Ciência & Saúde Coletiva
cienciaesaudecoletiva.com.br
ISSN 1413-8123. v.30, n.6
DOI: 10.1590/1413-81232025306.03572025EN





# Effects of workforce volatility, determinants of infant deaths and resilience in SUS Primary Care

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**Abstract** *This article aims to analyze the effects of the volatility of the Primary Health Care (PHC) workforce in the Unified Health System (SUS) on the resilience of services and the reduction in infant deaths. We used the relationship between the PHC workforce and child-sensitive indicators: vaccination (poliomyelitis and measles) and infant deaths. This ecological time series study adopted indicators relating to the workforce, vaccination coverage, and infant deaths from preventable causes from all Brazilian states between 2017 and 2022, totaling a balanced panel with 162 pieces of information in 11 variables. For the data analysis, a fixed effects panel regression model was estimated, demonstrating the existence of significant statistical significance in the association between the workforce of primary health care and the reduction of infant deaths, with doctors being the most contributing factor to this reduction, followed by nurses. Regarding vaccination coverage, the quadruple measles vaccine significantly reduced infant deaths.*
**Key words** *Health Systems, Health System Resilience, Workforce, Primary Health Care*

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## Introduction

Resilient health systems preserve their Essential Public Health Functions[1] (EPHF) when addressing external, disruptive events – pandemics or disasters – or internal events arising from chronic stressors, such as underfunding and lack of health professionals and medicines[2,3]. According to the Health Sciences Descriptors[4] (DECS), the resilience of health systems consists of the "adaptation capacity health systems must develop and sustain to adequately meet the sudden increase in demand caused by extraordinary events that affect the health of the population directly or indirectly, while maintaining its operation, safety, quality, and availability of services. It is the level to which a system continuously prevents, detects, mitigates damage, or reduces the likelihood of incidents".

The Health Workforce is considered by the World Health Organization (WHO) as one of the essential functions of resilient public health[5]. In Brazil, this aspect became the focus of public policy attention after the Eighth National Health Conference (1986), triggered by the Health Reform. In this sense, it began to encompass multiple dimensions, such as the composition and distribution of the workforce, training, professional qualifications, labor market, work organization, regulation of professional practice, labor relations, and traditional personnel management[6].

All SUS professionals, especially PHC professionals, provide healthcare to populations with specific social vulnerabilities and, consequently, specific health needs. PHC has direct responsibility for health actions in a given territory, considering its singularities, which allows for more timely interventions in specific situations to expand access to the RAS and offer comprehensive healthcare. Notably, the approval of the *Mais Médicos* Program, sanctioned by Law No. 12,871 of October 22, 2013, allowed the deployment of medical professionals in the Family Health Strategy (ESF) nationwide.

Brazil has continental territorial dimensions and marked regional inequality with consequences triggered in the geographic, population, and institutional distribution[7], one of the origins of health inequities in the country. Regarding the distribution of health professionals, mainly in primary care[8], we observe a more significant concentration in the Southeast, Northeast, and South. At the same time, there are professional and care gaps in the Midwest and North, where the number of professionals is below the target established by international agencies, such as the OECD, which conspires against the National Health System's (SUS) universality and decentralization principles[9].

The SUS is organized into three healthcare levels, and Primary Health Care (PHC) is the first level. According to the National Primary Care Policy (PNAB), PHC Units (UBS) are equipped with teams linked to the Family Health Strategy, composed primarily of family doctors, nurses, nursing technicians, and community health workers (ACS), who are essential in PHC actions in municipalities, such as prevention and promotion, assistance, care management, and feeding of databases and health indicators, directly impacting them[10]. The most significant PHC health indicators relate to child health (such as vaccination coverage and infant mortality), women's and pregnant women's health, and patients with chronic non-communicable diseases (such as hypertensive and diabetic patients)[11].

PHC is essential for achieving broad and effective vaccination coverage and curbing infant deaths. However, it faces structural problems, such as shortages of vaccines and essential medicines and lack of internet access in more vulnerable regions, which hinders data recording, service continuity, and the achievement of targets for these indicators sensitive to government investments[12]. The infant mortality rate (IMR) is part of the UN Sustainable Development Goals (SDGs). In Brazil, the rate significantly declined from 2000 to 2015. It showed an inverse relationship associated with accessibility to high-complexity services, population size, reference for childbirth, live birth rate, per capita income, and unemployment rate[13].

Unlike major disasters and pandemics, which manifest themselves abruptly and require immediate response, health systems address systemic crises daily, which manifest themselves slowly and gradually due to the mismatch between demand and capacity and can induce weaknesses in the system whenever a fundamental indicator (such as the workforce) has a downward trend. Thus, this study aims to gauge the effects of workforce volatility on resilience. To this end, we adopted the relationship between the workforce in PHC and childhood-sensitive indicators, namely, vaccination (poliomyelitis and measles) and infant deaths.

## Methods

### Study design

This ecological, quantitative, time series study's sources of information are the health indicators data that appear in the Department of Informatics of the Unified Health System (DATASUS) of the Ministry of Health (MS), with information from the entire national territory. It was prepared under the recommendations of the EQUATOR Network guidelines and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist[14].

### Information sources

The data used are based on health indicators in the Department of Informatics of the Unified Health System (DATASUS) database of the Ministry of Health (MS), including information from the entire national territory with free and universal access. We included information related to the SUS PHC workforce, vaccination coverage, and infant mortality from preventable causes, available in the National Immunization Program Information System (SIPNI), the National Health Establishment Registry System (CNES), and the Mortality Information System (SIM).

### Data collection procedures

The database was constructed with indicators collected by Federation Units (UF), considering 2018 to 2022, totaling a balanced panel with 135 pieces of information. The indicator "child deaths due to preventable causes in children under five years of age" was defined as the outcome variable of the model and the other indicators as independent variables, these being the information representative of the SUS PHC workforce considered in this work, such as the number of community health workers (ACS) and family doctors and nurses, besides VIP and VOP polio and measles vaccination coverage.

Initially, data were collected on the "family health team" variable. However, it would not be possible to observe the individual effect of each professional category. Therefore, the variables related to the professionals were included: Family Health Strategy and PHC doctors, family nurses, and ACS (corresponding to the core Family Health Strategy team).

### Data analysis procedure

A routine was developed in the statistical software R Studio version 2023.06.0 to analyze the space-time trend of infant deaths and their relationships with indicators of the workforce and vaccination variables and the estimation of a regression model of aggregated cross-sectional data to measure the effects of these variables over time.

The estimated fixed effect model considers that the intercept values for each regression vary per the effect of each state (UF) and that the slope coefficients (of the independent variables) for each equation are the same for each year. This study's model was defined as:

$$Yit = \beta Xit + \gamma Ui + eitY\mathit{it} = \beta \mathit{X}it + \beta \mathit{Ui} + \mathit{eit}$$

Where Yit*Yit* is the result of the UF "i" in year "t"; Xit*Xit* is the vector of independent variables of UFs "I" over time "t"; and Ui*Ui* consists of the unobservable set of UF "I". Notably, the unobservable are immutable over time, so we lack the time subscript. Finally, eit*eit* is the error term.

Thus, the equation's intercept is different for each UF. However, the effect of the independent variables is the same on the dependent variable, which indicates that characteristic aspects in each UF influence infant deaths, such as the PHC workforce and coverage of selected vaccines. We should emphasize the importance of resilience and that the volatility of the aspects that make up the EPHF (such as the workforce) must remain stable to ensure that the health system has a more appropriate performance and its potential for resilience improves.

Supplementary material for the research data can be found at the link: https://doi.org/10.48331/scielodata.FGFG8U.

## Results

Figure 1 shows an uneven distribution of family doctors in the Brazilian states, in which a trend can be observed for growth. In other words, the number of these professionals in the states increased and spread to the states of Amazonas, Rio Grande do Sul, and Minas Gerais. However, even with the growth, inequalities are still observed since São Paulo concentrated a total of 241 family doctors in 2022, while Alagoas, Amapá, Mato Grosso do Sul, and Tocantins have only one doctor, followed by Acre and

Paraíba with two, and Piauí with three to serve the entire population of the territory. Such discrepancy is not observed for preventable infant deaths since there is no evidence to show that the distribution is unequal between the states over time (Figure 2).

Graph 1 illustrates the Brazilian historical series and the variation rate in infant deaths over the last twenty years. A sharp reduction in preventable infant deaths can be observed over time, especially in 2020, when the series shows a break in its structure and indicates growth in the post-pandemic period.

Regarding the estimated regression model, aggregated ("pooled") and independent cross-sectional elements are presented; data from obtaining random samples from a population at different points in time are adopted. Table 1 presents the set of variables that comprise the adjusted model together with the respective estimated values of the model coefficients, the standard error of the coefficients, the T statistic values, the p-value, the odds ratio, and the 95% confidence interval.

Table 1 presents the results for the estimated fixed model, which provides statistical evidence of significant differences in reducing infant deaths related to the PHC workforce and vaccination. Doctors are the professionals who contribute most to this reduction, followed by nurses and ACS.

The negative coefficient (-0.49) for the physician variable suggests that each family doctor in the care unit reduces the mean probability of infant deaths by the same proportion. The odds ratio of 0.61 indicates that the likelihood of preventable infant deaths, keeping the other variables constant, reduces by 0.61 the likelihood with each doctor.

All vaccination coverage was also significant in explaining declining infant deaths at a 90% confidence level. The quadruple measles vaccine reduces infant deaths significantly, with -1.44 less probability of infant death for each unitary variation in this vaccination coverage.

Graph 2 shows the model's results for the number of expected infant deaths in Brazil when the effects of time are isolated. Thus, the estimates suggest that infant deaths are distributed unevenly across the territory in a statistically significant way.

The results suggest, for example, a significantly higher mean number of infant deaths for São Paulo than other states, regardless of

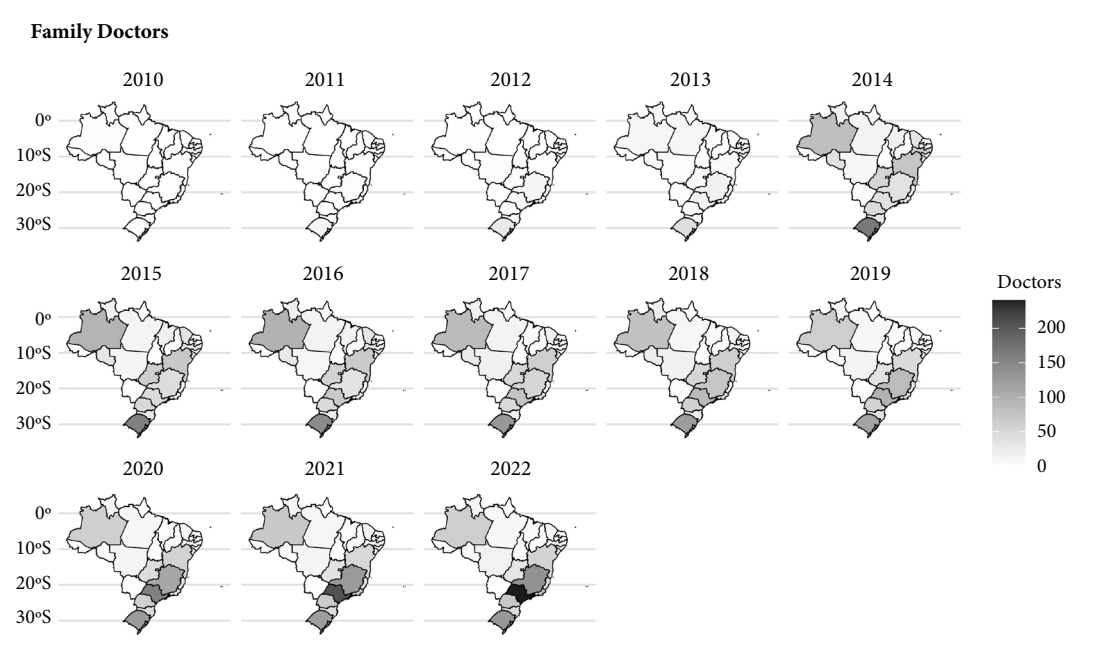



**Figure 1.** Spatial and temporal distribution of the number of family doctors in Brazilian states from 2010 to 2022.

Sources: Authors. National Register of Health Establishments (CNES).

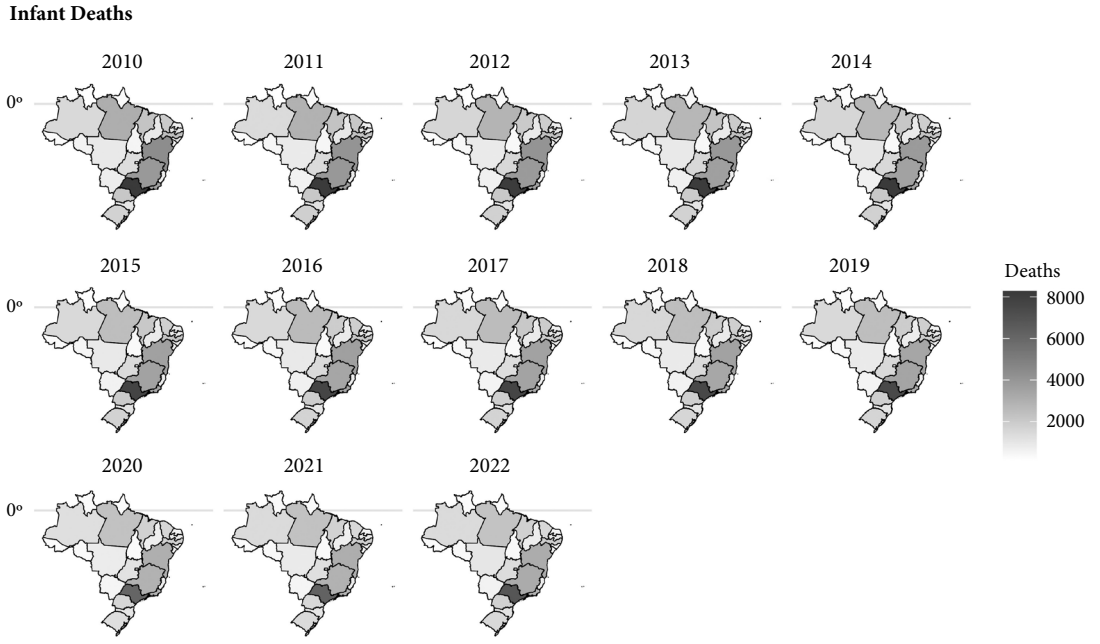
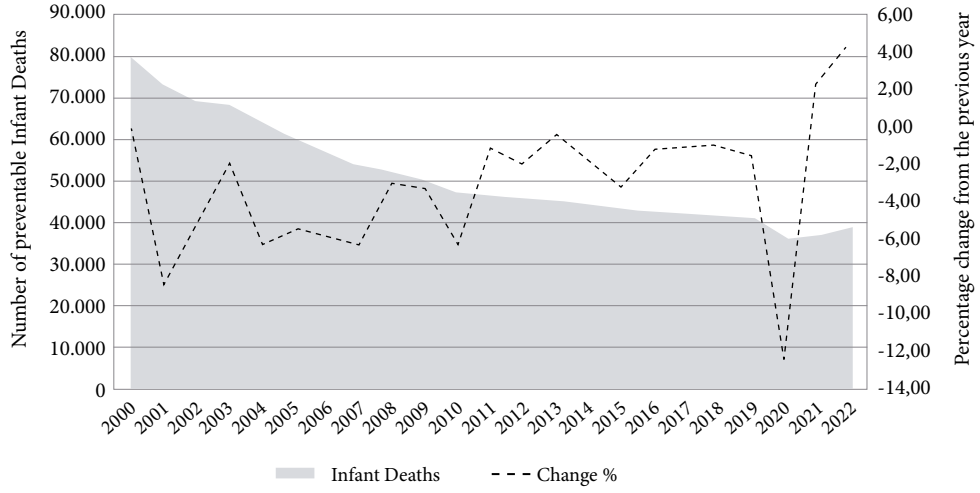



**Figure 2.** Spatial and temporal distribution of infant deaths in Brazilian states from 2010 to 2022.

Source: Authors. Mortality Information System (SIM).




**Graph 1.** Number of infant deaths in Brazil and percentage change from 2010 to 2022.

Source: Authors. Mortality Information System (SIM).

the other variables in the model, in proportion to the size of the population. Controlling for temporal effects, each unitary variation in the workforce and vaccination variables reduces, on average, approximately 2,241 infant deaths in Roraima in the period analyzed, followed by 2,237 in Acre. Conversely, on average, each negative unitary variation in the workforce and vaccination increases 7,967 infant deaths in the state of São Paulo in the period analyzed.

## Discussion

Unlike significant disasters and other disruptive events, which occur abruptly and require an immediate response, health systems (such as the SUS) address a systemic crisis daily, which manifests itself gradually due to the mismatch between demand and capacity and leads to weaknesses in the system as some fundamental indicator, such as the workforce, varies below average. Thus, this study aims to measure the workforce volatility impact effect on resilience. To this end, we adopted the relationship between the workforce in PHC and indicators sensitive to childhood, such as vaccination (poliomyelitis and measles) and infant deaths.

Research on resilience in health systems has increased in recent years following the COVID-19 pandemic. The number of search results for the terms "Health", "Systems", and "Resilience" in document titles in the Google Scholar database increased by approximately 25% from 2019 to 2022. The most recent research points to a resilience perspective instead focused on understanding how health systems are functioning so that they can face, respond, and adapt to pandemics and disasters and primarily to chronic stress and challenges arising from the demand/capacity relationship[2], corroborating research that highlights the stable importance of human resources in the effectiveness of health services, reinforcing the association of doctors and nurses with declining infant deaths[6].

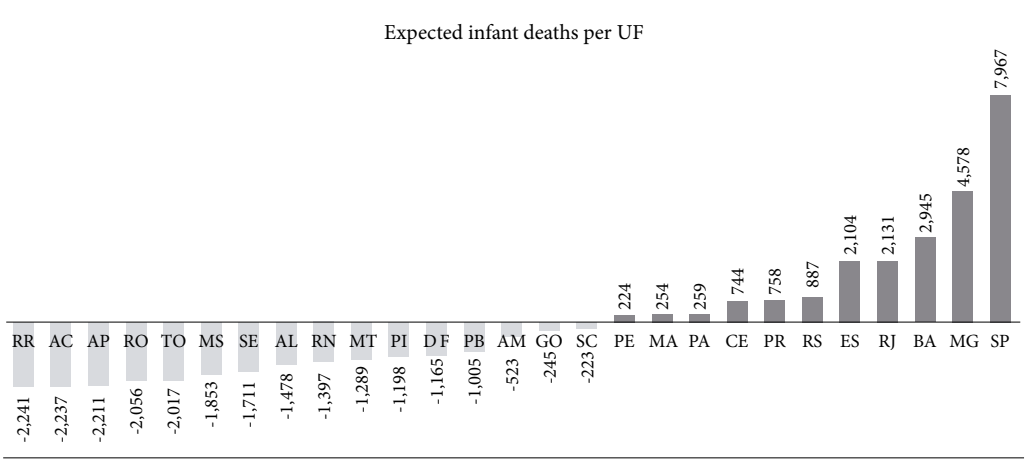
Thus, the issue of resilience puts pressure on the management models traditionally used to measure and evaluate the performance of health

**Table 1.** Fixed effects model for the outcome: infant deaths.

| Variable | Estimate | Standard Error | T | p-value | | Odds Ratio | 95%CI |
|---|---|---|---|---|---|---|---|
| ACS | 0.13 | 0.10 | 4.667 | **0.00** | *** | 1.14 | **(1.079-1.205)** |
| Doctor | -0.49 | 0.03 | -5.03 | **0.00** | *** | 0.61 | **(0.503-0.739)** |
| Nurse | -0.06 | 0.02 | -4.171 | **0.00** | ** | 0.94 | **(0.910-0.967)** |
| Measles second dose | 0.01 | 0.01 | 1.726 | **0.09** | . | 1.01 | (0.998-1.028) |
| Measles quadruple | -1.44 | 0.83 | -1.745 | **0.08** | . | 0.24 | (0.046-1.194) |
| VIP Polio coverage | 0.01 | 0.01 | 1.801 | **0.07** | . | 1.01 | (0.998-1.028) |
| VOP Polio coverage | 0.00 | 0.01 | -0.65 | 0.52 | | 1.00 | (0.980-1.010) |

Notes: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Balanced panel n=27, T=6 years and N=162.

Source: Authors.




**Graph 2.** Number of expected infant deaths in Brazil (isolating the effects of time).

Source: Authors.

systems. These models are typically based on analyzing institutional capacity, represented by the ability to promote collective well-being and use public resources effectively and with quality.

Research on health systems' resilience indicates that institutional capacity is insufficient (although necessary) for the proper functioning of health systems in a setting of abrupt changes and, therefore, is not a good predictor of how services adapt to unexpected events, maintain their EPHF during the crisis, or learn from this experience and transform positively when recovering from the shock.

To this end, metrics and methods to describe health systems' preventive, adaptive, and absorptive capacities are required, adhering to aspects that guide service resilience. Thus, these studies and the results of addressing COVID-19 in well-structured, supposedly more resilient systems are beginning to influence global health authorities.

Primary Health Care (PHC) has, among other things, the attribute of organizing care at the first care level provided, with characteristics that allow the health system to adapt and respond to a complex and rapidly changing world. However, insufficient human resources can compromise access and equity of care[15]. In this context, the measurement, provision, and planning of the SUS workforce must dialogue with the regulation of health work to guarantee comprehensive healthcare.

Notably, the COVID-19 pandemic has brought several challenges to the public health system, including PHC and child health. The country underwent a budgetary reallocation, prioritizing resources for hospital care, leaving PHC with fewer resources[16].

As shown in the historical series (Graph 1), the volatility rate in preventable infant deaths over the last twenty years has sharply reduced, especially in 2020, indicating a break in its structure and growth in the subsequent post-pandemic period. In this period, the Brazilian government disassociated childhood vaccination as one of the conditions for receiving *Bolsa Família* (a benefit provided to the population in the most vulnerable socioeconomic situation). Consequently, the decline in vaccination coverage also increased[17]. Another issue worth highlighting is that the inflection points in the series correspond to municipal election periods, which should be explained in later studies.

Factors such as social determinants and health conditions must also be considered in analyses of the effective functioning of health systems and, consequently, the resilience of their activities and functions. The system should offer professionals, teams, organizational support, and other necessary services, ensuring a satisfactory response from health systems to adverse events, considering cooperation between health professionals in favor of skills to predict future events based on learning from experiences and monitoring the current situation. Thus, as this study shows, preventive teamwork results in lower mortality results[18].

The great challenge of resilience management is finding ways to manage health systems' functioning so that they function as well as possible in their routine and significant crises. Stable functioning and a construction aligned with the context and capable of adapting can lead health systems to a position of high institutional capacity and resilient behavior, resulting in improved management processes, care flows, and care provided to users.

Records from the National Registry of Health Establishments (CNES) indicate that the FTS in Brazil comprises 3,953,686 million workers working in the SUS, led by the Southeast Region, with 1,691,770 workers. In all five regions, the category that leads the ranking of the most employed people is nursing technicians. Regarding Community Health Workers (ACS) predominate in the Northeast and Southeast, with 109,388 and 91,880, respectively. In the Southeast, South, and Midwest, the category of doctors ranks first regarding the number of workers working in the SUS[19], while nurses predominate in the North and Northeast.

The estimated fixed model result showed significant differences in reducing infant deaths related to the PHC workforce and vaccination, and doctors were the professionals who contributed to this reduction the most, followed by nurses and ACS. ACS play an important role in consolidating the SUS, facilitating the population's access to health actions and services and mainly linking health teams and the community, strengthening their relationships. In the context of comprehensive health, including nursing professionals in PHC teams contributes to bonding, qualified listening, and reception[20].

In this sense, the negative coefficient (-0.49) for the doctor variable suggests that each family doctor in the health unit curbs the mean probability of infant deaths in the same proportion. Keeping the other variables constant will reduce by 0.61 (odds ratio=0.61) times the likelihood of preventable infant deaths with each family doctor. Pasklan *et al.*[13] analyzed the relationship

between the quality of PHC services and infant mortality. IMR was inversely associated with the stratum of health management and population size, reference for childbirth, live birth rate, per capita income, and unemployment rate, concluding that infant mortality has a direct relationship with the socioeconomic conditions of the population, a fact corroborated in this study.

Regarding vaccination coverage, all of them were also significant in explaining the reduction in infant deaths at a 90% confidence level. The quadruple measles vaccine contributes significantly to curbing infant deaths, with -1.44 less probability of an infant death occurring for each unitary variation in this vaccination coverage.

The findings of this study show the relevance of investing in vaccination coverage and the PHC workforce since they contribute to the effectiveness and equity of Brazilian PHC, significantly impacting its indicators, more specifically regarding Public Health Functions No. 1 (Monitoring and evaluation of health and well-being, equity, social determinants of health and the performance and impact of health systems), 2 (Public health surveillance: control and management of health risks and emergencies), and 6 (Development of human resources for health).

Regarding applying the Brazilian capitals model, the model results for the number of expected infant deaths in the country suggest that infant deaths are distributed unevenly across the territory with statistical significance, just as the distribution of professionals was also configured. Therefore, controlling for temporal effects, for each unit reduction in the workforce and vaccination variables, on average, 2,241 infant deaths are reduced in Roraima (northern Brazil) and 2,237 in Acre in the period analyzed. However, in the opposite direction, each negative unitary variation in the number of workforce and vaccination entails a mean increase of 7,967 infant deaths in the state of São Paulo in the period analyzed. Such aspects can be explained by the determinants and conditions of health, mainly concerning basic sanitation, family health professionals, parental income and education, and ethnicity[21-24].

As Brazil is a country with continental dimensions, the management of health work requires special attention from all institutions that seek the correct adaptation between the needs of the population and their objectives in the SUS, with initiatives that foster the increase in knowledge, work regulation, for the provision and formulation of health education policies in the management of the health professionals' work, contributing to the success of experiences in the states and municipalities in strengthening the SUS.

## Conclusion

The findings of this study show the relevance of investing in vaccination coverage and the PHC workforce since they contribute to the effectiveness and equity of Brazilian PHC, significantly impacting its indicators, more specifically regarding Public Health Functions No. 1, 2, and 6, but which can be scaled to other countries.

The workforce promotes a reduction in infant deaths and, therefore, is mainly consolidated for the most socially vulnerable populations. It is necessary to plan and correctly measure the workforce in PHC together with federal, state, and, mainly, municipal agencies regarding strategic issues such as financing, hiring, retention, and qualification of workers with the creation of instruments that enable decision-making, monitoring, and evaluation of the workforce.

Monitoring and evaluating data related to essential public health functions (EPHF) is essential for new health management models to include resilience in their agenda and, most importantly, to operationalize it more effectively based on scientific evidence.

These findings from this study point to the possibility of a more comprehensive assessment of SUS resilience based on the level and volatility of the indicators presented through the EPFH to which they are attributed or even to the contribution of indicators that show the potential for resilience in health systems, performing more detailed analyses to examine the causality and effects of specific interventions.

## Collaborations

PC Nunes was responsible for the general conceptualization, data collection, discussion of results and writing of the article. A Jatobá was responsible for the general conceptualization, review of results, discussion of results and writing of the article. P Palmieri was responsible for the methodology and analysis of results. PP Simões was responsible for the methodology and data collection. OMA Oliveira was responsible for the methodology and data collection. PVR Carvalho worked on the management of the research project, conceptualization, data analysis, discussion of results and writing of the article.

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Article submitted 15/06/2024
Approved 26/02/2025
Final version submitted 28/02/2025

Chief editors: Maria Cecília de Souza Minayo, Romeu Gomes, Antônio Augusto Moura da Silva