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RESEARCH ARTICLE

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Relationship between SARS-CoV-2 vaccination and cases, program breakthrough cases, and deaths in Dois Vizinhos, Paraná, Brazil

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Abstract

Several vaccines have been produced in 2 years of the COVID-19 pandemic to control the infection outbreak. This study demonstrated the success of vaccination in controlling COVID-19 cases and deaths in a small city (41 424 people) with a low population density in Brazil. This study was based on a 1-year dataset since the application of the first dose in January 2021. The results show a reduction in positive cases and deaths as the vaccination coverage increased in the city, mainly after 15 000 inhabitants were vaccinated (35.21% of the population) in July 2021. At the time, 49.06% of administered vaccines were ChAdOx1-S recombinant, 39.80% inactivated SARS-CoV-2 virus (CZ02 strain), 9.70% Tozinameran, and 1.44% Ad26.COV2-S recombinant. From August 2021, a marked reduction in daily positive cases and deaths was observed, and incidence (≤2.49 per 1000 inhabitants) and mortality (≤0.02 per 1000 inhabitants) rates remained stabilized until January 2022, when a new outbreak occurred upon the emergence of the Omicron variant. However, the mortality rate (0.07 per 1000 inhabitants) remained low regardless of the Omicron high incidence rate (68.41 per 1000 inhabitants). These data demonstrate the COVID-19 vaccination effectiveness with a threshold of 35.21% of the population vaccinated in this city model.

Marina Wust Vasconcelos and Flavia Regina Oliveira de Barros equally contributed to this work.

KEYWORDS
COVID-19, daily bulletin, immunization, Southwest of Paraná, vaccine efficiency

1 | INTRODUCTION

In early 2020, the World Health Organization declared the COVID-19 (coronavirus disease-2019) pandemic, meaning that there are outbreaks of COVID-19 in several countries and regions of the world.[1] Due to the emergency condition during the pandemic, the primary immunological intervention strategy was the development of safe and effective vaccines against SARS-CoV-2 infection.

Brazil started vaccination late against COVID-19, compared to other countries such as Chile, Argentina, the United States, the United Kingdom, Costa Rica, Norway, Portugal, China, Singapore, and others. Brazil approved the first two vaccines for emergency use on January 17th, 2021, the Inactivated SARS-CoV-2 Virus (CZ02 strain) vaccine from the inactivated whole virus and ChAdOx1-S recombinant from the adenoviral vector. On July 18th, 2021, the country approved the vaccines Tozinameran from the messenger RNA and Ad26.COV2-S recombinant from the adenoviral vector.[2] In Brazil, vaccination for COVID-19 was initially prioritized for groups at higher risk of developing severe forms of the disease and death risk (health professionals, elderly, institutionalized elderly, and patients with comorbidities such as hypertension, diabetes mellitus, among others) and groups with a high degree of social and economic vulnerability (such as indigenous, quilombolas, riverside inhabitants, population deprived of liberty).[3]

Until March 10th, 2021, Brazil occupied third place in the world ranking of SARS-CoV-2 infections with 21 989 962 positive cases and second place in the cumulative number of deaths with 612 177.[4] Since daily positive case rates predict immune protection against symptomatic SARS-CoV-2 infection, the present study aimed to perform an exploratory analysis showing a correlation between vaccination and COVID-19 incidence and mortality rates in Dois Vizinhos, Paraná State (PR), Brazil, a city model with approximately 41 000 inhabitants located in southwest Paraná.

2 | MATERIALS AND METHODS

2.1 | Data collection

2.1.1 | City model description

Dois Vizinhos is a small town in Southwest Paraná (PR), Southern Brazil, with an estimated population of 41 424 inhabitants.[5] The municipality has one Hospital Structure, one Emergency Care Unit-UPA, one Specialty Center, and 11 family health units (or health posts), which decentralize basic services. Testing policies for COVID-19 during the period considered for this experiment (January 29th, 2021 to January 31st, 2022) consisted of one of these health units being chosen as the main reception center for individuals with respiratory flu symptoms. Symptomatic individuals were then forwarded to initial, isolated screening and underwent a medical consultation with a subsequent referral for sample collection for SARS diagnosis-CoV-2.

2.1.2 | Study description

The data for this retrospective investigation were collected from the official COVID-19 bulletin and vaccinometer on the Dois Vizinhos municipality webpage,[6] and posts on social media communications managed by the health department. The first doses received in Dois Vizinhos were on January 19th, 2021, and public records on vaccination on the city website started on January 29th, 2021. All data were extracted from January 29th, 2021, until January 31st, 2022 (after 12 months of vaccination in the city). Information such as date, number of positive cases, number of vaccines administered, age group, deaths related to COVID-19, and type and amount of vaccine doses received by the health department were compiled in Excel (Microsoft Corporation, 2018. Microsoft Excel, Available at: https://office.microsoft.com/excel). spreadsheet and then processed with the GraphPad Prism version 7.0 for macOS (GraphPad Software, La Jolla California USA, www.graphpad.com). All data regarding the number of COVID-19 vaccine doses received by the Health Department of Dois Vizinhos was included in the study, even when a small number of doses of one type of vaccine was received to provide an accurate portrait of the vaccination during the studied period. Scatterplot graphs were generated to show the relationship between the number of people vaccinated and the following variables: (a) daily new COVID-19 cases; (b) the cumulative number of COVID-19 cases; (c) daily COVID-19 deaths per 1000 inhabitants (daily deaths/city population × 1000); (d) cumulative deaths by COVID-19, followed by a nonparametric Spearman correlation analysis between variables. The estimated population size of 41 424 was used to calculate mortality and incidence rates of COVID-19 cases.

2.2 | Audience involvement

For this research, there was no involvement with patient or people records, only anonymous data collection. Furthermore, as described in Resolution No. 510 of the Brazilian National Council of Health in 2016, Article 1, item II, there is no need for the National Committee of Ethics in Research (CONEP) and the Research Ethics Committee (CEP) evaluation in research involving public access information.

3 | RESULTS

A total of 83 511 COVID-19 vaccine doses were received by the Health Department of Dois Vizinhos municipality January 29th, 2021 to January 31st, 2022. Table S1 shows the COVID-19 incidence and mortality rates per 1000 inhabitants and COVID-19 vaccine monthly availability during the first 12 months of vaccination in Dois Vizinhos, Paraná, Brazil (January 29th, 2021 and January 31st, 2022). The available data of COVID-19 positive cases, deaths, and the number of vaccinated individuals in the municipality of Dois Vizinhos, PR, were analyzed considering this 12-month period. With these data, it was possible to analyze the correlation holistically and systematically between immunization and SARS-CoV-2 infection. Figure 1 shows the 12-month cumulative number of people vaccinated (regardless of whether the vaccination was complete or incomplete), starting on January 29th, 2021, concerning the number of COVID-19-positive cases and deaths. The number of daily new COVID-19 cases decreased as the number of people vaccinated increased (Spearman $r = -0.3378$; 95% confidence interval [CI = −0.4486 to −0.2167; $p < 0.0001$), and a new wave only emerged when the Omicron variant was first confirmed in Paraná (Figure 1A).[7] Figure 1 appoints the first records of the Omicron variant detected in Brazil (December 04th, 2021) and Paraná State (January 12th, 2022). Despite the peak of cases in May and June, there is a trend toward reducing the number of daily new cases at the beginning of July 2021, when around 15 000 people (35.21% of Dois Vizinhos' population) had been vaccinated. The preceding month was the first time the Tozinameran and the Ad26.COV2-S recombinant vaccines were administered in Dois Vizinhos. Before July, 49.06% of administered vaccines were ChAdOx1-S recombinant, 39.80% Inactivated SARS-CoV-2 Virus (CZ02 strain) vaccine, 9.70% Tozinameran, and 1.44% Ad26.COV2-S recombinant (Table S1). These data suggest that a minimum of approximately 35.21% of vaccination coverage was required to reduce and maintain the number of new cases lower significantly.

A similar pattern was also observed for COVID-19 deaths (Figure 1C,D). Figure 1C shows the daily COVID-19 deaths per 1000 inhabitants in Dois Vizinhos. Interestingly, when Omicron was detected in this region (December 2021—January 2022), the mortality per 1000 inhabitants was not as high as seen for the

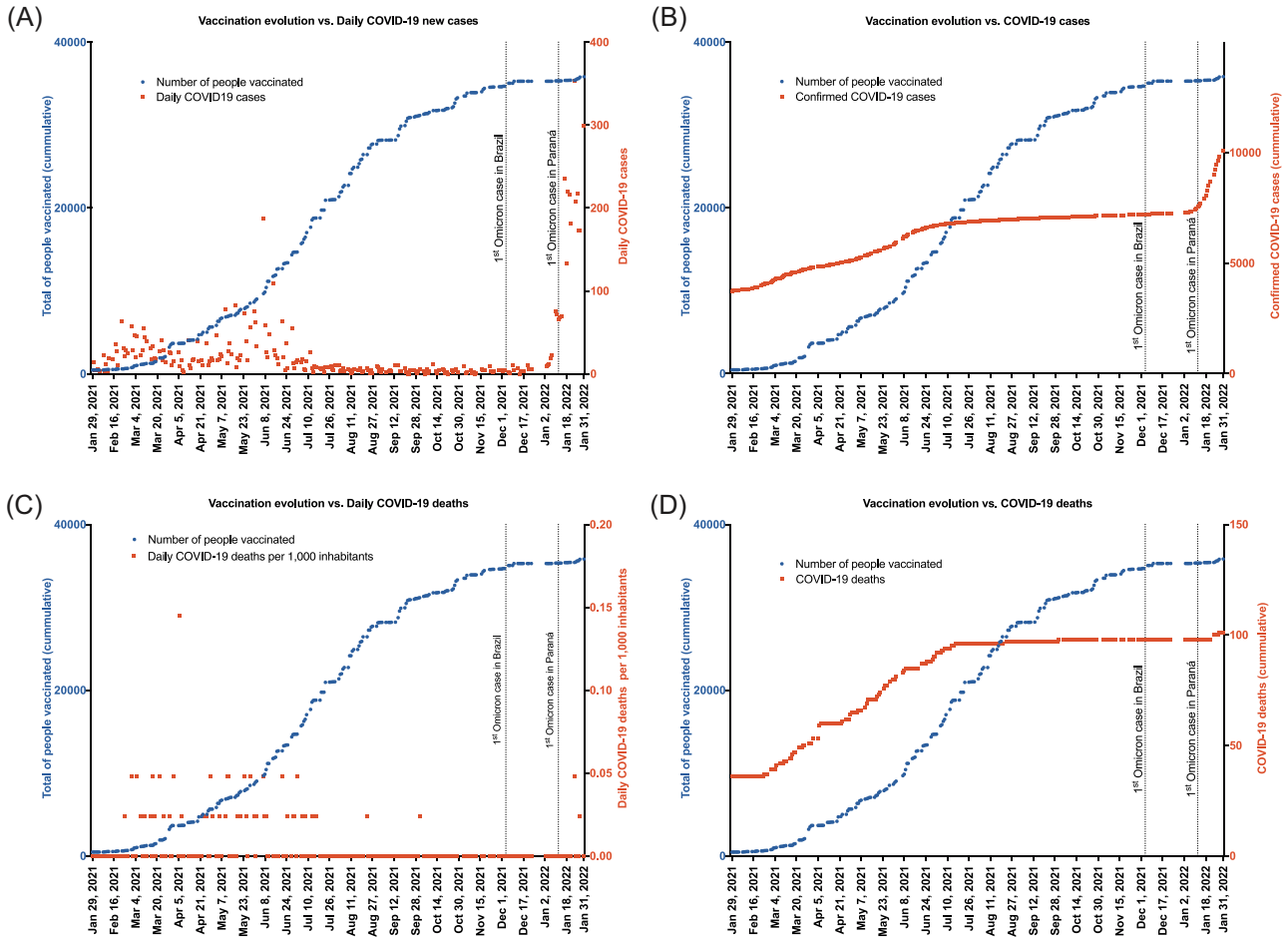

FIGURE 1 Vaccination progress versus COVID-19 cases and deaths in Dois Vizinhos, Paraná, Brazil, between January 29th, 2021, and January 31st, 2022. (A) Total of people vaccinated (blue) versus daily new COVID-19 cases (red); (B) Total of people vaccinated (blue) versus accumulated number of positive cases for COVID-19 (red); (C) Total of people vaccinated (blue) versus daily COVID-19 deaths per 1000 inhabitants (red); and (D) Total of people vaccinated (blue) versus accumulated COVID-19 deaths (red).

previous wave (Table S1). A negative correlation was observed between the number of people vaccinated and the daily COVID-19 mortality rate per 1000 inhabitants (Spearman $r = -0.2954$; 95% CI = −0.41 to −0.1717; $p < 0.0001$). Figure 1D shows the number of applied vaccine doses concerning the number of accumulated deaths by COVID-19 until January 31st, 2022. The curve of accumulated deaths had similar behavior to the curve of cumulative cases, confirming that vaccination coverage of at least 35% of Dois Vizinhos' population was necessary to keep the mortality rate low. On October 18th, the city reached 100% of adults over 18 years old vaccinated with at least the first dose and in November 2021, the first boost began to be administered for over 60 years old and health professionals. From August 2021 forward, a low COVID19 incidence along with no deaths were observed. However, after the Omicron variant was detected in Paraná, the incidence rate increased drastically, reaching the highest value observed in the period, while the mortality rate remained low (Table S1). Despite January 2022 having almost four times as many cases as May 2021, the number of deaths was five times lower.

4 | DISCUSSION

Our data shows that immunization of Dois Vizinhos-PR, a city with a little over 41 000 people, has effectively prevented infection by nonvariant strains and deaths by the SARS-CoV-2 during the first 12 months of vaccination. The negative correlation between the number of daily cases and the number of vaccinated people, as well as between the mortality rate and the number of inhabitants vaccinated, reflects the success of the vaccination program in a small city with a low population density (41 424 people; 86.42 inhabitants/km^2).[5] These results reinforce the importance of vaccines in controlling COVID-19 cases since isolation with lockdown and all other prophylactic measures, although effective if strictly adhered to, could not suffice in the actual scenario. Because of cultural and social issues, including professions that require people to expose themselves daily for work, only after vaccination reached a certain coverage, 15 000 people in this study, did the number of cases and deaths decrease and remain stable, highlighting the need for immunization through vaccination to control COVID-19.[8]

Since a minimum vaccination coverage is needed to protect the population,[9] the stabilization in the number of cases and deaths achieved in Dois Vizinhos, when approximately 35.21% of the population was vaccinated, suggests a threshold to be reached in a city of similar size. In a small city such as Dois Vizinhos, frequent monitoring of vaccination coverage is important. The dissemination of information by the municipality's health team on social media regarding vaccination against COVID-19 was a key factor in achieving the suggested minimum vaccination coverage. This becomes clear when comparing data from Brazilian municipalities of similar populations. Corroborating with immunization data from the municipality of Dois Vizinhos, the city of Serrana (State of São Paulo, Brazil), with approximately 46 000 inhabitants, agreed to participate in a study by the Butantan Institute, called "Project S." The project distributed Inactivated SARS-CoV-2 Virus (CZ02 strain) vaccines to almost the entire adult population of the municipality, these being 27 100 residents, to observe the effectiveness of the vaccine. A reduction of 80% (95% CI = 76.9%–82.7%) in symptomatic cases and 95% (95% CI = 62.7%–99.3%) of deaths resulting from vaccination was observed, promoting in the city an "immunization belt" with a collective barrier against the virus, including groups that had not yet been vaccinated. This drastically reduced transmission in the municipality, while neighboring municipalities had high levels of cases. In the municipality of Camaquã (State of Rio Grande do Sul, Brazil), with approximately 60 368 inhabitants, the immunization started on January 20th, 2021[10] and July 12th, 2021, it reached 48.94% of the population,[11] when the significant reduction of daily positive cases began.[12] Since November 2021, the number of daily positive cases has remained low, with a daily average of 2.56 new cases.[12] The same pattern of reduction of daily positive cases only as a result of increased immunization also occurred in the municipalities of Júlio de Castilhos (19 159 inhabitants; State of Rio Grande do Sul, Brazil),[13] Alegrete (72 493 inhabitants; State of Rio Grande do Sul, Brazil),[14] and Santa Maria (285 159 inhabitants; State of Rio Grande do Sul, Brazil).[15] These data support the importance of vaccination as a public health measure and not only as an individual action.[16]

The world has also faced a dramatic increase in new cases due to the emergence of another variant, but the number of hospitalizations and deaths remained stable.[17,18] With the emergence of SARS-CoV-2 Omicron at the end of 2021, questions and uncertainties about its behavior concerning vaccines have emerged in the face of this scenario and asked researchers.[19–21] This pattern of low mortality in cases of infection by the Omicron variant was also observed in the municipality of Dois Vizinhos, demonstrating the effect of the immunization program. World records show vaccines' importance in alleviating severe symptoms and decreasing mortality. However, most of the deaths in the Omicron variant outbreak can be attributed to unvaccinated persons, as the risk of infection and death associated with COVID-19 is higher for unvaccinated people.[10] It emphasizes the importance of maintaining constant monitoring of cases since, as more people are partially or fully immunized with the vaccine, more significant reductions of cases or mild symptoms are expected for infections with new variants. The case presented in this study clearly shows the relevance of vaccines in controlling the spread of SARS-CoV-2 and reducing deaths.

AUTHOR CONTRIBUTIONS

Marina Wust Vasconcelos: data curation, methodology, visualization, writing—original draft preparation. **Flavia Regina Oliveira de Barros**: conceptualization, formal analysis, methodology, software, writing—review & editing. **Jéssica Cousseau Pilonetto**: data curation, visualization, writing—original draft preparation. **Sandrieli Gonçalves and Schelder Gabriel Bertoncello Rosa**: data curation, visualization. **Sandrieli Gonçalves**: data curation, visualization, writing—original draft preparation. **Betty Cristiane Kuhn**: funding acquisition, validation, methodology. **Deborah Catharine De Assis Leite**: investigation,

validation, methodology. **Juliana Morini Küpper Cardoso Perseguini**: formal analysis, resources, validation. **Naiana Cristine Gabiatti**: formal analysis, validation, methodology. **Simone Neumann Wendt**: investigation, project administration, validation. **Nédia de Castilhos Ghisi**: conceptualization, funding acquisition, methodology, supervision, writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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