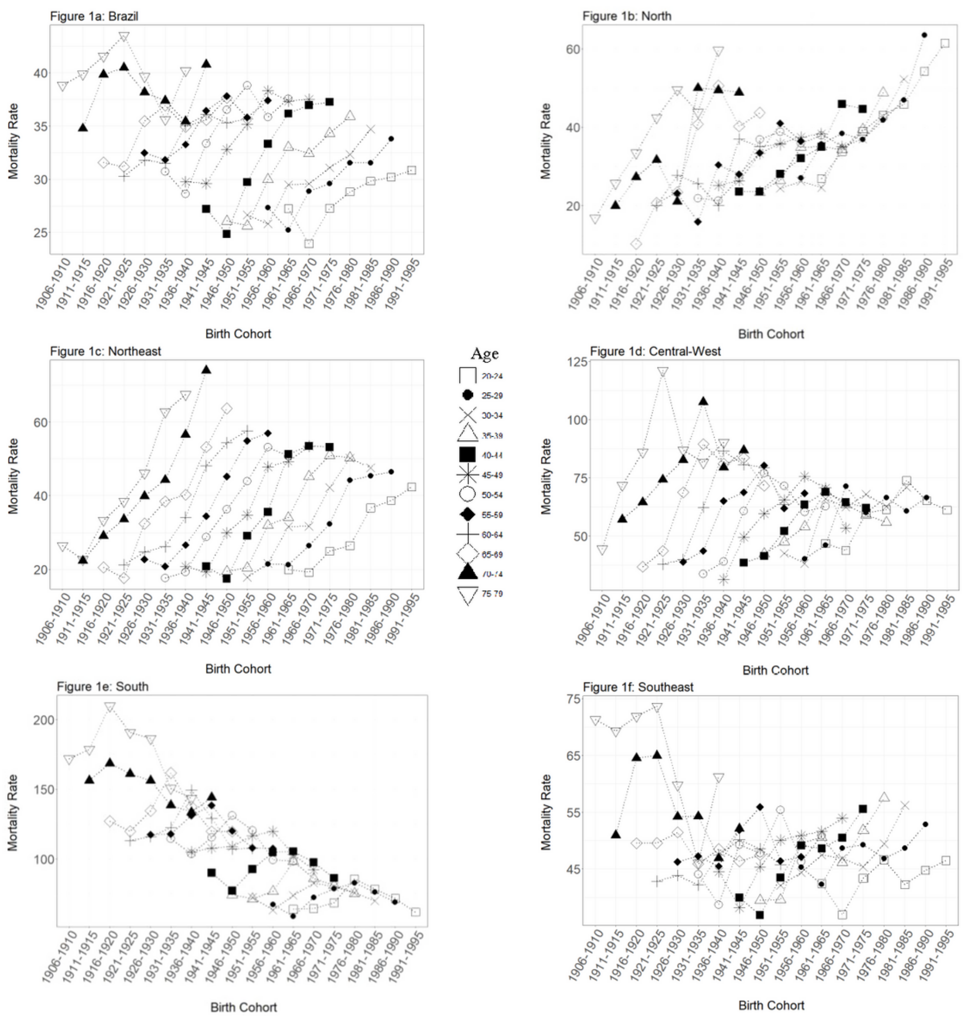

Figure 1

Suicide mortality rates by age bracket and birth cohort, Brazil and Regions, 1981 to 2015. Figure 1a: Brazil. Figure 1b: North. Figure 1c: Northeast. Figure 1d: Central-West. Figure 1e: South. Figure 1f.

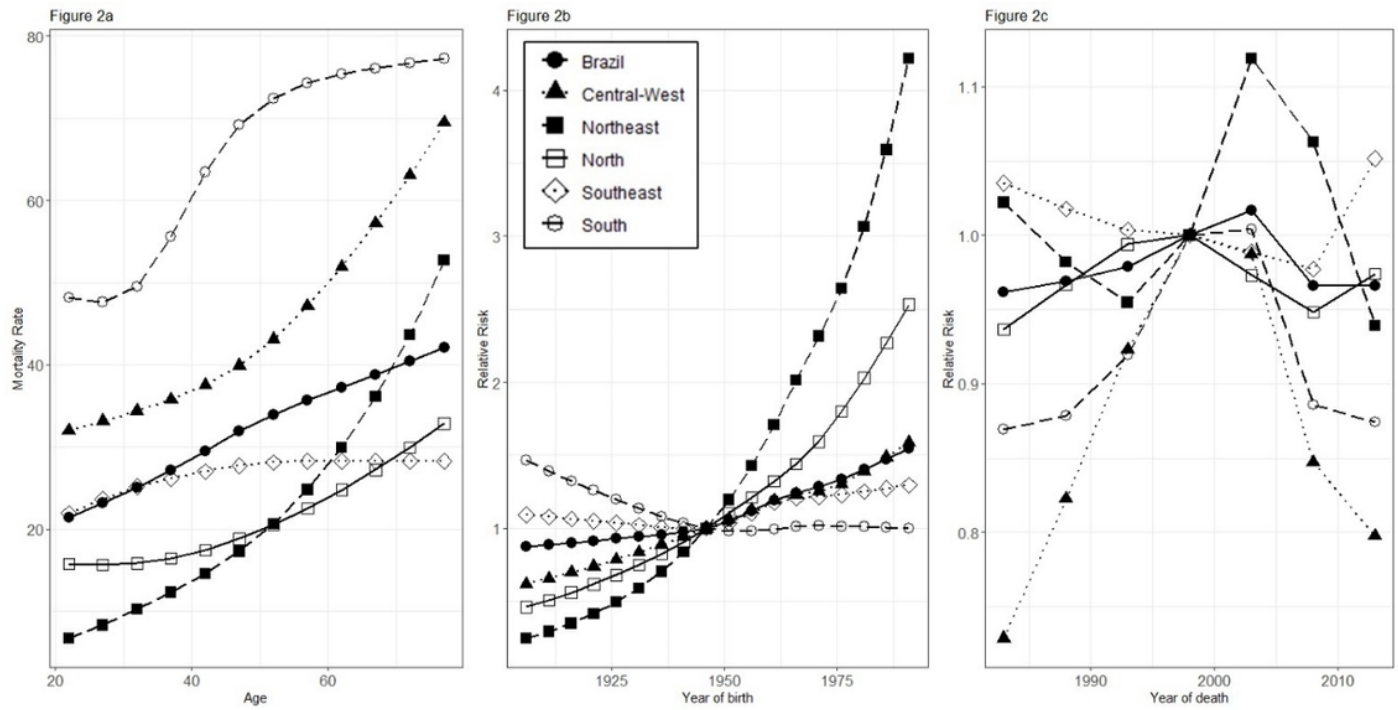

Figure 2

Models adjusted by age, period, and cohort for suicide mortality in the overall population, Brazil and regions, 1981 to 2015. Figure 2a: Age effect. Figure 2b: Period effect. Figure 2c: Cohort effect.

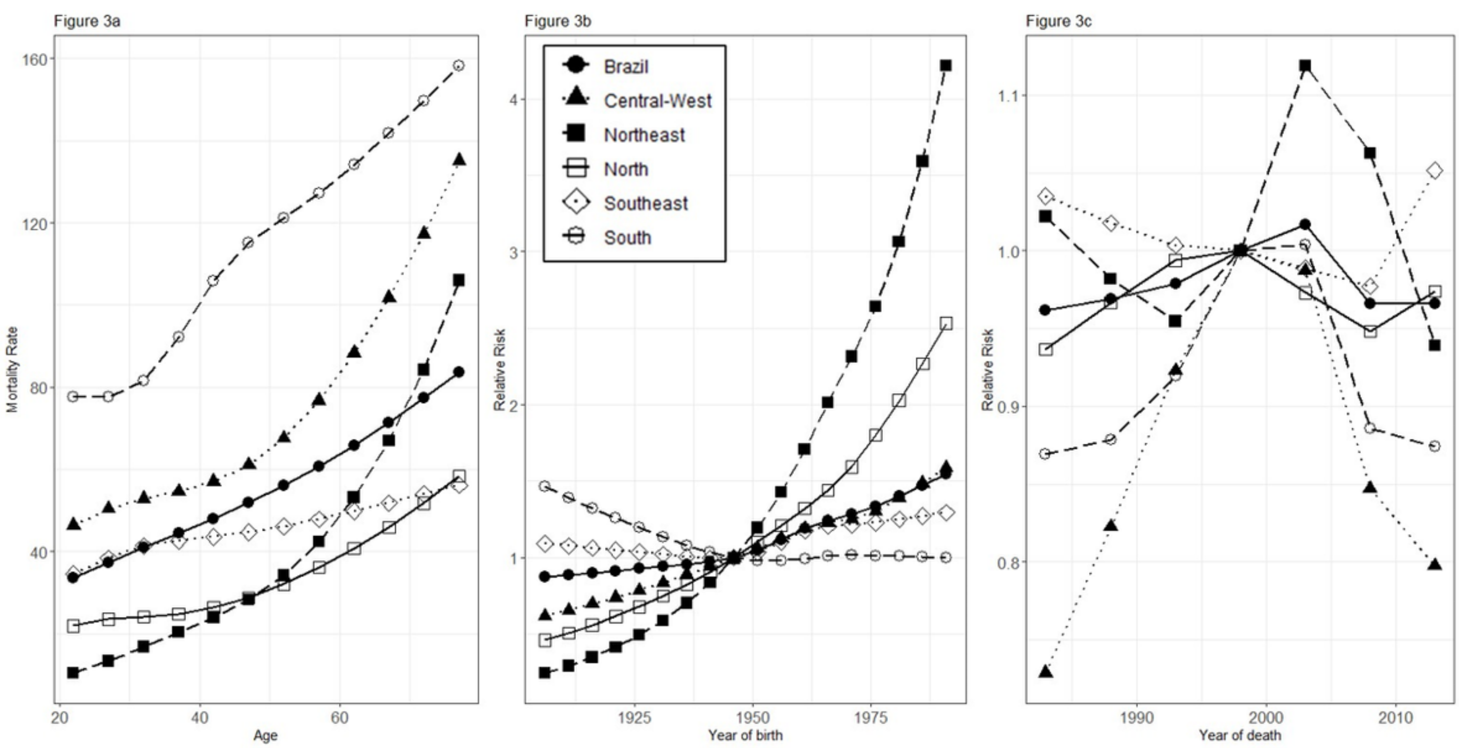

Figure 3

Models adjusted by age, period, and cohort for suicide mortality in the male population, Brazil and regions, 1981 to 2015. Figure 3a: Age effect. Figure 3b: Period effect. Figure 3c: Cohort effect

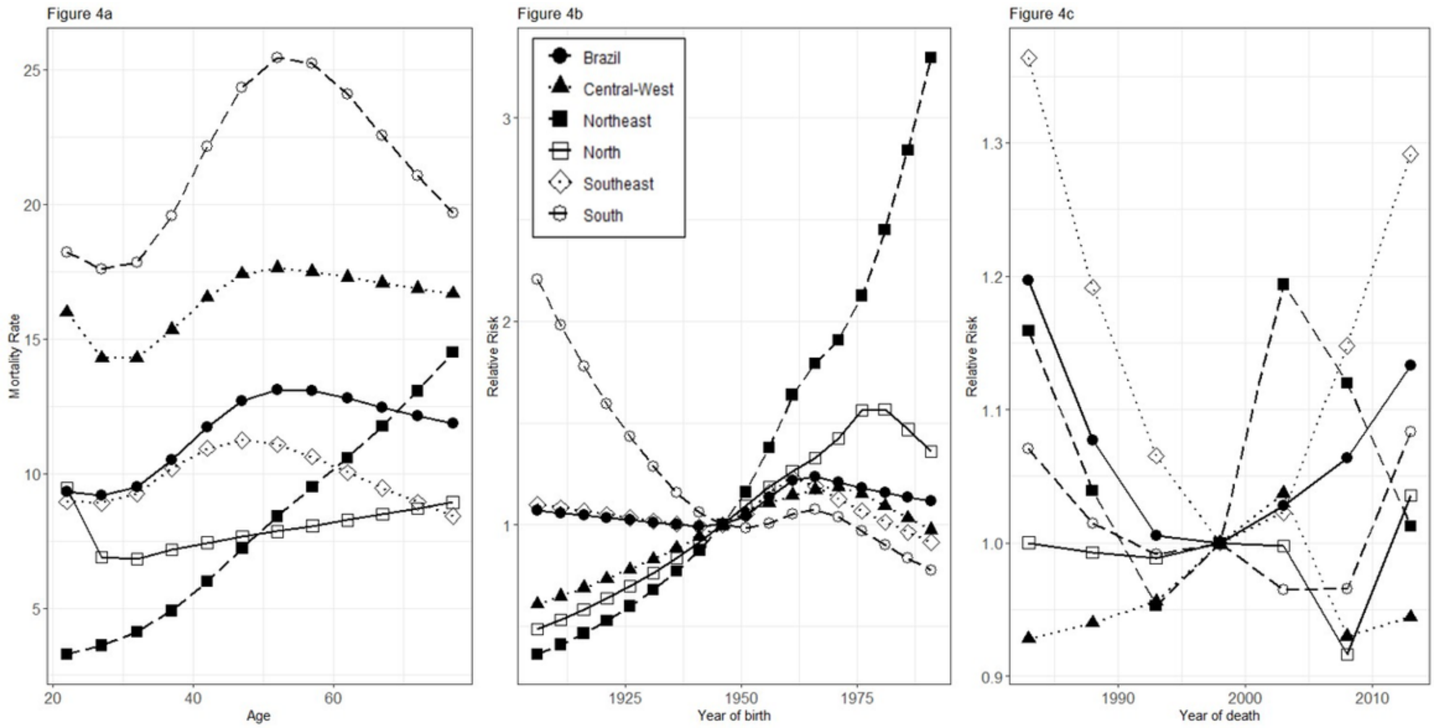

Figure 4

Models adjusted by age, period, and cohort for suicide mortality in the female population, Brazil and regions, 1981 to 2015. Figure 4a: Age effect. Figure 4b: Period effect. Figure 4c: Cohort effect.