The Determinants of Infant Mortality and Public Policies in Brazil 2004-2015: A Descriptive Study

Alexandre Hamilton Bugelli (alexandre.bugelli@umontreal.ca)

Université de Montréal École de Santé Publique: Universite de Montreal Ecole de Sante Publique

https://orcid.org/0000-0001-8527-1253

Roxane Borgès Da Silva

ESPUM: Universite de Montreal Ecole de Sante Publique

Ladislau Dowbor

Pontifical Catholic University of Sao Paulo: Pontificia Universidade Catolica de Sao Paulo

Claude Sicotte

ESPUM: Universite de Montreal Ecole de Sante Publique

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Abstract

Background

Infant mortality as a relevant indicator of population's health, social inequalities and living conditions has been fairly documented in the literature as it still represents a major challenge for emerging countries such as Brazil. While infant mortality rates have decreased in the last 30 years, some macro-regions of the country present great variability of infant mortality rates. These disparities, together with a rise in infant mortality and under-five mortality rates, and after the country experienced a political-economic crisis, draw attention to social determinants of health.

Method

We conducted a descriptive analysis of the determinants of infant mortality in Brazil between 2004 and 2015, based on the World Health Organization's Commission on Social Determinants of Health conceptual framework aiming at analyzing the evolution of these determinants to understand the behavior of the infant mortality rate observed in recent years in the country.

Results

Results suggested that there is a correlation between infant mortality and structural determinants such as income, the *Bolsa Família* Program, education and employment, and intermediary determinants such as the number of livebirths by prenatal visits, the number of physicians and nurses per thousand inhabitants, fertility rate, safe water, and sewage service coverage rates.

Conclusion

Results suggest that inequalities in infant mortality observed among macro-regions in Brazil are related to disparities in the distribution of Social Determinants of Health such as income, *Bolsa Família* Program coverage, education attainment, employment, fertility rate and of health-related determinants such as quality of and accessibility to healthcare and water supply, as well as sewage services. These disparities impose different dynamics between the structural and intermediary determinants of health that likely limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of IMR to remain at a relatively high level. Results also suggest that the increase of infant mortality rate in 2016 is attributable to the deterioration in one or more of those determinants, such as a fall in employment rate due to the economic crisis, may be pointed out as one of the causes of interruption on the trend of decline in infant mortality.

Background

Infant mortality as a relevant indicator of population's health, social inequalities and living conditions has been fairly documented in the literature [1–3] as it still represents a major challenge for public health and health systems' decision-makers in emerging countries such as Brazil. This observation gains even more

relevance, considering that in the last decades, Brazil has implemented an important health program in primary healthcare, the Family Health Strategy (FHS), and a conditional cash transfer program, *Bolsa Família* Program (BFP), having as main objectives the improvement of maternal and child health, education, and interruption of the intergenerational cycle of poverty observed in many regions of the country, that force families to prematurely putting children to work. The FHS was implemented in 1994 and focused on primary care teams that visited communities to deliver healthcare and were responsible for the health of the population of a specific geographical area [4]. In 2003, the Government implemented the BFP, aiming at providing cash transfers to families living in extreme poverty through compliance with health and educational conditionalities. The program's health conditionalities stipulated that parents should make sure that children under seven years of age comply with a growth monitoring and check-up routine and the national vaccination program. Pregnant women and breastfeeding mothers should participate in educational programs related to childcare and nutrition at their local health provider. The conditionalities linked to education required that children aged 6–17 years be enrolled in school and maintain a minimum attendance rate according to their age brackets [5].

Despite all those innovative initiatives, while infant mortality rates have decreased, some regions of the country are still showing wide disparities in infant mortality rates. Such disparities, along with a rise in infant mortality (IMR: deaths between birth and 364 days of life per thousand livebirths) and under-five mortality (U5MR: deaths between birth and under five-years of life per thousand live births) after a political-economic crisis (Fig. 1) draw attention to the social determinants of health (SDH) as factors of great influence on maternal and child health [6].

The Public Health perspective and the World Health Organization's (WHO's) Commission on Social Determinants of Health (CSDH) conceptual framework

Extensive research has been conducted aiming at elaborating theoretical and conceptual frameworks as tools capable of identifying and analyzing the SDH. One of the main models was developed in 1991 by Dahlgren-Whitehead that established the relationship between the individual, his or her environment, and his or her health. Individuals were placed at the center of the model, subjected to influencing factors that affect their health, such as lifestyle, behavior, social interaction, and living and working conditions [7]. Evans & Stoddart developed a model that also took into account prosperity and wealth production as factors impacting health [8]. Despite these conceptual models being quite comprehensive regarding the SDH, they did not include public policies as elements that could influence on health and health inequalities.

The WHO states that complexity defines health. Having this in mind and based on a comprehensive literature review on theoretical frameworks of the SDH, the WHO's CSDH consolidated a myriad of theoretical models in a single framework (Fig. 2) aiming at both the operationalization of empirical studies and providing an analytical tool for public health decision-makers aiming at health actions [9].

The framework is broken down into structural and intermediary determinants. Structural determinants encompass the social, economic, and political context which determines how and where a person is born

and lives, which also determines his or her socioeconomic position. Socioeconomic position influences the intermediary determinants (material circumstances, psychosocial circumstances, behavioral and/or biological factors, and the health system as a social determinant itself) and the exposure to risks. In this perspective, human rights and inequalities are closely related. The bridge between the structural and intermediary determinants is the social cohesion and social capital. The latter is based on the notion of empowerment, having the State as a promoter of equity. In fact, the framework advocates that public policies may act on both by promoting the SDH and the distribution of these determinants.

After conducting a literature review on the determinants of infant mortality in Brazil, we identified the main factors impacting infant mortality over the last ten years. In the perspective of macroeconomic policies and socioeconomic class (structural determinants), income arises as a factor to be analyzed in relation to infant mortality. BFP coverage rate, education attainment and employment rate are also connected to social and public policies in the social structural determinants of health. Access to quality and comprehensive health services (as factors linked to the health system), the fertility rate (as household decision and managing capacity for tackling childbearing) and housing (access to safe water supply and sewage services) are related to the intermediary social determinants of health. The literature review also identified socioeconomic inequalities as a factor that may hinder the effective use of the health service system in some macro-regions of the country. This particular element is in line with the main premises of the WHO's CSDH framework.

Based on these findings, we conducted a descriptive and retrospective analysis of the determinants of infant mortality in Brazil between 2004 and 2015, building on the WHO's CSDH framework aiming at analyzing the evolution of these determinants to understand the behavior and disparities of infant mortality rate (IMR) observed in recent years in the country.

Methods

This was a descriptive analysis in which we analyzed the association between infant mortality and possible determinants and their evolution between 2004 and 2015. The determination of this observational window was due to the fact that the BFP was implemented in October 2003. Also, the need to isolate a period in which there was a relatively continuous series of data on socioeconomic factors determined the end of the study period in 2015.

Data

In this study, we used average values of secondary aggregated data of the 26 Brazilian states between 2004 and 2015, having as units of analysis the five macro-regions. The country's capital, Brasília, is a hybrid administrative instance (city-state) which presents a disproportionate per capita income when compared to other states, which may introduce bias in our models. Therefore, Brasília was excluded from our study. We calculated the average values of the data in the study by states and grouped them in the respective macro-regions of the country: North, Northeast, Southeast, South, and Midwest.

Infant mortality

IMR is an indicator of population health outcome. We opted to use IMR, as 70% of this indicator consists of NMR, while IMR accounts for 90% of the U5MR. Also, IMR is widely used as an indicator of the population's health. In our study, IMR is a proxy of health outcome related to social determinants of health regarding both the structural and the intermediary set of determinants.

The structural determinants of infant mortality

1) The Real Gross Domestic Product (RGDP) per capita was used as a proxy of per capita income and it corresponded to the value of the deflated Gross Domestic Product of a state divided by its number of inhabitants in a given year and is related to the social class in the group of structural social determinants of health.

2) The coverage rate of the BFP was the proportion between the families followed by the BFP and the number of families enrolled in the program in a given year, as a proxy to evaluate the impact of social policy on infant mortality related to the structural group of determinants.

3) The educational attainment rate (EDA) corresponds to the ratio between the net secondary school enrollment rate and the net primary school enrollment rate in a given year and is related to socioeconomic position also in the structural group of determinants.

4) The employment rate (the appropriate Brazilian terminology is occupancy rate - OCC) of the population was calculated using the methodology proposed by the Brazilian Institute of Geography and Statistics (IBGE), as the ratio between the total of employed persons aged 10 years or more and the total economically active persons linked to the structural group of determinants as well.

The intermediary determinants of infant mortality

5) The proportion of livebirths by the number of prenatal visits (LBPRE) of women aged from 15 to 49 years (reproductive age) in a given year was used as a proxy of the quality of prenatal care. The higher this ratio, the better the results in terms of livebirths as a measure of the effectiveness of prenatal healthcare. This factor is related to the intermediary group of determinants related to the health system.

6) We also used the number of physicians and nurses by thousand inhabitants (MEDEN), which was conceived to assess the impact of the availability of health professionals on infant mortality and also as a proxy to evaluate the accessibility and comprehensiveness of healthcare. This indicator was obtained by dividing the sum of the average number of physicians plus the average number of nurses in a given year, divided by thousand inhabitants living in a state and it is a factor related to the health system in the intermediary group of determinants as well.

7) The fertility rate (FR) was calculated by the ratio between live births in a given year and the total female population of reproductive age (between 15 and 49 years) in a given state, in a given year: The fertility rate was obtained by the ratio between livebirths in a given year and the total female population of reproductive age (between 15 and 49 years). This indicator is related to the capacity of the household to manage and tackle childbearing as a result of material circumstances and behavior in the intermediary group of determinants.

8) Safe water supply (WCT) corresponds to the proportion of the total households with access to safe water supply service in relation to the total of households in a given year. These data were used as a proxy of living conditions in the intermediary group of social determinants.

9) The total sanitation service coverage rate (SWT) was the proportion of the total households with access to sewage collection and treatment services in relation to the total of households in a given year. This indicator was also used as a proxy of living conditions in the intermediary group of social determinants.

Data sources

The employment rate (OCC), the fertility rate (FR), the educational attainment rate (EDA), and Real Gross Domestic Product per capita (RGDP) were obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE). Those data were estimated through the PNAD survey (National Household Sample Survey). The PNAD was conducted annually by the IBGE since 1981 and surveyed several characteristics of the population such as household structure, education, labor, income, and fertility. The PNAD sample in 2012 consisted of 147,203 households, with 362,451 residents.

It is worth mentioning that for the Census Year of 2010, PNAD surveys were not conducted and there were no data values in that specific year since the IBGE uses different samples and methodology for Census and PNAD. Thus, for employment (OCC), Real GDP per capita (RGDP), household income stratified by the number of average nominal minimum wages (IS_A to IS_F), water and sanitation data, total safe water coverage (WCT), sewage collection and treatment coverage (SWT) and educational attainment (EDA) we applied linear interpolation to obtain the values for 2010.

For the year 2004, there were no data available in the DATASUS for the number of families covered by the BFP and for the number of physicians and nurses per inhabitant (MEDEN). We used backward linear regression forecasting (“backcasting” in fact) to generate values for the number of physicians and nurses for that year. For BFP coverage specifically, as the program was implemented in October 2003, we used data only from the period when the program had expanded from 2005 to 2009 to estimate values for 2004 [10].

In the perspective of macroeconomic and social policies, and socioeconomic class (structural determinants), income arises as a factor to be analyzed in relation to infant mortality. Education attainment, BFP coverage rate, and employment rate are also connected to social and public policies among the structural determinants related to infant mortality. The fertility rate is a proxy of behavior, as

household decision and managing capacity for tackling childbearing, the access to quality and comprehensive health services, related to the health system as a social determinant itself, and housing, through safe water supply and sewage services coverage rates are connected to the intermediary set of determinants.

Analysis

First, we conducted a correlational analysis, using scatterplots diagrams (diagrams 3 to 11 in Fig. 3) and Pearson's correlation matrix (Fig. 4), aiming at identifying possible correlations between the infant mortality rate (IMR) and the indicators related to the structural and intermediary groups of social determinants. Next, we made a descriptive analysis of these indicators, reviewing the degree of disparities among the macro-regions (Tables 1 to 4). Then, we analyzed the evolution of each indicator over the period based on graphs according to the 5 macro-regions of the country (graphs 1 to 10 in Fig. 5). For our analysis, we used the statistical software STATA® version 13.1.

Results

Correlational analysis

Scatterplots (diagrams 3 to 11 in Figure 3) suggested that income represented by the per capita RGDP (diagram 3), BFP coverage rate (diagram 4) and educational attainment (diagram 5) were inversely correlated with the IMR. It is worth mentioning that the scatterplot suggests that the is correlation between IMR and income might be nonlinear and that as income increases it may have different impacts on IMR, probably more intensively on lower-income households.

Although presenting greater dispersion, the employment rate (diagram 6), the number of physicians and nurses per thousand inhabitants (diagram 8), and sewage service coverage (diagram 11) also seem to be inversely correlated with IMR. Conversely, the fertility rate (diagram 9) was positively and strongly correlated with IMR. Highly dispersed, a possible correlation between infant IMR and the number of livebirths by prenatal visits (diagram 7) and coverage rate of water supply (diagram 10) seem unlikely.

The correlation matrix (Figure 4) suggested that IMR was negatively correlated with income (-0.67), fertility rate (0.74) and educational attainment (-0.65) and BFP coverage rate (-0.56), and positively and strongly correlated with fertility rate (0.74). Employment (-0.32), sewage service coverage rate (-0.41) and the number of physicians and nurses per 1000 inhabitants (-0.49) were weakly correlated with IMR. The number of livebirths by prenatal visits (-0.18) and water supply coverage rate (-0.24) seem not to be correlated with IMR.

Descriptive analysis

Tables 1, 2, 3, and 4 display the descriptive statistics of infant mortality rate (Table 1) and its structural determinants: income, BFP coverage rate (as result of social policies) (Table 1), educational attainment,

and employment rate (Table 2), and the intermediate determinants: number of livebirths by the number of prenatal visits, the number of physicians and nurses per 1000 inhabitants (both related to the health system), fertility rate (Table 3) and safe water supply and sewage services coverage rates (Table 4), according to the macro-regions.

Structural determinants of infant mortality in Brazil 2004-2015

Except for the employment and coverage rates of the BFP (Table 1), the disparities observed in the structural determinants of infant mortality of the North and Northeast macro-regions are noteworthy. As shown in the correlational analysis, results suggested a strong negative correlation between per capita income (Table 1) and infant mortality, corroborated by much lower per capita income levels observed in the North macro-region (R$ 11,963) and Northeast macro-region (R$ 8,805), both presenting the highest infant mortality rates (17.63 and 16.84, respectively). In the opposite direction, the South and Southeast macro-regions presented the highest per capita income and the lowest infant mortality rates. Although the Southeast macro-region recorded the highest average per capita income (R$22,845) and only the second-lowest average IMR in the period (13.96 deaths per thousand livebirths), conversely, the South macro-region recorded the second-highest per capita income (R$20,794) and the lowest IMR (12.09 deaths per thousand livebirths). Regarding social policies, the different results of a possible association between BFP coverage (Table 1) and infant mortality rate draw attention, since the Southeast macro-region presented the second-lowest IMR and a low coverage rate of BFP (48.96%) in relation to the other macro-regions, whereas the South macro-region presented the second-highest average coverage rate of BFP (56.67%). The highest average coverage rate of BFP was observed in the Northeast macro-region (60.24%), whereas the North macro-region recorded the third average coverage rate (51.10%).

Table 1 Infant mortality rate and structural determinants: per capita income (per capita RGDP) and Bolsa Família Program coverage rate

	Infant Mortality Rate*				Income (Per capita RGDP)**				*BFP coverage rate****			
	Mean	SD	CI		Mean	SD	CI		Mean	SD	CI	
North	17.628	1.64	15.53	20	11,963	3,996	6,429	16,665	51.10	23.18	6.74	71.85
Northeast	16.844	2.394	13.95	21.23	8,805	3,169	4,577	13,734	60.24	21.96	16.43	78.14
Southeast	13.958	1.247	12.39	15.86	22,845	7,414	12,329	32,707	48.96	21.81	7.77	70
South	12.097	1.377	10.32	14.77	20,794	7,379	11,491	32,297	56.67	20.43	17.52	74.89
Midwest	15.263	1.848	12.68	18.72	17,758	6,628	9,877	28,035	50.39	24.53	4.55	71.77

(*): Deaths by thousand live-births; (**): Values in Reals (Brazilian currency – R$) and (***): Percentage values

Table 2 Structural determinants: educational attainment and employment rate

	Educational Attainment*				Employment rate*			
	Mean	SD	CI		Mean	SD	CI	
North	46.24	5.53	34.7	52.85	92.42	0.669	91	93
Northeast	45.59	5.92	32.98	49.69	91.75	0.866	90	93
Southeast	56.29	2.72	52.71	59.46	91.58	1.676	89	94
South	58.76	2.35	55.47	63.41	94.83	1.029	93	96
Midwest	51.97	6.61	41.53	59.59	93.5	1.382	91	96

(*): Percentage values

The highest educational performance (Table 2) in terms of net enrollments in the secondary school by net enrollments in the primary school was also observed in the South macro-region (58.76%) and the second in the Southeast (56.29%). In contrast, a poor educational performance was observed in the North macro-region (46.24%) and Northeast macro-region (45.59%). Finally, the South macro-region also holds the highest average employment rate (Table 2) of the series (94.83), while the Midwest presented the second-highest (93.5%) while the Southeast macro-region presented the lowest (91.58%).

Intermediary determinants of infant mortality in Brazil 2004-2015

Regarding intermediary determinants, there are large disparities among macro-regions as well. A higher quality of prenatal care, represented by the number of livebirths by the number of prenatal visits (table 3), and greater availability of physicians and nurses (Table 3) follow the same patterns of the structural determinants, suggesting an association with lower infant mortality rates. The South macro-region recorded the second-highest average values for the number of live births by prenatal visits (0.47) and for the number of physicians and nurses per thousand inhabitants (2.77), while the Southeast macro-region recorded the highest values (5.82 and 3.02 respectively). Fertility rate also presented disparities between subregions, with a higher average value in the North (2.47 live births per women aged 15 to 49 years) and Northeast (2.2 live births per women aged 15 to 49 years) than in the other macro-regions. In this aspect, the South macro-region showed the lowest fertility rate (1.79 live births per woman aged 15 to 49 years).

Table 3 Intermediary determinants: livebirths by prenatal visits; number of physicians and nurses by thousand inhabitants and fertility rate

	Live births/prenatal*				Physicians and nurses/ 1000 inhabitants*				Fertility Rate*			
	Mean	SD	CI		Mean	SD	CI		Mean	SD	CI	
North	0.315	0.053	0.26	0.42	2.04	0.088	1.91	2.17	2.474	0.285	2.25	3.12
Northeast	0.228	0.032	0.2	0.31	1.925	0.104	1.76	2.09	2.204	0.227	1.9	2.59
Southeast	0.582	0.117	0.38	0.85	3.018	0.203	2.7	3.28	1.807	0.126	1.64	2.02
South	0.473	0.088	0.36	0.64	2.77	0.196	2.45	3.1	1.791	0.135	1.62	2.03
Midwest	0.312	0.497	0.25	0.4	2.317	0.146	2.05	2.54	2.024	0.14	1.83	2.26

(*): Unit values

Table 4 Intermediary determinants: safe water supply and sewage service coverage rates

	Water supply coverage*				Sewage service coverage*			
	Mean	SD	CI		Mean	SD	CI	
North	95.25	3.441	8.9	101	14.75	4.751	5	23
Northeast	102.67	3.055	97	109	40.67	4.64	34	47
Southeast	110	3.045	104	114	95.92	6.33	87	105
South	113.75	3.467	107	118	41.58	9.2	28	58
Midwest	117.67	3.576	112	123	28.83	7.222	19	40

(*): Percentages values

The Midwest macro-region presented the highest safe water supply average coverage rate (Table 4), and, conversely, the lowest sewage service average coverage rate, and the third lower IMR (15.26 deaths per thousand livebirths). In this regard, the South macro-region recorded the second-highest average coverage rate of water supply, and although it recorded the second-highest sewage service average coverage rate (Table 4) (41.58%), it barely reached half of the sewage service average coverage rate of the Southeast macro-region (95.92%).

In summary, the South macro-region presented the lowest average IMR, recorded the highest educational attainment and employment rates, the second-highest per capita income, BFP coverage rate, quality of prenatal care, access to health professionals, water supply coverage rate and, particularly, the second-lowest sewage service coverage rate.

The evolution of infant mortality in Brazil and its determinants 2014-2015

Although our analysis so far suggested that there is a correlation between IMR and income, fertility rate, education, employment, BFP, and sewage services coverage rate and that there are many disparities regarding the indicators of social determinants of infant mortality in Brazil at the structural and intermediary levels, one must analyze the evolution of these factors over time to verify if these disparities are persistent and how they may impact IMR. In graphs 1 to 10 (Figure 5), we analyzed the evolution of each of these factors regarding the indicator of interest, the infant mortality rate between 2004 and 2015 according to the annual average values of indicators of the macro-regions and the country as a whole.

Infant mortality rate

In Graph 1 we noted a downward trend in the infant mortality rate (IMR) over the entire period, with higher rates in the North and Northeast macro-regions. The Northeast macro-region presented the greatest downward trend in IMR (36%), although differences between this region and the North macro-region in relation to the others are still high, with much higher rates compared with to the national average. The IMR in the Southeast macro-region declined more slowly than the country's average rates (18.2% and 28.5% respectively). Infant mortality rates in the South macro-region are the lowest over the period and declines have remained above the national average (30%).

Structural determinants of infant mortality

Per capita Income (Per capita RGDP)

Graph 2 shows that income grew over the entire period, especially after 2009. The South, Southeast, and Midwest regions presented the highest averages of per capita income (227%, 162% and 213.5%), however, the Southeast macro-region presented an expressive decrease of per capita income between 2014 and 2015.

Bolsa Família Program

The coverage rates of BFP (Graph 3) presented the greatest growth between 2004 and 2009 in all macro-regions. After this period, the BFP coverage seems to grow at decreasing rates. The Northeast and the South macro-region recorded higher coverage rates in relation to the country’s average. Regarding the IMR, it should be mentioned that the Northeast macro-region presented the highest IMR at the beginning of the interval but also faster declines in relation to the others (Graph 1). The South macro-region also presented slightly higher BFP coverage rates in relation to the national average.

Educational attainment

For the educational attainment indicator, the South macro-region had the highest national average, all over the period (Graph 4). It is worth noting that such macro-region also recorded the lowest average IMR (Graph 1). The indicator of educational attainment in the Midwest macro-region, together with that of the Northeast macro-region, seems to have grown faster than the others, although, that indicator also suggests the existence of inequalities between the North and Northeast macro-regions in relation to the others.

Employment

What stands out in Graph 5 is a significant drop in the employment rate between 2014 and 2015, mainly in the Northeast (-2.93%) and Southeast (-3.67%) macro-regions, which reached the lowest employment levels at the end of the series (89.3%). Another result to be highlighted is that the South macro-region presented the highest employment average rate throughout the period.

Intermediary determinants of infant mortality

Quality and effectiveness of prenatal care

It should be noted that during the entire period, the number of live births by prenatal visits (Graph 6) in the South and Southeast macro-regions presented the higher coefficients, with the greatest increase observed in the Southeast macro-region between 2009 and 2011 (18%). On the other hand, the Northeast macro-region presented the poorest performance in terms of prenatal care over the period and the lowest availability of health professionals over the interval (Graph 7).

Availability of healthcare professionals

The North and Northeast macro-regions counted with a low proportion of physicians and nurses per thousand inhabitants in relation to the others (Graph 7). The Southeast and South macro-region recorded a higher availability of physicians and nurses over the period, which also suggests the existence of inequalities in terms of effectiveness and availability of health services between macro-regions with implications to the performance of prenatal care.

Fertility rate

Graph 8 showed a steady declining trend of fertility rate over the entire period in all macro-regions. Exceptionally, the curves of the South and Southeast macro-regions in Graph 8 perfectly overlapped each other and were the ones showing the lowest fertility rates during the period. The Northeast macro-region presented the greatest decline in fertility rates between 2004 and 2015 (-28.6%), converging to the national average (1.85 live births per women aged 15 to 49 years). Although the North macro-region also demonstrated important declines in fertility rate, it remained far higher in relation to the national average (2.25 live births per women aged 15 to 49 years).

Access to safe water supply and sewage services

Regarding the access to safe water (Graph 9), there were almost imperceptible increases only in the South, Southeast, and Midwest macro-region between 2013 and 2015. Those macro-regions also presented higher levels of water supply coverage rates in relation to the national average. In the North and Northeast macro-regions, some oscillation were observed, with the coverage rates in 2015 remaining practically at the same levels as in 2004. All series seem to be stationary which may explain the huge dispersion observed in the scatterplot's diagrams and the weak probability of correlation to IMR.

On the other hand, in Graph 10, results suggest that access to sewage services probably acts differently, with different impacts depending on the socioeconomic context. The South macro-region showed an average coverage rate of sewage service that barely reached half of that observed in the Southeast macro-region (41.6% and 95.9%, respectively). It is noteworthy that although both macro-regions had higher average income, employment and educational achievement, lower fertility rate and greater access and quality health services, the Southeast had the highest average coverage of sewage services.

Discussion

This study provides a retrospective descriptive analysis of the disparities and the evolution of the determinants of infant mortality in Brazil between 2004 and 2015, based on the WHO's CSDH framework, aiming at understanding the behavior and the disparities of infant mortality rate (IMR) in recent years in Brazil.

The overall results of this study suggest a possible association between lower infant mortality rates and per capita income, education attainment, employment rate, fertility rate, quality of prenatal care, and access to health professionals. In contrast, higher infant mortality rates were observed along with all factors underlined above, in addition to lower safe water supply and sewage service coverage rates. Results also suggest that disparities in IMR observed among macro-regions in Brazil is due to huge inequalities in the distribution of those social determinants of health.

Although our data are limited to explain the slowdown in the reduction, as well as the recent increase in infant mortality indicators, results suggest that disparities in the distribution of the SDH limited further declines in the IMR, especially in the North and Northeast macro-regions. A variation in these social determinants in regard to the economic and political crisis likely has interrupted the secular trend of declining rates. In this regard, the marked fall of the employment rate between 2014 and 2015 may have had a delayed impact on IMR, among other factors.

In this subsection we will discuss the results in light of the structural and intermediary determinants of infant mortality in Brazil.

Structural determinants of infant mortality in Brazil 2004–2015

Several results emerge from this analysis and one of the highlights is that between 2004 to 2015, the average infant mortality trend in Brazil presents a declining trend and although the Northeast macro-region presented the greatest downward trend, differences between this region and the North macro-region respecting the others persist, with fairly higher infant mortality rates in relation to the national average. Studies carried in Brazil confirmed the existence of disparities in infant mortality, with higher rates observed in the North, Northeast, and Midwest regions [11, 12], mainly linked to socioeconomic and living conditions [13] and the quality [14] and access to healthcare [15]. The literature also reported that the North and Northeast macro-regions presented the lower levels of GDP per capita [12].

An association between income and infant mortality is in line with the literature [11–13], although Garcia, in a study conducted in Brazil between 1993 and 2008, reported that income affected infant mortality but to a lesser extent over time [16], which may explain the greatest declines in IMR in the Northeast macro-region that also recorded the lowest average of per capita income, while the Southeast macro-region presented the highest average per capita income and a slower reduction in IMR. The marked reduction in IMR in the Northeast macro-region was associated with an effect of the increased coverage of FHS and BFP in reducing poverty and malnutrition, which were among the major causes of diarrheal diseases and infant mortality under-one and under-five years [17, 18]. On the other hand, in a study on the effect of BFP coverage on IMR between 2003 and 2008, Shei [19] stated that IMR was already in a declining trend prior to the implementation of the BFP, although the declines appeared to have accelerated after the program was implemented.

The South macro-region demonstrated extremely higher performance in terms of educational attainment, although the results also revealed the existence of continuing inequalities in the North and Northeast macro-regions. Studies reported that IMR is inversely related to education [17, 20], stressing the greater access to healthcare by social groups with higher income, higher schooling levels and higher access to public services. Higher educational attainment also improves the perception of health and the knowledge about different medical expertise and treatment of diseases [12].

A possible association between educational attainment and income, mediated by employment is reported in studies on the pathways of the social determinants of health and health outcome [21]. Also, in a study using data from a mixed study based on interviews conducted in the Metropolitan Area of São Paulo, Ventura *et al.* [22] reported that among adults living in the same household, the fact of one having or not having a job was indicated as a determinant of the degree of stability and vulnerability of families regarding infant mortality. In regard, one must recall that the South macro-region witnessed the lowest IMR and also recorded the highest average rates of educational attainment and employment.

Intermediary determinants of infant mortality in Brazil 2004–2015

As advocated by the WHO's CSDH, the health system is itself a social determinant of health, which also has important implications for health inequalities.

The poor performance in terms of prenatal care observed in the North, Northeast and Midwest macro-regions, also related to socioeconomic inequalities, may be related to health inequities. Evidence demonstrating that quality [14], disparities in the access of health services [23], and availability of primary care physicians [15] are factors influencing infant mortality.

These findings reinforce the idea that there is a hierarchical relationship between the structural and intermediary determinants that would allow - or not - the emergence of health inequalities related to the use of health systems [9].

The literature confirms an association between decreasing fertility rates and decreasing infant deaths [17, 18, 24]. The current study found a continuous drop in the fertility rate in all macro-regions, although inequalities were observed in the North and Northeast macro-regions. On the other hand, the South and Southeast macro-regions presented the lowest fertility rates during the period. The literature also points out an increase in primary healthcare as one of the reducers of the fertility rate in Brazil [24] which gives added strength to the idea of health systems as a SDH.

Although the literature reports an association between adequate sewage service provision and infant mortality [18], our results were controversial, as the lowest infant mortality was observed in the presence of a relatively low sewage service coverage rate. These findings suggest that by improving SDH, one may conclude that some determinants may lose relevance in relation to others. This hypothesis is in line with the saturation-threshold theory formulated by Shuval *et al.* [25]. In a statistical study on the cost-benefit of sanitation investments in relation to the population's health, the results showed that among lower socioeconomic strata, there is a threshold below which investments exclusively in community water supply and/or sewage service result in little improvement in health status. Likewise, at the higher end of the socioeconomic scale, there is a saturation point in which further investments in conventional community sanitation could not result in significant health benefits. A higher average coverage rate of safe water in the Midwest macro-region also seems to have had a modest effect on IMR.

These findings suggest that determinants such as sanitary services, among others, may lose ability or have little or no significant impact in reducing IMR in the presence of inequalities related to other determinants. Conversely, our results pointed to educational attainment, employment and fertility rate as central drivers to both the higher and the lower infant mortality rates.

Although our data are limited to explain the decrease in reduction, as well as the recent increase in infant mortality indicators, results suggest that disparities in the distribution of the SDH limited further declines in the IMR, especially in the North and Northeast macro-regions. A variation in these social determinants in regard to the economic and political crisis likely has interrupted the secular trend of declining rates. In this regard, the marked fall of the employment rate between 2014 and 2015 may have had a delayed impact on IMR in 2016.

Strengths and limitations

This study provided a retrospective descriptive analysis of the evolution of social- and health-related determinants of infant mortality in Brazil between 2004 and 2015 using the WHO's CSDH conceptual framework. This analysis relied on a relatively long series of socioeconomic factors for assessing their evolution over time to understand the evolution of infant mortality and its determinants in recent years in Brazil.

In the 2010 Census, PNAD surveys were not conducted and there were missing data for income, employment, water, and sanitation, as well as educational attainment. We used backward linear interpolation to obtain the values for 2010. For the year 2004, there were no data available in DATASUS for the number of families covered by the BFP and for the number of physicians and nurses available. We used backward linear regression for back-casting these missing data. Although there were few interpolations to estimate missing data, this fact must be taken into consideration when interpreting our results. Also, the use of secondary data is susceptible to reporting errors and estimations that also may lead to bias. The coverage rates of safe water and sewage services exceed 100%, suggesting the existence of overreporting or more than one contract per household, which should be considered when interpreting the results. Although we suggested that there might be associations between our indicators and IMR, our data are limited to effectively allow us to prove these associations or any relation of causality.

Conclusion

Our study contributes to the literature by providing a comprehensive perspective of social determinants of infant mortality in light of the WHO's CSDH conceptual framework. Results suggest that inequalities in infant mortality observed among macro-regions in Brazil are related to disparities in the distribution of social determinants of health such as income, BFP coverage, education attainment, employment, fertility rate and of health-related determinants such as quality of and accessibility to healthcare and water supply, as well as sewage services. The results also suggest that these disparities limit further reductions in infant mortality, which would probably explain both the slowdown in the reduction and the tendency of the infant mortality rate to remain at relatively high levels. Although our data are limited to explain a possible cause for the increase of infant mortality rate in 2016, a possible deterioration in one or more of those determinants, such as a fall in employment rate due to the economic crisis, may be pointed out as one of the causes of interruption on the trend of decline in infant mortality.

More quantitative longitudinal studies are needed to establish an association between these determinants and infant mortality rates in Brazil, as well as to understand their dynamics.

Abbreviations

FHS: Family Health Strategy

BFP: Bolsa Família Program

IMR: Infant mortality rate

U5MR: Under-five mortality rate

SDH: Social Determinants of Health

WHO: World Health Organization

CSDH: Commission on Social Determinants of health

RGDP: Real Gross Domestic Product per capita

EDA: Educational Attainment

OCC: Employment rate

LBPRE: Number of live births per prenatal visits

MEDEN: Average number of physicians and nurses per habitant

FR: Fertility rate

WCT: Safe water supply coverage rate

SWT: Sewage services coverage rate

IBGE: Brazilian Institute of Geography and Statistics

PNAD: National Household Sample Survey

NMR: Neonatal mortality rate

Declarations

Ethics approval and consent to participate

Not applicable. The present study does not require ethical approval or consent for participation, since it was based on aggregated data at the population level and in the public domain that is freely accessible.

Consent for publication

Not applicable. The present study did not use humans and animals.

Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors hereby declare that they have no competing interests.

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Authors' contributions

All authors contributed to the theoretical basis of this study. The descriptive analysis was conducted by A. Bugelli under the supervision of R. B. Da Silva and C. Sicotte. All authors contributed to the discussion and interpretation of results. The final manuscript was read and approved by all authors.

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Authors' information

Alexandre Bugelli, PhD Program at École de Santé Publique de l'Université de Montréal (ESPUM), 7101, Park Avenue, 3rd floor, Montreal (Québec) H3N 1X9, Canada and CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Ministry of Education of Brazil, Brasilia – DF 700040-020, Brazil – Science without Borders Program – proc. 12940/13-5) scholar. Student affiliated to the Centre de Recherche en Santé Publique (CReSP), 7101, Park Avenue, 3rd floor, Montreal (Québec) H3N 1X9, Canada;

Roxane Borgès Da Silva, professor at École de Santé Publique de l'Université de Montréal (ESPUM), 7101, Park Avenue, 3rd floor, Montreal (Québec) H3N 1X9, Canada. Researcher at the Centre de Recherche en Santé Publique (CReSP), 7101, Park Avenue, 3rd floor, Montreal (Québec) H3N 1X9, Canada ;

Ladislau Dowbor, professor at Pontifícia Universidade Católica de São Paulo (PUCSP)/School of Economics and Business Administration - Graduate Program, Rua Monte Alegre, 984, Perdizes, São Paulo – SP, CEP 05014-901, Brazil and Claude Sicotte, professor at École de Santé Publique de l'Université de Montréal (ESPUM), 7101, Park Avenue, 3rd floor, Montreal (Québec) H3N 1X9, Canada.

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Figures

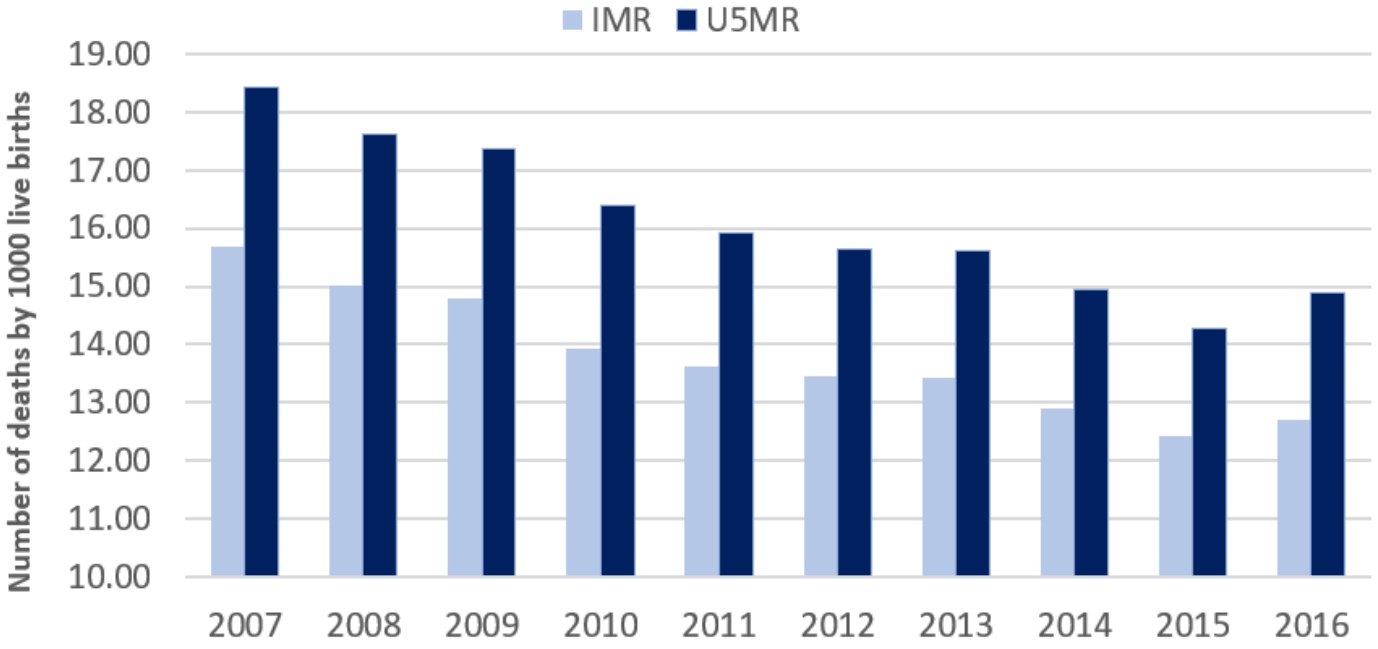

Figure 1

Infant mortality rate (IMR) and under -five-years mortality rate (U5MR) in Brazil, 2007-2016, (SIM-TABNET/DATASUS/Health Ministry:http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sim/cnv/evita10uf.def)

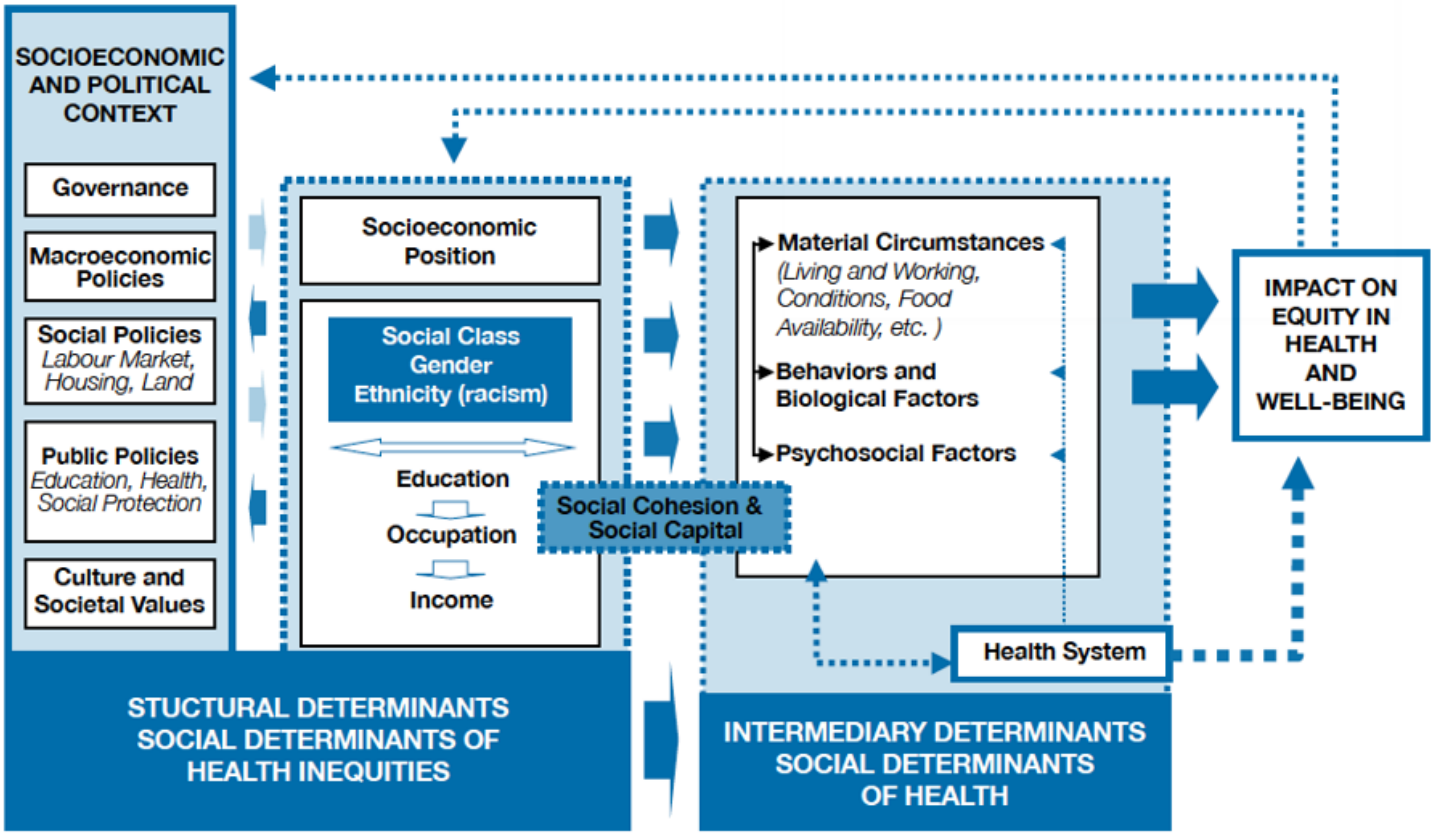

Figure 2

WHO's Commission of Social Determinants of Health – CSDH [9]

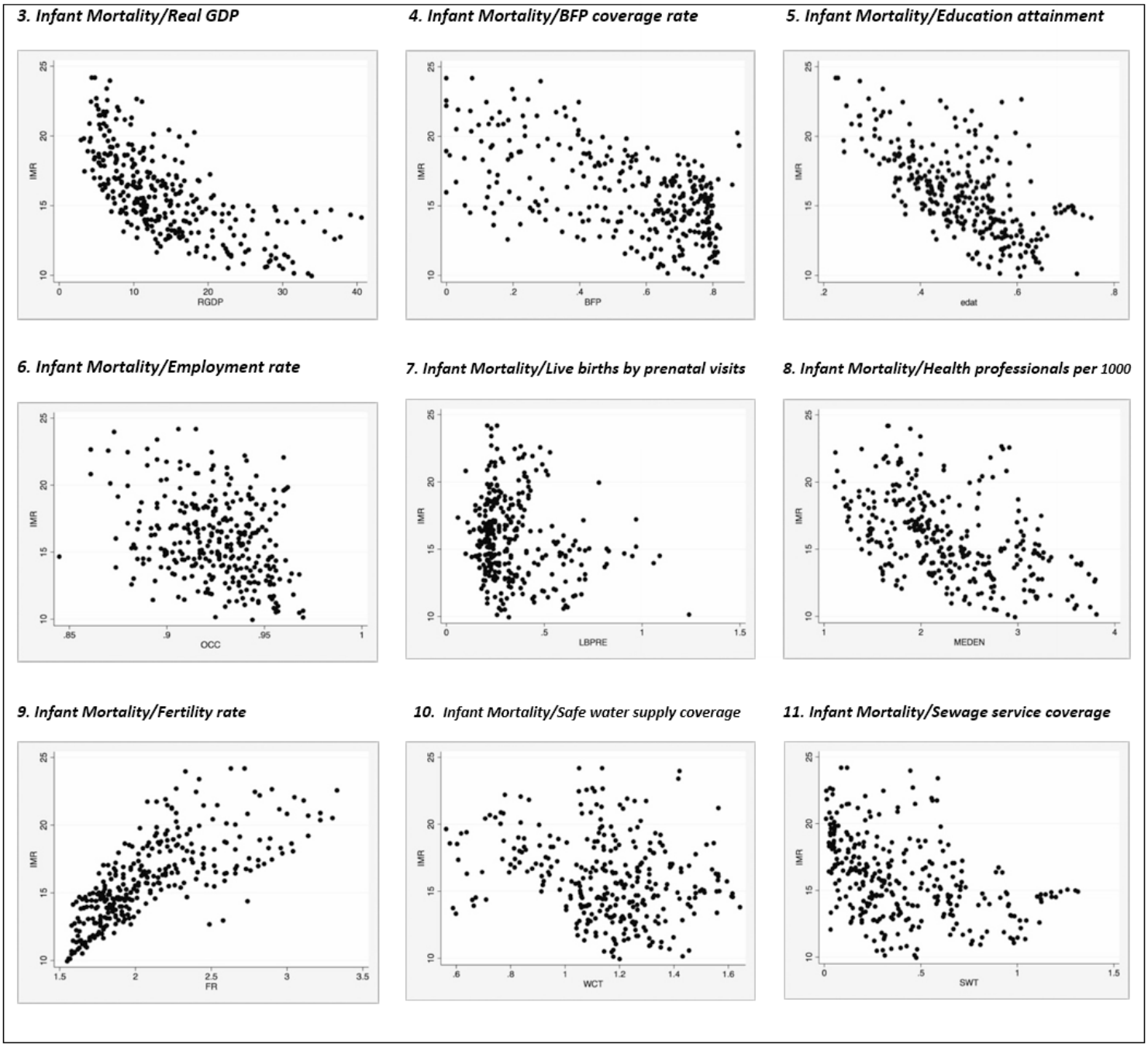

Figure 3

Scatterplots diagrams of infant mortality and possible determinants Diagrams 3 to 11 present scatter plots between infant mortality and: 3. real GDP per capita; 4. Bolsa Familia Program coverage (BFP); 5. educational attainment (ratio between the net secondary school enrollment rate and the net primary school enrollment rate-EDAT); 6. employment rate (OCC); 7. the ratio between the number of livebirths and the prenatal visits (LBPRE) 8. the proportion of the number of physicians and nurses per 1000 inhabitants (MEDEN); 9. Fertility rate (FR); 10. safe water supply coverage rate (WCT) and 11. sewage service coverage rate (SWT).

	imr	rgdp	occ	fr	edat	wct	swt	bfp	lbpre	meden
imr	1.0000									
rgdp	-0.6682	1.0000								
occ	-0.3191	0.1500	1.0000							
fr	0.7364	-0.5998	-0.1639	1.0000						
edat	-0.6475	0.6335	0.1962	-0.4521	1.0000					
wct	-0.2443	0.0969	-0.2036	-0.3890	0.2100	1.0000				
swt	-0.4116	0.5290	-0.1888	-0.5700	0.3934	0.3663	1.0000			
bfp	-0.5640	0.3806	0.1947	-0.4390	0.3752	0.2772	0.1335	1.0000		
lbpre	-0.1843	0.4030	-0.1276	-0.1976	0.2889	0.0382	0.4112	-0.3116	1.0000	
meden	-0.4932	0.6326	-0.0145	-0.4846	0.4269	0.2911	0.4722	0.0457	0.5097	1.0000

Figure 4

Correlation matrix

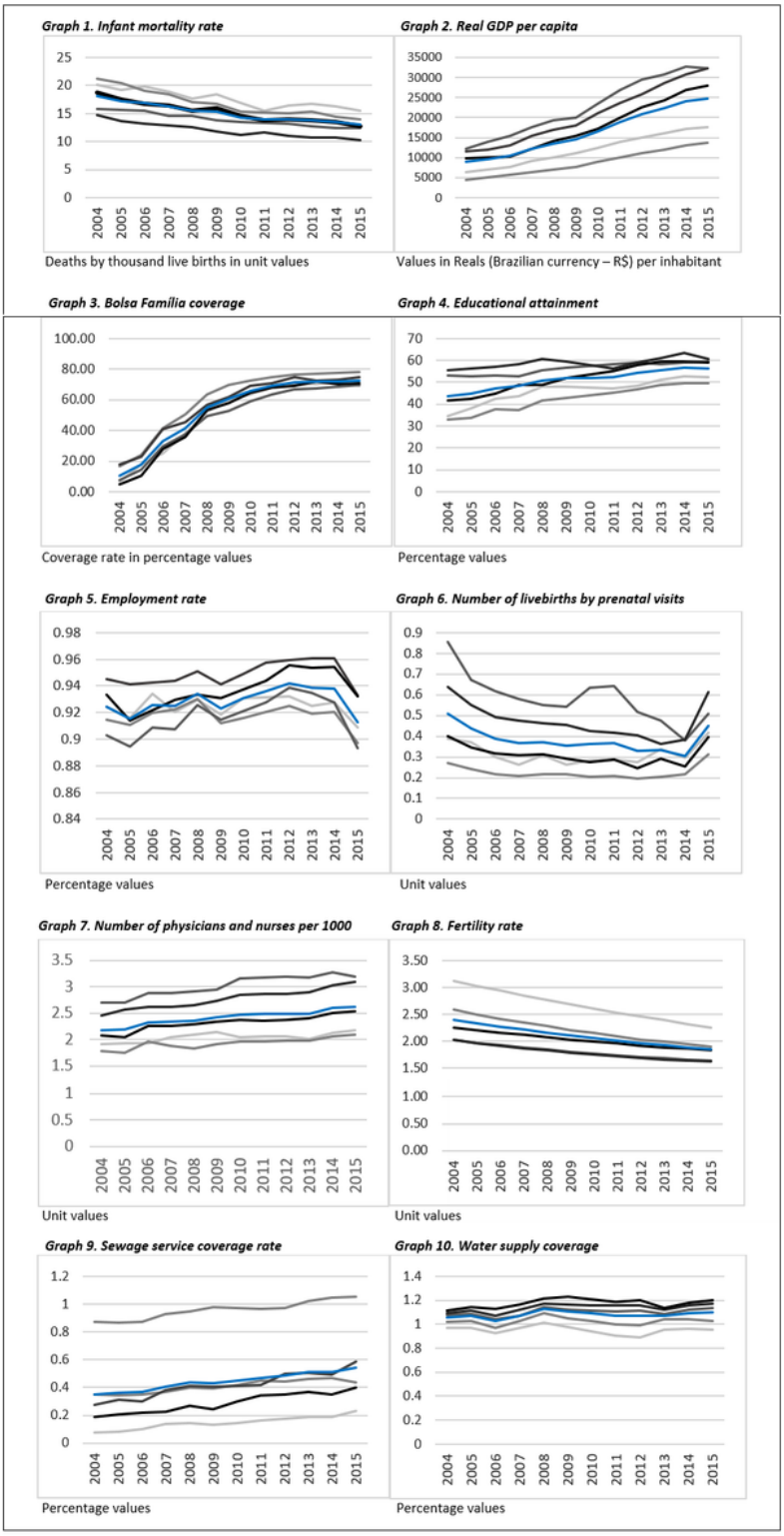

Figure 5

Please see the Manuscript file for the complete figure caption.