

RESEARCH ARTICLE

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## Effects of the COVID-19 pandemic on self-reported 12-month pneumococcal vaccination series completion rates in Canada

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### ABSTRACT

Routine childhood vaccination improves health and prevents morbidity and mortality from vaccine-preventable diseases. There are indications that the COVID-19 pandemic has negatively impacted immunization rates globally, but systematic studies on this are still lacking in Canada. This study aims to add knowledge on the pandemic's effect on children's immunization rates with pneumococcal vaccine using self-reported immunization data from CANImmunize. An interrupted time series analysis was conducted on aggregated monthly enrollment of children on the platform (2016–2021) and their pneumococcal immunization series completion rates (2016–2020). Predicted trends before and after the onset of the COVID-19-related restriction (March 1, 2020) were compared by means of an Autoregressive Integrated Moving Average (ARIMA). The highest monthly enrollment was 3,474 new infant records observed in January 2020, and the lowest was 100 records in December 2021. The highest Self-reported pneumococcal immunization series completion rate was 78.89%, observed in February 2017, and the lowest was 6.94% in December 2021. Enrollment decreased by 1177.52 records (95% CI: –1865.47, –489.57), with a continued decrease of 80.84 records each month. Completion rates had an immediate increase of 14.57% (95% CI 4.64, 24.51), followed by a decrease of 3.54% each month. The onset of the COVID-19 related restrictions impacted the enrollment of children in the CANImmunize digital immunization platform and an overall decrease in self-reported pneumococcal immunization series completion rates. Our findings support efforts to increase catch-up immunization campaigns so that children who could not get scheduled immunization during the pandemic are not missed.

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### Background

Immunizing children against routine vaccine-preventable diseases (VPDs) has been among the most effective interventions in reducing childhood morbidity and mortality and indirectly saving the world a substantial economic loss.<sup>1</sup> Between 2000 and 2020, in developing countries, the use of routine childhood vaccines against measles, pneumonia, severe diarrhea, and meningitis has averted approximately 20 million deaths and saved around US\$ 350 billion in the cost of illness.<sup>2,3</sup> This achievement was possible because of the successful mobilization of beneficiaries, excellent planning, and execution of childhood immunization programs.<sup>4</sup>


In the past two decades, routine childhood immunization has successfully cut pediatric deaths and placed Canada on the elimination journey for VPDs such as measles, rubella, and polio.<sup>5</sup> That was due to the equitable access to childhood vaccines achieved through the publicly funded immunization programs.<sup>6</sup> However, VPDs have been increasing in the last decade, with 20.7 cases per 100,000 population from 2013, with Invasive Pneumococcal Disease (IPD) accounting for more cases (44%) and mainly among children less than one year of age (92.4 cases per 100,000 population).<sup>7</sup> In collaboration with provinces and territories, the Canadian federal government has established a National Immunization Strategy for 2016–2025 to

reach goals such as the 95% coverage for childhood vaccines.<sup>8</sup> Key actions were set to address vaccination uptake, which is mainly impeded by vaccination hesitance and refusal.<sup>9</sup>

Unfortunately, in March 2020, the outbreak of the highly infectious and deadly Coronavirus disease of 2019 (COVID-19) emerged as an unprecedented challenge.<sup>10</sup> Countries governments across the world adopted the World Health Organization (WHO)'s public health and social measures to limit the spread of SARS-CoV-2 and mitigate its associated health loss.<sup>11,12</sup> Those measures included face mask-wearing; restrictions on public and private gatherings; cautious opening and closure of schools and businesses; domestic movements as well as public transport restrictions, and stay-at-home orders; and international travel restrictions.<sup>12</sup> Two years into the pandemic, the world has already recorded more than 400 million cases, a death toll surpassing 6 million, and the disruption of many preventive interventions, such as routine immunization programs for children.<sup>12,13</sup>

Disruptions to the routine childhood vaccines started right after the onset of the pandemic, affecting vaccines' supply and demand, their cold chain, and delivery.<sup>4,14</sup> Consequently, 23 million children did not receive their scheduled vaccines,<sup>15</sup> the number of doses administered globally fell by 31.3%,<sup>16</sup> and vaccination coverage dropped by approximately 7.7%.<sup>16</sup>

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A drop in ordering vaccines was also noted in countries such as the USA, where a 50% reduction happened right after the onset of pandemic-related restrictions.<sup>14</sup>

As observed in many countries, the effect of the COVID-19 restrictions on vaccination rates created an initial shock after the onset of restrictions or delayed recovery of the service after a few months of the pandemic. In some countries, such as Canada, such data on childhood vaccines is still lacking. There is a possibility that the national goal of achieving community protection against all VPDs by 2025 could have been disrupted by the onset of the pandemic-related restrictions,<sup>8</sup> as restrictions caused an approximately 80% drop in in-person doctor visits for children's services, including vaccination during the first wave of infections.<sup>17</sup> Alternatively, the pandemic's restrictions in Canada might not have significantly refrained the country's overall immunization rates, as observed in the later data on infants' immunization rates in Brazil and adolescents' routine immunization with the human papillomavirus vaccine in the United States of America.<sup>18,19</sup>

The lack of knowledge on the possible effects of timely vaccination and the adoption of immunization tools hinders interventions aiming to recover vaccination uptake and may further increase the risk of VPDs, especially during this period when most restrictions have been eased. In this study, the impact of the pandemic on immunization efforts in Canada was studied. Changes in children's enrollment on the pan-Canadian digital vaccination platform and self-reported pediatric pneumococcal immunization series completion rates were assessed to describe how the pandemic's related restrictions affected previously observed trends. The availability of this knowledge provides insights into how the pandemic has affected immunization and will guide interventions that aim to control and prevent VPDs during the current stage of the pandemic, as all provinces are alleviating COVID-19 restrictions. We hypothesized that the onset of COVID-19-related restrictions in Canada would impact both outcomes in a step-change format, an assumption based on the interim reports from the World Health Organization (WHO) on the impact of the pandemic on universal immunization coverage.<sup>13</sup>

## Methods

### Study design and settings

We conducted a quasi-experimental study to assess the impact of the COVID-19 pandemic restrictions on infant vaccination rates in Canada. COVID-19's related restrictions, the interrupting variable, were considered a natural event affecting everyone in Canada, while vaccination rates in terms of enrollment of children on the CANImmunize platform and self-reported on-time pneumococcal immunization series completion rates were considered the population-level outcomes. We conducted a single cohort interrupted time series analysis to examine these questions.

### Source of data

All data was collected from the CANImmunize database. CANImmunize is a pan-Canadian digital vaccination tool

established in 2016 to support Canadians in managing their own immunization information.<sup>20</sup> Data extraction happened in February 2022 and the extracted dataset contained information about children's date of birth, the date every child's record was created, the number of pneumococcal doses recorded in every record, and the date each dose was reported by CANImmunize users (parents and guardians) using their unique accounts.

Immunization data in CANImmunize is self-reported. CANImmunize uses children's information, such as age, sex, and jurisdiction, to create a custom immunization schedule for every record.<sup>20</sup> Most children's records were created after the child was born and already started their immunization journey, which means that reporting immunization in CANImmunize was done retrospectively. Because of that, the date of vaccination for many children became older than when their record was created on CANImmunize.

This study included only CANImmunize records of children that contained at least one dose of any pediatric vaccine; however, records with incorrect entries of children's date of birth were excluded from both enrollment and series completion analysis. For the analysis of enrollments, the plan was to include records created from 2016 to 2021; however, the earliest children's records were created in September 2017. So, we included all records created from 2017 to 2021 that fulfilled all inclusion criteria.

On the other side, for a successful analysis of series completion before 13 months, every included child must have turned 13 months by the date this data was pulled. Consequently, only children born from January 2016 to December 2020 were included in the analysis.

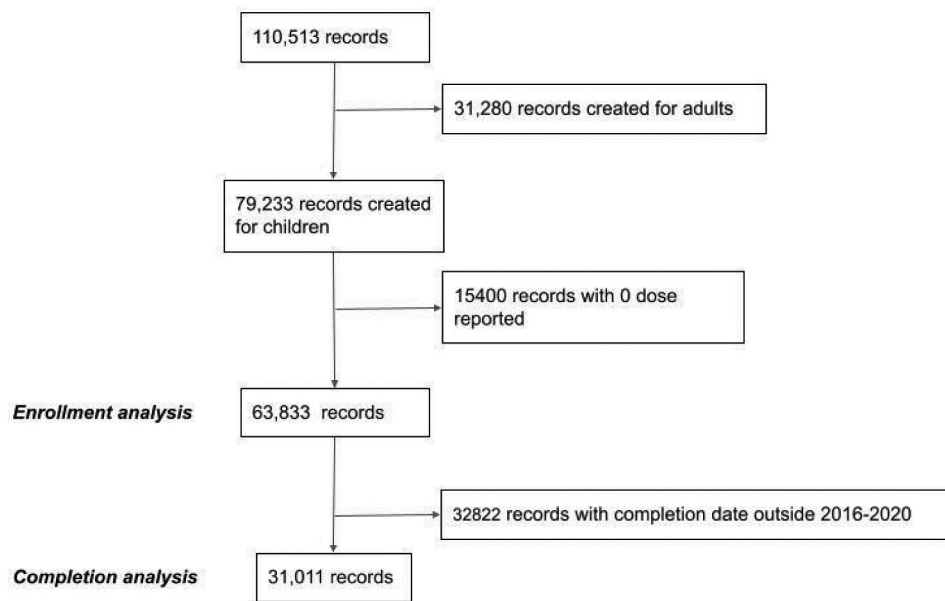
The data management has been described in [Figure 1](#).

### Statistical analysis

Two outcomes were assessed; Enrollment of children on the CANImmunize platform, which was evaluated as the number of records created on CANImmunize from 2017 to 2021; and the on-time completion rate of self-reported immunization series for pneumococcal vaccine. The number of new records was counted monthly using the record's unique identifiers on CANImmunize. On-time completion of the immunization series for the pneumococcal vaccine was defined as the reception of three doses of pneumococcal vaccine before the child turns 13 months of age.<sup>21</sup> It was calculated using the child's date of birth, the date the child turned 13 months, and the number of doses of pneumococcal vaccines every child received in that period.

The count of children that were born every month during the observation period served as the denominator, while the count of children born in the same month and received all doses of pneumococcal vaccine before they turned 13 months served as the numerator to provide the monthly completion rate in percentage.

A total of 52 (from September 2017 to December 2021) and 60 (from January 2016 to December 2020) monthly time series were generated for enrollment and immunization series completion rates, respectively. The nadir of enrollment and completion rates during the Covid19 pandemic was 100 records and 6.94% completed series, all in December 2021, respectively.



**Figure 1.** The data management flow.

The point estimate and the confidence interval for the impact of the pandemic on both outcomes were assessed using Autoregressive Integrated Moving Average (ARIMA) models.<sup>22</sup>

### Model identification

After examining the trend and patterns of both outcomes' time series (see [Figure 2](#)), the ARIMA model was used to account for autocorrelation and seasonality bias. The Dickey-Fuller test was used to confirm the series' stationarity<sup>22</sup> prior to fitting an ARIMA model. We used an automated algorithm, specifically *auto.arima()* in the *forecast* package for R, to identify the ARIMA model terms based on minimizing the information criteria (AIC, BIC).<sup>22</sup> The statistical R version 4.1.3 was used for all analyses, and both the *P*-value and the confidence interval were reported. The *P*-value less than 0.05 was considered statistically significant.

### Ethical considerations

Data collection and handling were conducted according to the CANImmunize privacy policy.<sup>23</sup> Additionally, ethical approval to conduct this research has been obtained from the Ottawa Health Sciences Research Ethics Board (OHSN REB) prior to the start of all research activities.

## Results

### Overview of our data

A total of 63,833 pediatric records created in CANImmunize from 2017 to 2021 have met the study's inclusion criteria. The highest enrollment of children occurred in January 2019, with 3374 records, as [Figure 2\(a\)](#) shows. The trend for enrollment displayed seasonality features, including a spike in the number of enrolled children toward the end of each year. However, there was a decrease in counts of enrolling children observed

after the onset of COVID-19 restrictions, and the tall spikes observed in the pre-restriction period have not been repeated. Additionally, the post-restriction trend did not recover to reach the pre-restriction level; instead, it decreased further until the end of 2021.

The trend for pneumococcal immunization series completion rates has been decreasing since the end of 2018, and the recovery that happened in the early months of 2020 was not sustained.

### ARIMA model

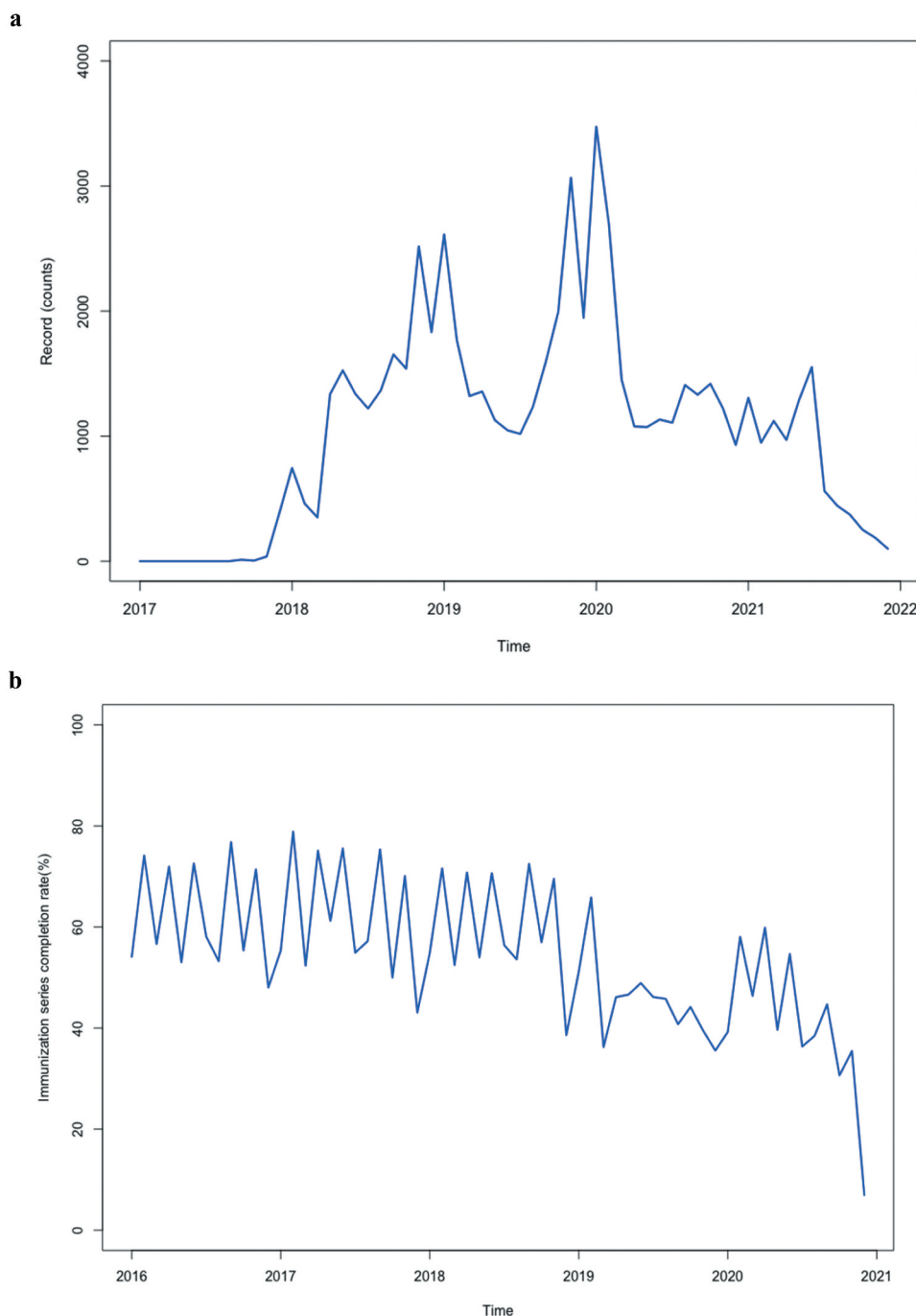
#### Enrollment series

The model with the lowest information criteria selected by the algorithm was  $(1,1, 0) \times (0, 0, 1)$  [12]. The estimated step change was  $-1177.52$  records (95% CI:  $-1865.47, -489.57$ ), while the estimated change in slope was  $-80.84$  records per month (95% CI  $-227.03, 65.34$ ). ([Figure 3](#)) shows the values predicted by our ARIMA model in the absence of the intervention (counterfactual) compared with the observed values. This means that restrictions that were imposed to curb the impact of COVID-19 in March 2020 were associated with an abrupt and continued decline in enrollment by 1177.52, with a further decrease of 80.84 records each month during the study period. The *p*-value for the Ljung-Box test for white noise is 0.73 at 24 lags.

#### Pneumococcal series completion rates

The model with the lowest information criteria selected by the algorithm was  $(3,0,0)(1,1,0)$  [12]. The estimated step change was 14.57% (95% CI 4.64, 24.51), while the estimated change in slope was  $-3.54\%$  per month (95% CI  $-5.31, -1.76$ ).

[Figure 4](#) shows the values predicted by our ARIMA model in the absence of the intervention (counterfactual) compared with the observed values. This means that restrictions that followed the onset of COVID-19 restrictions in March 2020



**Figure 2.** (a) shows the time series of monthly enrollment of children on CANImmunize from January 2016 to December 2021. (b) displays the time series of on-time completion rates of immunization series for the Pneumococcal vaccines from 2016 to 2020.

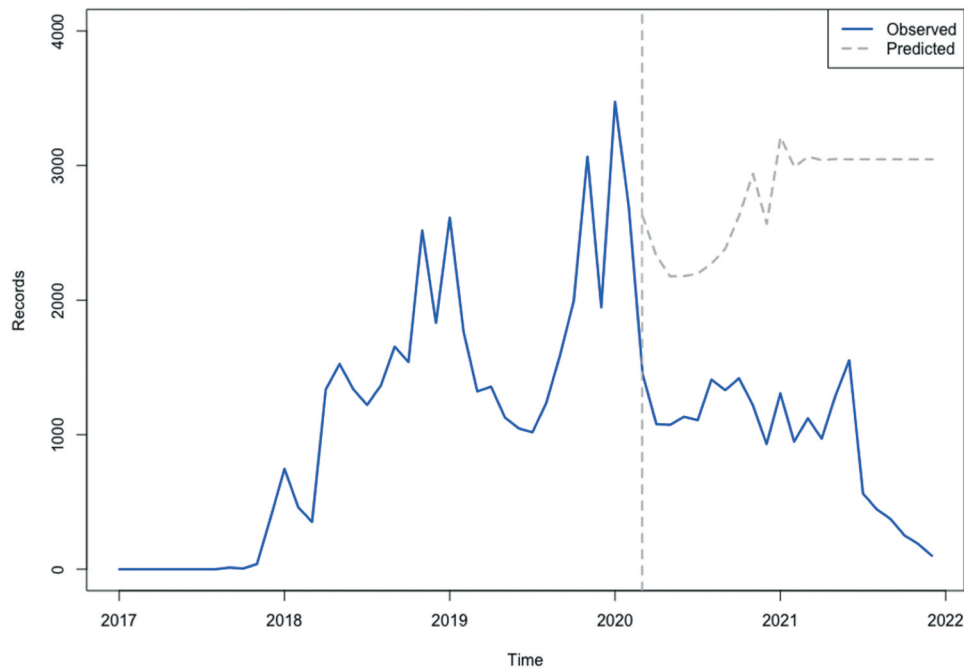
were associated with an increase in self-reported completion of scheduled pneumococcal immunization series by 14.57%, followed by a decrease of 3.54% each month during the study period. The p-value for the Ljung-Box test for white noise is 0.98 at 24 lags.

## Discussion

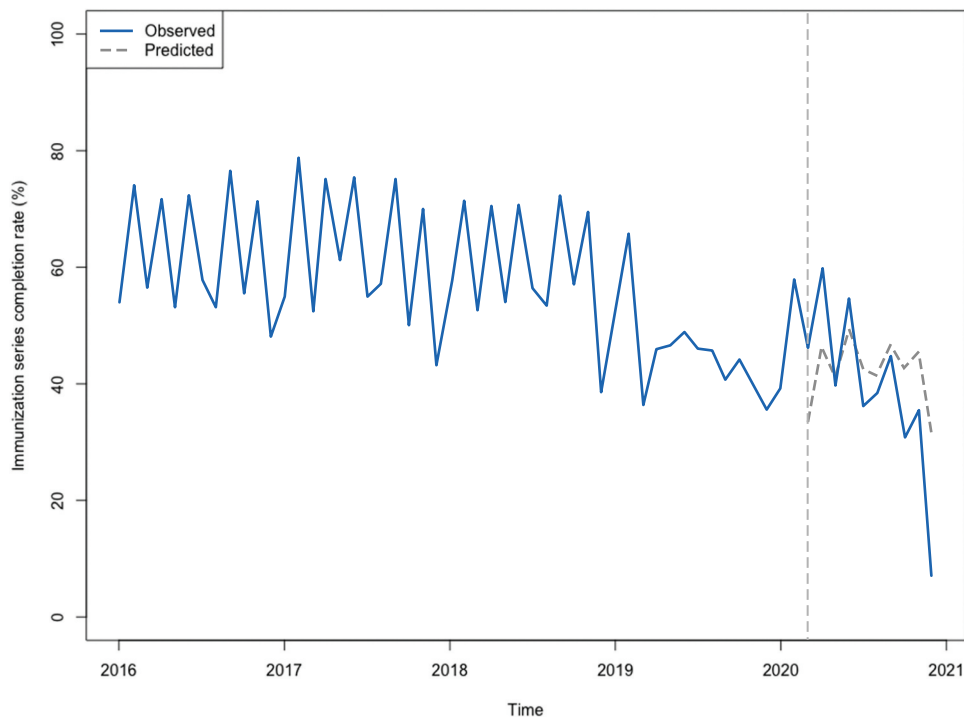
This study found that the onset of COVID-19 in Canada was associated with changes in immunization rates among users of the CANImmunize platform. The monthly enrollment of children on the platform has dropped by  $-1177.52$  records (95%

CI:  $-1865.47, -489.57$ ), with a continued drop of 80.84 records each month. Pneumococcal immunization series completion had an initial increase of 14.57% (95% CI 4.64, 24.51); however, a sustained decrease of  $-3.54\%$  each month that was spent in the pandemic has produced an estimated net effect of  $-20.83\%$ .

These findings are consistent with results from early studies emerging on the impact of the COVID-19 pandemic on routine childhood vaccines globally. In North America, studies in the United States of America and the Dominican Republic have reported a decline of 5–18% and 10% in vaccination coverage, respectively.<sup>25–29</sup> In South America, studies in Columbia and Brazil have reported a drop in



**Figure 3.** Shows both the observed and forecasted children's enrollment on CANImmunize from 2016 to 2021 (The red-dash line represents the cut-off, the onset of COVID-19 related restrictions in Canada)<sup>24</sup>.



**Figure 4.** Shows the predicted completion rates compared to observed rates from 2016 to 2020. The red-dash line represents the cut-off, the onset of COVID-19-related restrictions in Canada<sup>24</sup>.

vaccination coverage of 14.4–20% and 10 to 20%, respectively.<sup>30</sup> European countries, in general, saw a 1% decrease in vaccination coverage, while the African region saw a 2–18% decrease.<sup>31,32</sup> Middle eastern countries such as Jordan have reported a decrease in vaccination coverage of 11.1%,<sup>33</sup> while Lebanon reported a national level decrease of 31% in the utilization of immunization services during the pandemic.<sup>34</sup>

The pandemic-related drop in the uptake of routine vaccines could not be generalized worldwide. For instance, the Brazilian immunization programs appeared to have challenges that were not necessarily furthered by the pandemic, as Alves J. G et al showed in their study. They didn't find a significant impact of the pandemic on the already declining completion rates of routine pediatric immunization in Brazil;<sup>18</sup> therefore, catch-up programs targeting children that missed their scheduled doses

due to the pandemic's restrictions would not significantly improve the completion rate of the pediatric immunization programs. On the other side, unlike our findings on the adoption of CANImmunize during the pandemic, the initiation and uptake of the HPV immunization series among adolescents in the United States have not been affected by the Covid-19 pandemic,<sup>19</sup> highlighting the role of having schools open on the Canadian immunization program in relation to the USA's.

Our findings did spot a slight increase in the completion rates during the first 3 months of 2020, including March, the first month of the pandemic. However, this was not a positive result of the pandemic. Rather, it was a seasonality feature of the data that is observed around the start of every year. It is influenced by the annual commencement of schools and daycares during that period. It is believed that a significant number of parents update their immunization records to fulfill school enrollment requirements in provinces such as Ontario.<sup>35</sup> Unfortunately, the same observation would not be possible in 2021, as many schools were closed as a measure to mitigate the Covid-19 pandemic's effects.<sup>36</sup>

To our knowledge, no studies assessed the impact of the pandemic-related restrictions on population engagement in digital tools for vaccination, such as CANImmunize, and the impact of the pandemic on pneumococcal vaccination in Canada. A key strength of our study is that we used a large dataset observed over a long period. It has allowed us to compare and understand changes in the trend of each outcome. Additionally, this research was the first to detect the effect of the COVID-19 pandemic on children's immunization in Canada. It will serve as hypothesis-generating while other nationwide evaluations are conducted.

The findings of this study depict the extent to which the COVID-19 pandemic has affected the adoption of digital immunization platforms, as well as the completion of pediatric immunization series among adopters of such platforms. Digital platform use increased considerably during the pandemic<sup>37,38</sup> and data from digital platforms can serve as an early indicator of trends in vaccination. Our observations in the CANImmunize database are consistent with data emerging from other sources. Together they speak to an emerging challenge that requires immediate attention from a public health perspective. The study also points to an opportunity to use digital platforms to inform public health decision-making.

This study had some limitations. Outcomes were assessed in a population that is actively utilizing a free digital tool for managing immunization records, which may not be representative of the general population. This study was also a single-group interrupted time series analysis, lacking a parallel comparison group. Furthermore, all data on vaccination was self-reported. However, vaccinations reported by parents are used by some provinces as the official source of data. Parents are required to register such information to public health for school entry under the *Immunization of School Pupils Act* in Ontario.<sup>35</sup>

Additionally, disparities in the effect of the pandemic on immunization rates due to factors such as geographical location and socioeconomic status of the CANImmunize users have not been assessed. The company's privacy policy limits access to the socioeconomic data of users and prohibits the collection of a complete user postal code. The combination of

those roll blocks made it impossible for the analysis to utilize other datasets that could provide socioeconomic data, such as the Canada Revenue Agency's publicly available data on household income tax per postal code. Additionally, geographical disparities were not assessed due to the difficulties in increasing the power of the analysis. As a result, the scope of the analysis was limited to the national level impact, given that all provinces and territories of Canada share similar federal immunization goals and strategies.<sup>8</sup> However, we agree that further research is recommended to test and elucidate the possibility of disparities in the effect of the pandemic on children's immunization rates among all provinces and territories of Canada.

## Conclusion

The COVID-19 pandemic has negatively affected enrollment in the CANImmunize app immediately and the whole time under pandemic restrictions. Pneumococcal immunization series completion rates had an initial increase but an overall estimated net effect of -20.83%. Further research is needed to assess the impact of the COVID-19 pandemic on pediatric vaccination rates in Canada. There is a strong need for the development and implementation of catch-up intervention programs to mitigate the effects of the pandemic on the 2025 Public Health Agency of Canada's goals of achieving community protection against VPDs.

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## Disclosure statement

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