# The impact of the COVID-19 pandemic on routine immunizations in Canada

by

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## Abstract

**Study 1:**

### Introduction

In Canada, the COVID-19 pandemic has interrupted many routine health services, placed additional strain on the health care system, and resulted in many Canadians being either unable or unwilling to attend routine immunization appointments. We sought to capture and synthesize information about changes to routine immunization programs in response to the pandemic and plans to catch-up any missed immunizations.

### Methods

Provincial/territorial (P/T) public health leaders were interviewed via teleconference between August-October 2020 to collect information on the following topics: how routine immunization delivery was affected during and after initial lockdown periods, plans to catch-up missed doses, and major challenges and achievements in continuing routine immunization programs. Data were coded and categorized according to common responses and descriptive analysis was performed.

### Results

Interviews occurred with participants from 11 of 13 P/Ts. School immunization programs were reported to be most negatively affected by the pandemic (n=9). In the early pandemic period, infant, preschool, and maternal/prenatal programs were prioritized, with most P/Ts continuing these services with adaptations for COVID-19. After the initial lockdown period, all routine programs were continuing with adaptations in most P/Ts. Infant, preschool, and school programs were most often targeted for catch-up through measures such as appointment rebooking and

making additional clinics and/or providers available. Major challenges included resource limitations (e.g., staff shortages, PPE shortages, limited infrastructure) (n=11), public health restrictions (n=8), and public hesitancy to attend appointments (n=5).

**Conclusions**

Canadian routine immunization programs faced some disruptions due to the COVID-19 pandemic, particularly the school, adult, and older adult programs. Further research is needed to determine the measurable impact of the pandemic on routine vaccine coverage levels.

**Study 2:**

**Introduction**

Routine immunization programs have been disrupted by the coronavirus disease 2019 (COVID-19) pandemic globally, but little is known about the impact on school immunization coverage in Canada. The objectives of this study were to: 1) assess the change in coverage for two school-based vaccines in Alberta, Canada, before and during the pandemic; 2) ascertain whether coverage has returned to pre-pandemic levels; and 3) determine whether coverage differed by school zone and type.

**Methods**

Using a retrospective cohort study of administrative health data in Alberta, this study compared absolute differences in coverage for human papillomavirus (HPV) and meningococcal conjugate A, C, Y, W-135 (MenC-ACYW) vaccines between pre-pandemic (2017-2018 school year) and

pandemic (2019-2020 and 2020-2021 school years) cohorts using Pearson's chi-square tests. Coverage was also compared by school zone (Calgary, Edmonton, Central, North, South) and authority type (public, Catholic, private, charter, francophone) by calculating crude relative risks. The 2019-2020 cohort was followed over a one-year period to assess catch-up.

**Results**

Compared to the 2017-2018 cohort, at the end of the school year, immunization coverage for HPV was significantly lower in the 2019-2020 (absolute difference: 60.8%; 95% CI: 60.4-61.3%) and 2020-2021 cohorts (absolute difference: 59.9%; 95% CI: 59.4-60.3%). There was a smaller, significant decline in MenC-ACYW coverage comparing 2017-2018 to 2019-2020 (absolute difference: 6.1%; 95% CI: 5.6-6.5%) and 2020-2021 (absolute difference: 32.2%; 95% CI: 31.6-32.7%). Private schools had low coverage for both vaccines in both cohorts, while coverage fluctuated by zone. During follow-up, coverage for HPV and MenC-ACYW improved in the 2019-2020 cohort, increasing from 5.6% to 50.2%, and 80.7% to 83.0%, respectively.

**Conclusion**

HPV and MenC-ACYW coverage during the COVID-19 pandemic declined in comparison to pre-pandemic, and coverage also differed by school zone and type. Coverage has not yet returned to pre-pandemic levels, suggesting further catch-up is needed.

## Preface

The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Vaccination in a pandemic: The impact on routine vaccinations and future COVID-19 vaccine acceptance", Ethics No. Pro00102401, July 9, 2020.

Some of the research conducted for this thesis forms part of a national research collaboration, led by Professor S.E. MacDonald at the University of Alberta. The data analysis in chapter 3 is my original work with the assistance of Y.R. Paudel, as well as the literature review in chapter 1. S.E. MacDonald and D. Voaklander were supervisory authors for the manuscript in chapter 3 and contributed to manuscript edits.

Chapter 2 of this thesis has been published as H. Sell, A. Assi, S.M. Driedger, E. Dubé, A. Gagneur, S.B. Meyer, J. Robinson, M. Sadarangani, M. Tunis, and S.E. MacDonald, "Continuity of routine immunization programs in Canada during the COVID-19 pandemic," Vaccine, vol. 39, issue 39, 5532-5537. I was responsible for the creation of the interview guide, data collection and analysis as well as the manuscript composition. A. Assi carried out project administration and assisted with the interview guide, data collection, analysis, and contributed to manuscript edits. S.E. MacDonald was the supervisory author and was involved with conceptualization, interview guide development, data analysis, and manuscript composition. All other authors assisted with conceptualization and contributed to manuscript revisions.

## Dedication

I would like to dedicate this thesis to my parents, Pat and Mike. I would not be where I am today without all of your support. I cannot thank you enough for everything you have given me.

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I would like to acknowledge my primary supervisor Dr. Shannon MacDonald for all of her support and guidance throughout the completion of this project and over the past two years. I am so grateful for all of the opportunities you have provided me and your dedication to your students is unmatched. Thank you for taking me on as a student.

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I would also like to thank Yuba Raj Paudel for his assistance with Chapter 3 of this manuscript. I am so grateful for the time you spent helping me with this project and the feedback you provided.

Additionally, I would like to thank all of the other Applied Immunization (Aimm) research team members for providing me with mentorship, advice, and support over the past two years, including Ali Assi and Robin Humble. It was truly a pleasure to work with you all.

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Lastly, I would like to acknowledge the financial support I received throughout my graduate program, including a WCHRI graduate studentship funded by the Stollery Children's Hospital Foundation through the Women and Children's Health Research Institute, and awards I received through the School of Public Health (Dr John Waters Memorial Award in Public Health) and the Government of Alberta (Alberta Graduate Excellence Scholarship).

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## List of Abbreviations

| | |
|---|---|
| AHCIP | Alberta Health Care Insurance Plan |
| COVID-19 | coronavirus disease 2019 |
| CI | confidence interval |
| dTap | diphtheria, tetanus, acellular pertussis |
| DTaP-IPV-Hib-HB | diphtheria, tetanus, acellular pertussis, inactivated polio vaccine, *Haemophilus influenzae* type b, hepatitis B |
| HPV | human papillomavirus |
| ICU | intensive care unit |
| Imm/ARI | Immunization and Adverse Reaction to Immunization |
| MenC-ACYW | meningococcal conjugate A, C, Y, W-135 |
| MMR | measles, mumps, rubella |
| MMRV | measles, mumps, rubella, varicella |
| NACI | National Advisory Committee on Immunization |
| PPE | personal protective equipment |
| PSIR | Provincial School Immunization Record |
| P/T | province or territory |
| RR | relative risk |
| Tdap | tetanus, diphtheria, acellular pertussis |
| VPD | vaccine-preventable disease |
| WHO | World Health Organization |

# Chapter One: Background

## Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had significant impacts on societies worldwide. Since the early stages of the pandemic, literature has highlighted the growing concern among public health officials and health care providers regarding declines in routine health services during the pandemic, particularly routine childhood immunizations. Early international evidence has shown that childhood immunization coverage significantly declined following the onset of the COVID-19 pandemic (Ackerson et al., 2021; Bramer et al., 2020; McDonald et al., 2020; Murthy et al., 2021; O'Leary et al., 2021; World Health Organization, 2020d), including coverage for infants in Alberta, Canada (Alberta Government, 2021f; MacDonald et al., 2022). However, the impact of the COVID-19 pandemic on school-based immunizations in Alberta remains in the early stages of exploration and is still unclear. It has been speculated that due to school closures and resource shortages, Canadian school-based immunization programs have been especially impacted by the COVID-19 pandemic (Piché-Renaud et al., 2021). As such, the motivation behind this project was to advance knowledge of how the COVID-19 pandemic has impacted immunizations for Canadian children by examining what has been done to address missed doses, whether coverage for school-based immunizations in Alberta has returned to pre-pandemic levels, and whether coverage during the pandemic period differed by school-level factors such as provincial zone or school type.

## The COVID-19 pandemic in Alberta, Canada

*First and second waves (March 2020-January 2021)*

On December 31, 2019, the Wuhan Municipal Health Commission in Wuhan, China released a media statement on their website reporting an outbreak of viral pneumonia cases in the region, which was picked up by the World Health Organization's (WHO) Country Office in China (World Health Organization, 2020c). On January 9, 2020, the WHO reported that a novel coronavirus was identified as the cause of the outbreak (World Health Organization, 2020c). Cases quickly spread worldwide, with the first Canadian COVID-19 case being reported in Toronto on January 25, 2020 and the first Albertan case on March 5, 2020 (Alberta Government, 2020a). Following increases in the severity of the disease and continuing global spread, the WHO officially declared COVID-19 to be a pandemic on March 11, 2020 (World Health Organization, 2020c). At the time, COVID-19 cases continued to spread across Canada (Government of Canada, 2021b), marking the first wave of the pandemic. Shortly after the WHO's declaration, Canadian federal and provincial governments instituted a chain of stay-at-home orders beginning on March 16, 2020. These orders included school, daycare, and business closures, event cancellations, travel restrictions, work-from-home requirements, and bans on social gatherings (Alberta Government, 2021b; Government of Canada, 2020b).

In May 2020, the Alberta Government re-opened non-essential services, including restaurants and retailers, after case counts and hospitalizations declined across the province (Alberta Government, 2020c, 2021a). As provincial and territorial governments are responsible for implementing and lifting public health measures, each province or territory (P/T) has had varying levels of restrictions throughout the pandemic. In June 2020, more businesses re-opened in Alberta including personal care and wellness services (e.g., massage clinics, gyms), theatres, and libraries (Alberta Government, 2020d). Throughout the following months, many businesses remained open with capacity restrictions, physical distancing, and masking requirements.

However, COVID-19 cases and hospitalizations rapidly began to increase in the province during the months of August to November 2020 (Alberta Government, 2021a), marking the start of the second wave of the pandemic. In response, the Alberta Government implemented further restrictions on November 24, 2020, prohibiting indoor social gatherings and closing high schools, followed by a second round of stay-at-home orders on December 8, 2020, banning both indoor and outdoor social gatherings and closing many businesses (Alberta Government, 2020f). This second lockdown lasted until January 2021, when restrictions on outdoor gatherings were eased and some personal care services re-opened (Alberta Government, 2021g, 2021h). Figure 1 shows a timeline of the restrictions implemented in Alberta from March-December 2020.

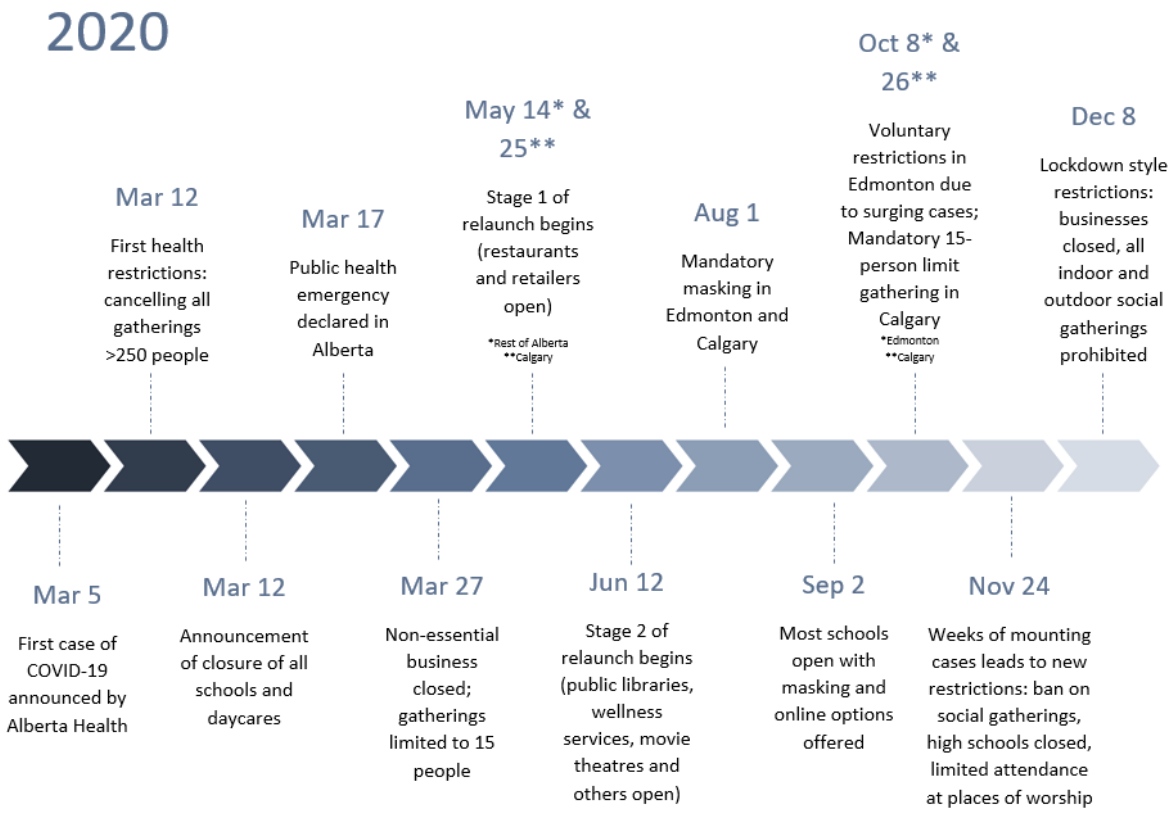


**Figure 1.** Timeline of public health restrictions in Alberta from March-December 2020.

*Third wave, mass immunizations, and restriction relaxation (February 2021-July 2021)*

Case counts in Alberta were relatively low in February 2021 (Alberta Government, 2021a), enabling restrictions to be eased throughout February and March. However, in March 2021, cases began to rise again (Alberta Government, 2021a), leading to a third round of stay-at-home orders in April and May (Alberta Government, 2021l). Around this same time, COVID-19 vaccines (AstraZeneca, Moderna, Pfizer) became widely available in Alberta, with older age groups being prioritized to receive a vaccine first (Alberta Government, 2021i, 2021j). By May 2021, all Albertans over the age of 12 were eligible to receive the Pfizer vaccine, and those 18 years of age or older could receive Moderna (Alberta Government, 2021n). Alberta paused use of the AstraZeneca vaccine for first doses due to supply issues and safety concerns in younger populations (Alberta Government, 2021k, 2021o).

Alberta officially began the first stage of the 'Open for Summer' plan on June 1, 2021 (Alberta Government, 2021p). This plan consisted of three stages, each lifting additional public health restrictions, contingent on the percentage of eligible Albertans who received their first dose of a COVID-19 vaccine and the number of hospitalizations across the province. Alberta officially reached Stage 3 on July 1, 2021, and until August 2021 few restrictions were in place (Alberta Government, 2021p). All health, personal care, retail, and restaurant services were allowed to operate with no restrictions on capacity.

*Fourth wave and present state (August 2021-present)*

The fourth wave of the COVID-19 pandemic, beginning in August 2021, resulted in large rises in COVID-19 cases and hospitalizations (Alberta Government, 2021q). On September 20, 2021, the Restrictions Exemption Program came into effect, ordering many non-essential businesses to require proof of immunization or a negative COVID-19 test result, as well as

mandatory masking, in order to continue normal operations (Alberta Government, 2021c). Businesses that chose not to implement proof of immunization or a negative test result were subject to additional public health restrictions (e.g., capacity limitations, physical distancing). This program was lifted on February 8, 2022, with most remaining public health restrictions due to be lifted on March 1, 2022 (Alberta Government, 2022b). Figure 2 shows a timeline of the restrictions implemented in Alberta from January-September 2021.

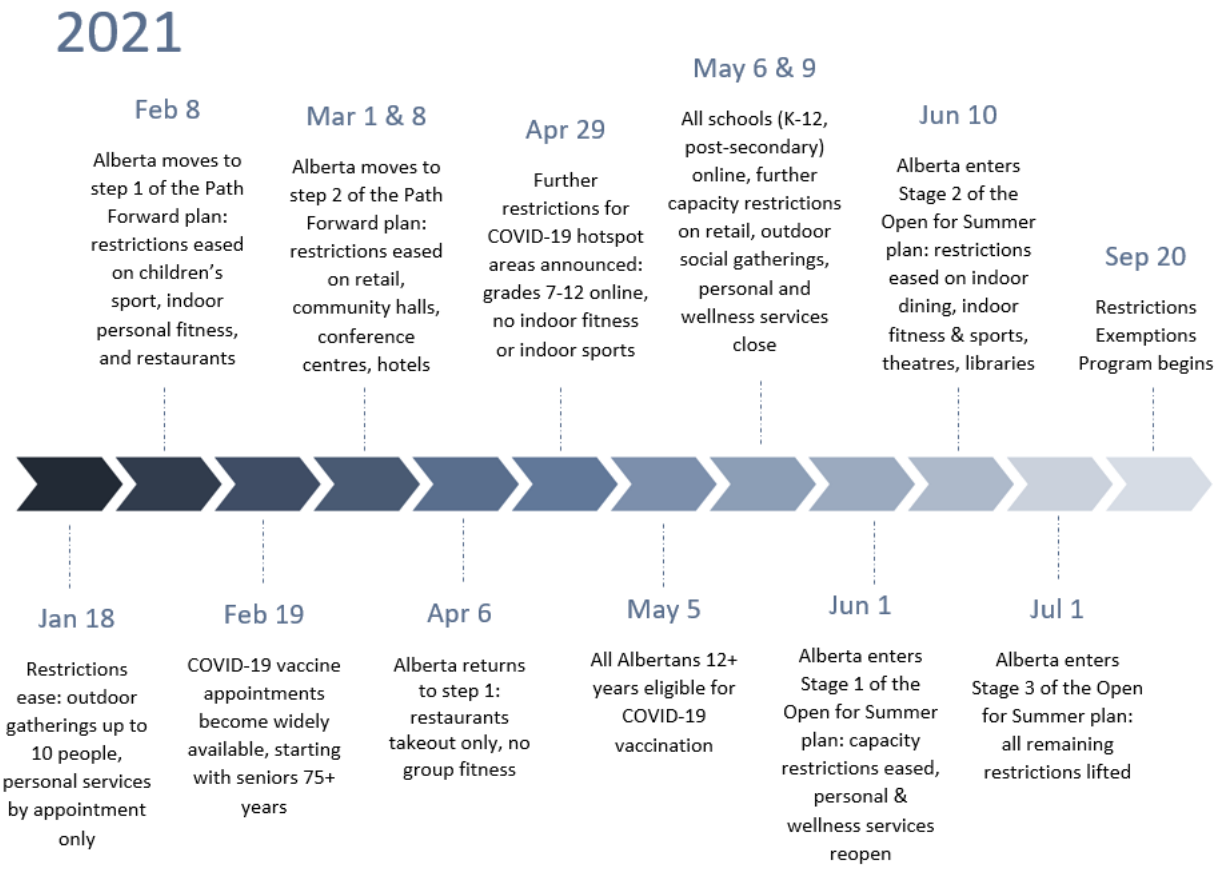


**Figure 2.** Timeline of public health restrictions in Alberta from January-September 2021.

**COVID-19 impact on health care systems**

The social and economic impacts of the COVID-19 pandemic have been far-reaching, affecting factors such as employment, resource availability, financial markets, mental health, and quality of life (Statistics Canada, 2020). One of the most notable impacts has been on global health care systems. Throughout the pandemic, health care systems have struggled to cope with the additional strain on resources resulting from COVID-19 testing and contact tracing, admission of COVID-19 patients to hospitals and intensive care units (ICUs) (Barrett et al., 2020; Emanuel et al., 2020), and later in the pandemic, the introduction of mass immunization campaigns against COVID-19. Many countries have experienced shortages of healthcare workers, pharmaceutical drugs, personal protective equipment (PPE), ventilators, and hospital and ICU beds throughout the pandemic (Brophy et al., 2021; Rowan & Laffey, 2020; Sen-Crowe et al., 2021; Socal et al., 2021).

In Canada, ICU admissions for major respiratory conditions requiring ventilation, including COVID-19, increased 129% in April 2020 compared to previous months (Canadian Institute for Health Information, 2021a). Primary care services such as physician visits were also greatly impacted during the early stages of the pandemic. Following the announcement of stay-at-home orders in Canada in March 2020, many physician clinics began offering virtual or telephone appointments for non-urgent services rather than in-person appointments. Data from the Canadian Institute for Health Information (2021b) estimated that 52% of physician care in Ontario was provided virtually in April 2020. Interestingly, visits to hospitals and clinics for non-COVID-19-related reasons were found to have decreased following the onset of the pandemic, including in Alberta (Rennert-May et al., 2021). In April 2020, it was estimated that emergency department visits declined by 50% across Canada (Canadian Institute for Health Information,

2021b). Possible explanations for this decline may include patients' fear of contracting COVID-19 in health care settings, changes in physician behaviour to keep hospital resources available, and reductions in viral respiratory conditions overall due to physical distancing and hand hygiene (Public Health Ontario, 2021; Rennert-May et al., 2021).

**COVID-19 impact on routine immunizations**

In particular, routine immunizations have been impacted by the shifts in health care that have occurred during the COVID-19 pandemic. There has been mounting concern among public health experts and health care providers regarding declines in routine immunization coverage during the pandemic, particularly for those given in childhood (World Health Organization, 2020d). A growing body of literature has examined the impact of the COVID-19 pandemic on routine childhood immunization uptake and coverage around the world. In a global survey conducted early in the pandemic, 85% of respondents from 61 countries reported a decline in routine immunization rates in May compared to January and February 2020 (World Health Organization, 2020d). McDonald et al. (2020) showed that measles-mumps-rubella (MMR) immunization rates fell 19.8% in England in the three weeks following the introduction of physical distancing measures in late March 2020. Similarly, in the United States, Langdon-Embry et al. (2020) found a 62% decrease in infant immunization during March and April 2020 in New York City, while Bramer et al. (2020) reported declines ranging between 5-20% for infant vaccine coverage in May 2020 in Michigan. These decreases are concerning as high immunization coverage rates are essential to prevent vaccine-preventable disease (VPD) outbreaks in the post-pandemic period. For example, multiple measles outbreaks occurred in Guinea in 2015 due to immunization disruptions during the Ebola epidemic (Suk et al., 2016).

Due to the disruptions in routine immunization resulting from the COVID-19 pandemic, some experts predict that the incidence of diseases such as measles, pertussis, and polio may increase (Ghatak et al., 2020).

Within Canada, each P/T is responsible for administering health services, including routine immunizations (Government of Canada, 2021c). As such, the processes for routine vaccine delivery in the P/Ts vary, although most primarily use public health and/or physician delivery. Currently, few published studies have assessed the impact of the COVID-19 pandemic on routine immunizations in Canada, particularly for school-aged children. A survey of 475 pediatricians and family physicians in Ontario conducted in May-June 2020 found that 26% of respondents only provided immunizations to children of a specific age because of the pandemic (Piché-Renaud et al., 2021). Of these respondents, most prioritized infant immunizations and postponed those for preschool-aged children (77%) and teenagers (97%). An Albertan study that assessed coverage for infant vaccines (i.e., measles, pertussis-containing, and rotavirus vaccines) before and during the COVID-19 pandemic found that coverage for all three vaccines declined in April 2020, but the declines were largest in vaccine doses given to children of older ages (MacDonald et al., 2022).

In May 2020, the National Advisory Committee on Immunization (NACI) released guidance on routine immunizations during the COVID-19 pandemic, recommending that routine immunizations continue in order to prevent VPD outbreaks, particularly for infant vaccines (administered at ≤18 months of age) (National Advisory Committee on Immunization, 2020). According to these guidelines, school-based and adolescent vaccines could be postponed until regular health services resumed, or schools reopened. Given the focus on maintaining infant vaccines in Canada, immunizations for school-aged children have likely been disrupted, leaving

this group susceptible to diseases such as meningococcal meningitis or human papillomavirus (HPV) (Canadian Pediatric Society, 2020).

**Conceptual framework**

Socio-ecological models recognize that there are multiple levels of influence on human health and health-related behaviours (McLeroy et al., 1988). Socio-ecological frameworks have been applied in studies of various health-related outcomes, including immunization (Dubé et al., 2019; Ferrer et al., 2014; Kumar et al., 2012). This framework can be used to understand the interrelationship between multiple levels of influence (e.g., individual, interpersonal, organizational, community, public policy) on vaccine uptake. Previous work in this area has shown that the act of getting vaccinated is influenced by individual factors, such as one's perceptions on disease risk or vaccine characteristics (e.g., safety, effectiveness), fear of needle pain, previous immunization experiences, and trust in public entities, such as the government or health care system (Dubé et al., 2019; Kumar et al., 2012). At the interpersonal level, vaccine uptake can be influenced by an individual's social network, such as whether friends or family were vaccinated (Kumar et al., 2012). Organizational-level factors include delivery aspects of immunization services that can either facilitate or discourage immunization, such as having a regular health care provider (Kumar et al., 2012) and immunization settings (e.g., public health offices, physician clinics, schools, pharmacies) (Dubé et al., 2019). Community-level factors consist of broad socio-cultural factors that create an environment in which immunization is supported or not (Dubé et al., 2019), including the presence of disease and perceived risk in the community (Kumar et al., 2012). Finally, policy-level factors include funding (e.g., making vaccines freely available through government funding), immunization requirements (e.g., school-

entry or travel requirements), recommendations by public health or medical organizations, or other policies that may facilitate immunization (Dubé et al., 2019). Additionally, there are also practical issues including accessibility, affordability, and acceptability of immunization services.

The current study focused on immunization factors mainly at the organizational and policy levels. Specifically, we examined how decisions made by government, public health policymakers, and public health programs, such as school closures, program suspensions, and the implementation of catch-up programs, impacted immunization coverage levels during different time periods of the COVID-19 pandemic.

**School-based immunizations**

School-based immunization programs have historically resulted in high uptake and completion rates for many vaccines globally, including HPV (Paul & Fabio, 2014) and influenza (Pebody et al., 2015). These programs are cost effective ways to improve vaccine uptake (Jacob et al., 2016), as the school setting allows for immunizations to be given to a large number of children in a short period of time. Additionally, school-based immunization programs have been shown to improve equity in immunization coverage, particularly for low socioeconomic status groups, by facilitating access (Musto et al., 2013).

In Canada, public health nurses provide some routine immunizations for school-aged children and adolescents in schools, although schedules and doses may differ across P/Ts (Adedzi & Dubé, 2020; Government of Canada, 2021d). In Alberta, the school-based immunization program consists of four vaccines: hepatitis B, HPV, diphtheria-tetanus-acellular pertussis (dTap), and meningococcal conjugate A, C, Y, W-135 (MenC-ACYW) (Alberta

Government, 2021e). Details on the number and timing of doses for these vaccines are provided in Table 1.

**Table 1**. Number and timing of doses for school-based vaccines in Alberta, Canada.

| **Vaccine** | **Number and timing of doses** | **Minimum interval between doses** |
|---|---|---|
| Hepatitis B | 2019-2020 school year and beyond:<br>2 doses in Grade 6 | Minimum interval between doses 1 & 2: 6 months |
| | 2017-2018 school year and prior:<br>3 doses in Grade 5 | 2nd dose: 1 month after dose 1<br>3rd dose: 6 months after dose 1 |
| Human papillomavirus (HPV) | 2018-2019 school year and beyond:<br>2 doses in Grade 6<br>(3 doses if first dose is at age 15 years or older) | Minimum age dose 1: 9 years<br>Minimum interval between doses 1 & 2: 6 months |
| | 2017-2018 school year and prior:<br>3 doses in Grade 5 | Minimum age dose 1: 9 years<br>2nd dose: 2 months after dose 1<br>3rd dose: 4 months after dose 1 |
| Diphtheria-tetanus-acellular pertussis (dTap) | 1 dose in Grade 9 | Minimum age: 12 years<br>Minimum interval: N/A |
| Meningococcal Conjugate A, C, Y, W-135 (MenC-ACYW) | 1 dose in Grade 9 | Minimum age: 12 years<br>Minimum interval: N/A |

*Notes.* dTap: diphtheria-tetanus-acellular pertussis; HPV: human papillomavirus; MenC-ACYW: meningococcal conjugate A, C, Y, W-135; N/A: Not Applicable.
Sources: (Alberta Government, 2021e; Alberta Health Services, 2021b, 2021c).

Although school-based and other routine childhood vaccines are strongly recommended for Canadian children, only three provinces (Ontario, New Brunswick, and Manitoba) have legislation that requires schoolchildren to be up to date on their routine immunizations prior to

school entry, unless parents file an exemption (Adedzi & Dubé, 2020). Specifically, the provinces of Ontario and New Brunswick require children to be vaccinated against diphtheria, tetanus, polio, pertussis, measles, mumps, rubella, and meningococcal disease, while Ontario also requires varicella (only for children born in 2010 or later). Manitoba only requires immunization against measles prior to school entry (Adedzi & Dubé, 2020). Alberta does not currently have any legislation mandating immunization prior to school entry.

**School-based immunizations during the COVID-19 pandemic**

In Alberta, like many other provinces, schools closed on March 16, 2020, and did not re-open for in-person instruction for the remainder of the 2019-2020 school year (Alberta Government, 2020b). As a result, school immunization programs normally held in the spring were suspended (National Advisory Committee on Immunization, 2020), meaning that many children who were due for immunization in the 2019-2020 school year may have missed doses of vaccines such as hepatitis B, HPV, dTap, or MenC-ACYW. During the 2020-2021 school year in Alberta, parents were given the option for their children to attend school either in-person or online (Alberta Government, 2021d). School immunization programs in Alberta planned to provide in-school delivery for the 2020-2021 school year (Alberta Health Services, 2021d), but this was not possible in all Canadian jurisdictions, such as Toronto, Ontario (Toronto Public Health, 2020). However, with repeated school closures due to spikes in COVID-19 cases and some students attending school online during the 2020-2021 school year, it is likely that doses may also have been missed in this group.

The Ontario study by Piché-Renaud et al. (2021) found that school-based immunizations were identified by surveyed pediatricians to have been most negatively impacted by the COVID-

19 pandemic. Initial descriptive data from the Alberta Ministry of Health has provided estimates of coverage for the two doses of HPV vaccine and the single dose of MenC-ACYW vaccine in 2019 and 2020 (Alberta Government, 2021f). The data showed that coverage for the first dose of HPV vaccine was slightly lower in 2020 compared to 2019 (70.3% and 67.0% for females, respectively; 68.6% and 65.3% for males, respectively). Similarly, coverage for the single dose of MenC-ACYW was slightly lower (81.7% in 2019 to 80.5% in 2020). These differences are small as these vaccines were administered prior to school closures in mid-March 2020. In contrast, coverage for vaccines normally given in the spring, such as second dose HPV and hepatitis B vaccines experienced large drops in coverage. Specifically, second dose HPV immunization in 2020 showed an 85% reduction among females and an 87% reduction among males compared to 2019. Likewise, second dose hepatitis B immunization in 2020 declined 61% compared to 2019 (Alberta Government, 2021f). However, limitations to this report include that data are only available for one school year, there is no comparison to pre-pandemic school years, and there is no follow-up to determine whether catch-up occurred.

**Rationale**

Overall, there is a lack of published literature that explores the impact of the COVID-19 pandemic on routine immunization programs across Canada, especially in relation to how immunization coverage has been affected by the pandemic. This topic is still in the early stages of exploration, particularly for school-based vaccines. Given that the COVID-19 pandemic is ongoing and Albertan schools have been continually impacted by fluctuations in public health restrictions, it is likely that immunization coverage for children in both the 2019-2020 and 2020-2021 school years has been impacted. Furthermore, current literature has not yet synthesized

information regarding measures that have been taken by provincial/territorial public health officials to meet the challenges posed by the pandemic in maintaining routine immunizations.

It is essential to quantify the impact of the pandemic on routine immunization coverage as this information can assist public health in identifying populations of children with missed immunizations and devising strategies for catch-up. It is also important to understand and document the processes that led to drops in immunization coverage, and the strategies that have been undertaken to prevent or recover from them. Identifying the range of strategies, highlighting new and innovative approaches, and learning from successful and unsuccessful approaches will enhance our ability to respond to similar challenges in the future. Findings from this thesis can guide knowledge users at the Alberta Ministry of Health and NACI regarding communication with key stakeholders, including physicians, public health nurses, and immunization program coordinators, with respect to identification of populations at risk of VPD outbreaks and the need for catch-up immunization programs. Additionally, examining whether routine immunization coverage returns to pre-pandemic levels ensures that the risk of future outbreaks is minimized.

**Objective and research questions**

The objective of this thesis was to examine the impact of the COVID-19 pandemic on routine immunization programs across Canada and assess the impact of the pandemic on school-based immunization coverage in Alberta. The following research questions were explored:

1) What actions have public health leaders across Canada taken to maintain routine immunizations during the pandemic?

2) What is the impact of the COVID-19 pandemic on school-based immunization coverage in Alberta?
3) Has coverage for school-based immunizations in Alberta returned to pre-pandemic levels?
4) Does school-based immunization coverage during the COVID-19 pandemic differ by provincial zone or school type?

Research question one was explored in the first study outlined in Chapter 2, while research questions two to four were explored in the second study described in Chapter 3.

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## Chapter Two: Continuity of routine immunization programs in Canada during the COVID-19 pandemic

The work presented in this chapter has been published in a peer-reviewed journal. The journal reference is provided below.

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## Introduction

The COVID-19 pandemic has disrupted societies worldwide, resulting in temporary business closures, the cancelling of events, and, central to this study, the interruption of routine immunization programs. Canada's health care system provides universal access to many essential health care services, which are publicly funded and delivered. Each P/T in the country is responsible for administering health services, including routine immunizations (Government of Canada, 2019). The processes for routine vaccine delivery in the P/Ts vary, although most primarily use public health and/or physician delivery (see Table A1 in Appendix A for further detail). Due to the pandemic, some public health clinics and physicians' offices have had restricted availability of in-person services, instead offering telephone or online appointments. Furthermore, the pandemic has placed additional strain on the Canadian health care system via COVID-19 testing and contact tracing, as well as health care utilization by COVID-19 patients (Barrett et al., 2020). The implementation of public health restrictions has also meant that many Canadians have either been unable or unwilling to attend immunization appointments (National Advisory Committee on Immunization, 2020; Ontario Ministry of Health, 2020). As such, despite NACI's recommendation to continue routine immunizations to prevent VPD outbreaks (National Advisory Committee on Immunization, 2020), it is likely that Canadian routine immunization programs have been adversely affected by disruptions from the COVID-19 pandemic.

Although Canadian data are not yet available, preliminary data from other jurisdictions have quantified the impact of COVID-19-related disruptions on routine immunization coverage. In a global survey, 85% of respondents from 61 countries reported a decline in routine immunization rates in May compared to January and February 2020 (World Health Organization,

2020e). McDonald et al. (2020) found that measles-mumps-rubella (MMR) immunization rates fell 19.8% in England in the three weeks following the introduction of physical distancing measures in late March 2020. Notably, data from New York City showed a 62% decrease in immunization for infants aged <2 years during the early stages of the pandemic (March-April) compared to the same time period in 2019 (Langdon-Embry et al., 2020). It is important to understand and document the processes that led to these drops in immunization coverage, and the strategies that have been undertaken to prevent or recover from them. Identifying the range of strategies, highlighting new and innovative approaches, and learning from successful and unsuccessful approaches will enhance our capacity to respond to similar challenges that we will undoubtedly face in the future.

Little is known about the impact of the COVID-19 pandemic on routine immunization programs in Canadian P/Ts and what measures have been taken by P/T public health officials to meet the challenges posed by the pandemic. As such, the current study was undertaken to capture and synthesize information about the continuity of routine immunization programs during the pandemic through interviews with public health representatives across Canada. We were particularly interested in ascertaining changes to routine immunization programs in response to the pandemic and plans to catch-up any missed immunizations.

## Methods

This pan-Canadian environmental scan involved key informant structured interviews with public health leaders from P/Ts across Canada. The goal was to recruit public health leaders who were knowledgeable of immunization services in all 13 P/Ts. Canadian Immunization Committee members in each P/T were initially targeted for recruitment, but as some individuals

were unavailable, convenience sampling was additionally conducted through referrals from members of the research team, which consists of individuals that partake in immunization research in Canada, P/T Ministries of Health, and the NACI Secretariat at the Public Health Agency of Canada. Key informants were contacted via an initial email sent by the NACI Secretariat, inviting them to participate in the study. Interested individuals were emailed an information sheet and consent form. Informed consent was obtained after the nature of the study and any potential benefits and risks had been fully explained. Up to two email reminders were sent to non-responders to optimize response rate. Some participants were recruited via snowball sampling, with study participants suggesting additional key informants. Interviews (35–60 min long) were conducted by members of the research team (HS, AA, MK) from August through October 2020 via teleconference.

The focus of the interviews was to gain in-depth perspectives from individuals who had knowledge about or direct experience with delivery of routine immunization programs during the pandemic. Topics to be explored were identified from scientific literature and news articles, and augmented by the immunization experts on the research team, including the NACI Secretariat. This information was synthesized into questions about: how routine immunization delivery was affected during and after initial lockdown periods, what plans there were to catch-up missed doses, and major challenges and achievements in continuing routine immunization programs. The interview guide was reviewed and edited by immunization experts and pilot tested with an individual who worked in provincial immunization programming, but was not involved in the study, to check face and content validity, flow, and comprehension. Ethical approval for this study was obtained from the Health Research Ethics Board at the University of Alberta.

Interviews were audio-recorded and transcribed verbatim by one member of the research team (HS). The same team member then coded and categorized participant responses. Coding and categorization were validated by other team members (SM, AA) to ensure they accurately reflected and were fully representative of participants' responses. Descriptive analysis of response counts was performed using Microsoft Excel.

## Results

Invitation emails from the NACI Secretariat were sent to 35 potential participants: 13 agreed to participate, 1 declined, and 21 did not respond. Five more participants were recruited via referrals from other participants. Before the interview, participants were given the opportunity to invite other colleagues to provide additional perspectives on routine immunization programs. Therefore, some interviews contained more than one participant. In total, there were 18 interviews with 25 participants from 11 of the 13 P/Ts. As shown in Table 2, 12 participants provided a P/T-level perspective, 9 provided a regional/municipal perspective, and 4 provided both P/T and regional/municipal perspectives. Job titles of participants included positions such as Immunization Program or Policy Manager (n=7), Medical Officer of Health (n=5), and Public Health or Medical Consultant (n=3).

Interview results were synthesized into the following topics, presented below: changes in routine vaccine delivery due to the pandemic; plans for catch-up; and challenges and achievements related to routine immunization program continuity during the pandemic.

**Table 2.** Demographic information of the study sample (N=25)[a]

| Characteristic | Number of participants, *n* |
|---|---|
| **Province/Territory** | |
| British Columbia | 1 |
| Alberta | 4 |
| Saskatchewan | 3 |
| Manitoba | 4 |
| Ontario | 3 |
| Quebec | 3 |
| Newfoundland and Labrador | 1 |
| Nova Scotia | 3 |
| New Brunswick | 0 |
| Prince Edward Island | 1 |
| Nunavut | 1 |
| Northwest Territories | 1 |
| Yukon | 0 |
| **Perspective** | |
| Provincial/Territorial | 12 |
| Regional/Municipal | 9 |
| Both | 4 |
| **Job Title** | |
| Immunization Program or Policy Manager | 7 |
| Medical Officer of Health | 5 |
| Public Health or Medical Consultant | 3 |
| Director of Immunization or Communicable Disease Control | 2 |
| Policy Analyst | 2 |
| Public Health or Communicable Disease Specialist | 2 |
| Other | 4 |

*Notes.* P/T = province/territory; PPE = personal protective equipment
[a]Some P/T responses fell into more than one category

## Changes in routine vaccine delivery due to the pandemic

### *Early pandemic period*

During the early pandemic period (i.e., March-April 2020, when lockdown measures were first introduced), all P/Ts reported changes to routine immunization programs, with programs being affected to varying degrees. School immunization programs were reported to be the most negatively affected (n=9), followed by preschool (n=2) and adult (n=2) programs. Infant, preschool, and maternal/prenatal programs were most often prioritized. Most P/Ts

reported continuing their infant (n=11) and preschool programs (n=10) with adaptations, such as shortened appointment times (i.e., only providing immunizations) and implementation of COVID-19 public health restrictions (e.g., PPE, COVID-19 screening). Almost half of P/Ts reported a reduction in available appointments for both of these programs (n=5). A few P/Ts reported temporary suspension of infant (n=3) and preschool (n=4) programs, particularly in regions with high COVID-19 incidence. Maternal/prenatal programs were also prioritized, with ten P/Ts commenting that these programs continued with adaptations for public health restrictions, but six also indicating a reduction in appointments. All P/Ts reported suspension of school-based vaccines, due to school closures in mid-March 2020. A few P/Ts reported suspension of adult (n=2) and older adult (n=3) programs, but overall these programs continued across P/Ts, often with reduced availability and prioritization for high-risk groups. Figure 3a shows all P/T responses for the early pandemic period.

*Mid-pandemic period*

In the period after the initial lockdown (i.e., May-October 2020), most P/Ts reported that infant (n=11), preschool (n=11), and maternal/prenatal (n=10) programs were continuing with adaptations, such as shorter appointment times or implementation of public health restrictions (e.g., PPE, COVID-19 screening). Some P/Ts reported ongoing suspension of school, adult, and older adult programs, but most P/Ts were continuing these programs with the same adaptations (Figure 3b).

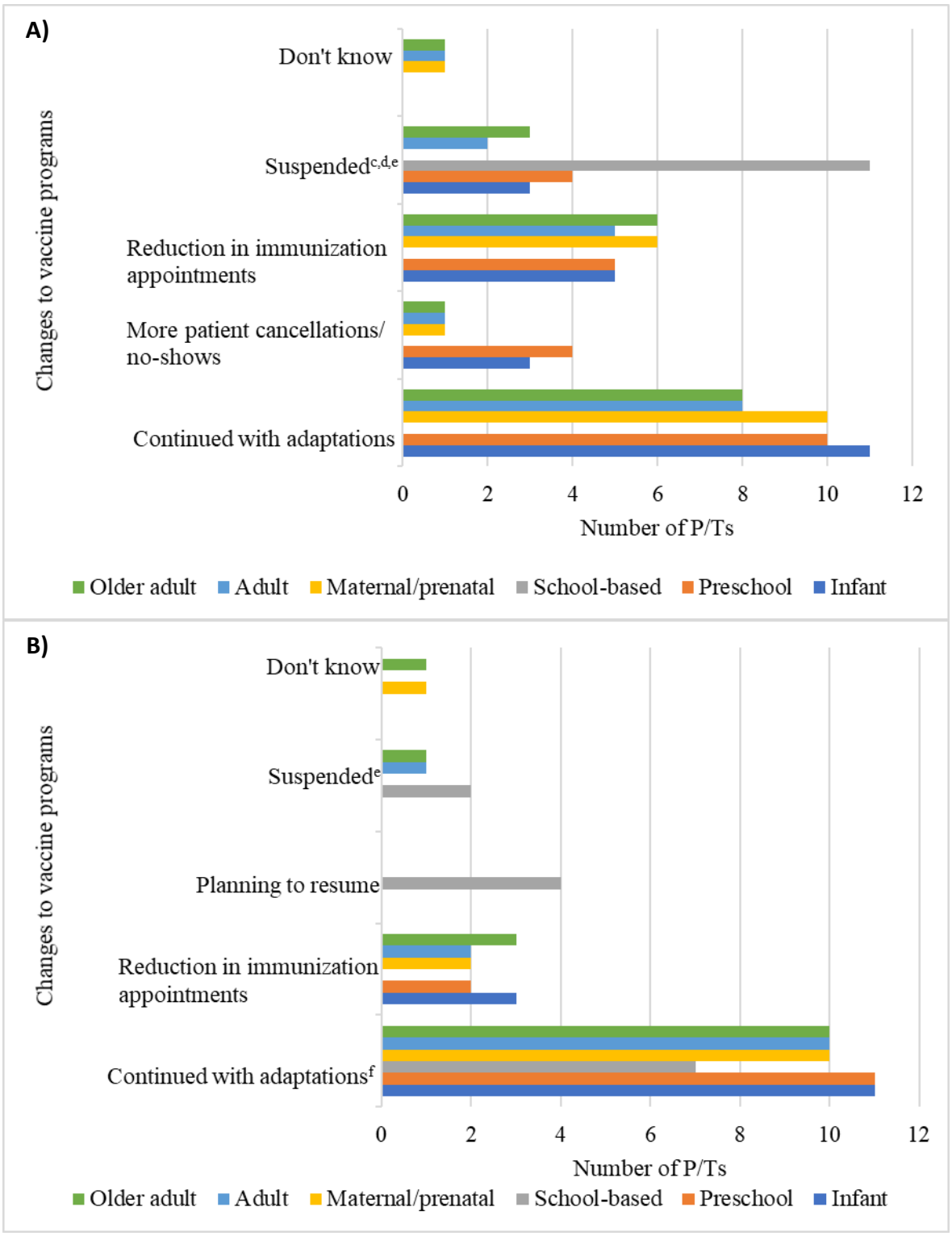


**Figure 3.** Routine immunization program changes a) during initial lockdown period (~March-April 2020) (top) and b) after initial lockdown period (~May-October 2020) (bottom) (N=11).[a,b]

*Notes.*

[a]See Table A1 in appendix A for list of routine programs in each P/T.

[b]Some P/T responses fall into more than one category, so totals may add up to more than 11.

[c]Some P/Ts temporarily suspended the program in some but not all regions.
[d]Some P/Ts continued immunizing high-risk groups only, although programs for the general population were suspended.
[e]In some P/Ts, only non-publicly funded vaccines (e.g., travel vaccines, shingles vaccine) were suspended.
[f]Some P/Ts have resumed immunization in some but not all regions.

**Plans for routine immunization catch-up**

The P/T plans to catch-up vaccines missed due to the pandemic are presented in Tables 3 and 4. School-based vaccines (Table 4) are presented separately, as the strategies for this program are distinct from other programs, which are typically provided in public health clinics and physicians' offices. For infant and preschool immunizations, many P/Ts reported that clients were contacted to rebook their immunization appointments (Table 3). Some P/Ts increased the number of immunization providers for infant (n=4) and preschool (n=2) immunizations, some increased the number of clinics, while others were continuing to offer regular infant (n=2) and preschool (n=3) clinics. Adult and older adult programs were less likely to be actively targeted for catch-up, with P/Ts reporting that these immunizations would be opportunistic at other appointments, provided at regular clinics, or given upon request. Some P/Ts reported increasing providers for adult (n=3) and older adult (n=2) vaccines.

**Table 3.** Routine infant, preschool, and adult immunization program catch-up measures as reported by P/Ts (N=11).[a]

| Response | Infant | Preschool | Maternal/ prenatal | Adult | Older adult |
|---|---|---|---|---|---|
| **Changes to program delivery** | | | | | |
| Increased available providers (e.g., physicians, nurse practitioners, additional nurses) | 4 | 2 | 2 | 3 | 2 |
| Additional clinics offered | 1 | 3 | 0 | 0 | 0 |
| Shortened appointment times | 1 | 1 | 0 | 0 | 0 |
| **Communication** | | | | | |
| Clients were contacted and their immunization appointments were rebooked | 5 | 5 | 1 | 2 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| Public health released communications to health care providers encouraging them to resume routine immunizations | 1 | 1 | 1 | 1 | 1 |
| **Passive catch-up** | | | | | |
| Continuing to offer routine clinics to the best of their ability | 2 | 3 | 0 | 2 | 3 |
| Opportunistic immunization at other appointments | 0 | 0 | 3 | 4 | 5 |
| Clients can be immunized upon request | 0 | 0 | 1 | 1 | 1 |
| No catch-up measures implemented[b] | 2 | 1 | 3 | 2 | 1 |
| Don't know | 0 | 0 | 2 | 2 | 1 |

*Notes.*
[a]Some P/T responses fall into more than one category so column totals may add up to more than 11.
[b]Some P/Ts stated that catch-up was not needed for programs that were maintained during the pandemic.

School-based immunization programs were most likely to be targeted for catch-up, with 10 of 11 P/Ts reporting summer catch-up programs to reach students who had missed immunizations due to school closures, and all P/Ts sharing plans for fall catch-up to reach remaining students (Table 4). The summer catch-up programs were mostly appointment-based (n=7) and held in either public health offices (n=7) or in community locations, such as schools or community centres (n=3). Notably, larger jurisdictions within some P/Ts with high COVID-19 incidence were unable to implement summer catch-up, and instead were planning for fall catch-up. Fall catch-up programs were anticipated to be held within schools (n=10) if restrictions in each jurisdiction allowed it, with appointments at public health offices (n=1) or community locations (n=1) available for students unable to attend at school.

**Table 4.** Routine school-based immunization program catch-up measures as reported by P/Ts (N=11)[a]

| Response | Number of P/Ts (N=11) |
|---|---|
| **Summer catch-up program** | **10** |
| Appointment-based | 7 |
| In public health offices | 7 |

| | |
|---|---|
| In community (e.g., schools, community centres) | 3 |
| Encouraged providers to offer these vaccines | 2 |
| Don't know | 1 |
| **Fall catch-up program** | **11** |
| Appointment-based | 2 |
| In public health offices | 1 |
| In community (e.g., community centres) | 1 |
| In schools | 10 |
| Use alternative providers (e.g., pharmacists, primary care) | 1 |
| Details of delivery unknown | 1 |

*Notes.* [a]Some P/T responses fall into more than one category so column totals may add up to more than 11.

**Challenges and achievements related to routine immunization program continuity during the pandemic**

Many challenges were mentioned by P/Ts in maintaining continuity of routine immunization programs. Most P/Ts indicated that limited resources due to managing the COVID-19 response, including staff shortages, PPE shortages, and limited infrastructure, were a significant challenge (n=11). Public health restrictions, such as increased infection control measures, school and clinic closures (n=8), and public hesitancy to attend clinics/appointments due to COVID-19 (n=5) were also frequently reported. Other common challenges included decreased immunization supply due to decreased distribution or changes in delivery schedules (n=2), delivery of care including switching to virtual care (n=2), limited knowledge and uncertainty about the COVID-19 pandemic (n=2), and routine immunizations not being seen as a priority by the public during COVID-19 (n=2). Additionally, one P/T mentioned that contacting parents was a challenge.

Despite the many challenges, various achievements were reported by P/Ts in providing routine immunization programs during the pandemic. The most commonly reported were the reorganization of delivery programs to continue immunizations including summer catch-up programs, continuing the immunization of high-risk groups (e.g., immunocompromised, post-

exposure prophylaxis), and continuing routine offerings with adaptations (n=9). Other frequently reported achievements included greater collaboration between various stakeholders including the public, health services, community agencies, and government (n=3), and greater awareness of health care including public appreciation and the importance of immunizations (n=3). Achievements indicated by only one P/T were that child immunization rates remained stable and information and technology improvements to immunization registries.

## Discussion

Public health and immunization experts have emphasized the critical need for the continuation of routine immunizations during the COVID-19 pandemic (Bonanni et al., 2021; Ontario Ministry of Health, 2020; World Health Organization, 2020b). The maintenance of high immunization coverage rates in the population is essential to prevent VPD outbreaks in the post-pandemic period. For example, multiple measles outbreaks occurred in Guinea in 2015 due to immunization disruptions during the Ebola epidemic (Suk et al., 2016). With COVID-19 lockdown periods causing disruptions to routine immunization, some experts predict that the incidence of diseases such as measles, pertussis, and polio may increase (Ghatak et al., 2020). It is estimated that 80 million children under one year of age are at risk of these diseases due to COVID-19-related disruptions in routine immunization (World Health Organization, 2020a). Furthermore, missed immunization doses can be problematic as there is evidence that individuals who miss doses may be less likely to catch-up later (National Advisory Committee on Immunization, 2020). Delaying catch-up of missed doses to the post-pandemic period may place additional strain on a health care system that is already overburdened from the COVID-19 pandemic (Bechini et al., 2020; National Advisory Committee on Immunization, 2020).

Most public health representatives in our study were adamant about the importance of continuing immunization programs, while also following national and provincial guidelines to prevent COVID-19 transmission. Although there were some suspensions of routine immunization programs during the initial lockdown period, most P/Ts eventually resumed all programs with adaptations for COVID-19 restrictions. The suspension of routine immunization programs appears to be in line with global trends (Dinleyici et al., 2021). Of 129 countries for which data were available, 53% reported moderate to severe disruptions or full suspension of immunization between March and April 2020 (World Health Organization, 2020a). In the current study, most P/Ts had catch-up via increasing clinics or providers and contacting clients to rebook appointments for infant, preschool, and school programs. While active catch-up efforts were not implemented for adult and older adult programs in most P/Ts, efforts to immunize these groups at other medical appointments were mentioned. P/Ts appeared to be aligning with Canada's NACI recommendations for continuity of routine immunizations, with most or all prioritizing immunization for those under two years of age and pregnant women, taking precautions to prevent COVID-19 transmission, and combining immunizations with other medical visits (National Advisory Committee on Immunization, 2020).

The success in continuing most routine immunization offerings during the pandemic will not be achieved without considerable effort, with P/Ts reporting various challenges, most notably having limited resources due to pandemic response efforts, such as staff shortages, PPE shortages, and limited infrastructure to comply with public health restrictions. Resource shortages have been identified as a major challenge in other countries, with Chandir et al. (2020) reporting a shortage in PPE during the early weeks of the pandemic in Pakistan, and a reduction in the number of available vaccinators due to travel restrictions. Similarly, Ghatak et al. (2020)

highlight lack of infrastructure to maintain social distancing and PPE shortages as contributing factors to the reduction in immunization services in India. Given that resource shortages were a challenge for all P/Ts, it may be important to consider factors such as accessing larger spaces for immunization to allow physical distancing and managing immunization programs with fewer staff in any future pandemic preparedness planning.

Surveys of parents in other jurisdictions have found several barriers to immunization during the pandemic, including uncertainty around whether immunization services were operating (Bell et al., 2021), difficulties in making appointments (Bell et al., 2021), and fears of exposure to COVID-19 (Alsuhaibani & Alaqeel, 2020; Bell et al., 2021). In particular, public hesitancy to attend immunization clinics has been widely noted as a barrier to providing routine immunizations during the pandemic, often resulting in reduced attendance (Alsuhaibani & Alaqeel, 2020; Bechini et al., 2020; Dinleyici et al., 2021; Ghatak et al., 2020). P/Ts in our study also reported that some clients were hesitant to attend immunization appointments, especially during early stages of the pandemic. These findings highlight the importance of clear, consistent, and timely communication from public health or immunization providers regarding the importance of routine immunization and the implementation of measures to prevent disease transmission in clinic settings. A recent study found that advice for parents to continue immunizations resulted in confusion and immunization delays due to conflict with stay-at-home orders (Alsuhaibani & Alaqeel, 2020). As well, offering additional hours or days specifically for immunization could encourage individuals to make in-person visits. P/Ts in our study mentioned offering immunizations at other medical appointments, which may be useful for catching up missed adult and older adult immunizations. As noted by MacDonald et al. (2020) a multi-

pronged approach will likely be needed to catch-up missed immunization doses, given the variation in COVID-19 incidence and public health restrictions across P/Ts.

**Strengths and limitations**

A strength of this study was the variety of perspectives that were obtained on routine immunization programs during the COVID-19 pandemic from most P/Ts. As well, the use of key informant interviews rather than survey methods allowed us to gather in-depth perspectives on routine immunization programs in each P/T. However, as only a few select individuals were interviewed from each P/T, the perspectives gathered are not representative of entire P/Ts. Additionally, it is possible that individuals who did not accept the interview invitation may be located in an area that was overwhelmed by COVID-19 cases and therefore could have different responses. However, it is worth noting that the two P/Ts not represented in this study (i.e., New Brunswick and Yukon) have had relatively low COVID-19 incidence throughout the pandemic (Government of Canada, 2021a). Furthermore, there may be variation in individual perspectives across a single P/T, although the perspectives shared were very consistent within a given P/T. At the time the interviews were conducted, most P/Ts did not have up-to-date information on routine immunization coverage rates during the pandemic. Similarly, given that the COVID-19 pandemic is ongoing and there is a lack of available information on immunization coverage rates, we do not know which P/T strategies were the most effective in ensuring continuity of routine immunization programs.

## Implications

This study adds to existing literature by identifying and synthesizing pan-national public health approaches to the continuity of routine immunization programs during the pandemic. Results can inform policymakers and program planners and can assist in future development of national guidelines. As well, we anticipate that the information in this study will enable P/Ts to learn from one another by comparing their approach to maintaining routine immunization during the pandemic with others across Canada.

It will be important to follow up this study with an assessment of whether the planned strategies for routine immunization programs occurred as anticipated. In addition, it will be critical to assess the impact of the COVID-19 pandemic on immunization coverage levels in each P/T. This will permit evaluation of what strategies had the most positive impact on maintenance of immunization coverage levels.

## Conclusion

Our findings show that routine immunization programs across Canadian P/Ts faced some disruptions due to the COVID-19 pandemic, particularly the school, adult, and older adult programs. Catch-up has been implemented for most programs, but there are continued challenges with resource shortages and public health restrictions. Further research is needed to determine the quantitative impact of the pandemic on routine vaccine coverage levels in order to identify potential risks of future VPD outbreaks.

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## Appendix A

**Table A1.** Routine immunization providers by vaccine program and province/territory.

| **Province/ Territory** | **Infant** (e.g., diphtheria, rotavirus) | **Preschool** (e.g., MMRV) | **School-based** (e.g,. HPV, meningitis) | **Maternal/Prenatal** (e.g., pertussis, if publicly funded) | **Adult** (e.g., Td booster) | **Older Adult** (e.g., pneumococcal, shingles) | **Influenza** |
|---|---|---|---|---|---|---|---|
| **British Columbia** | Public Health (at health units), some family doctors | Public Health (at health units), some family doctors, pharmacists (≥ 5 years) | Public Health (at schools) | Health units, most pharmacies, some doctor's offices | Health units, most pharmacies, some doctors' offices | Health units, most pharmacies, some doctor's offices | Health units, most pharmacies, some doctor's offices |
| **Alberta** | Public Health (Community or public health centres) | Public Health (Community or public health centres) | Public Health (at schools) | Public health office or pharmacy | Community or public health centres | Community or public health centres, some family doctors, some pharmacists | Community or public health centres, pharmacies (≥5 years), doctor's offices |
| **Saskatchewan** | Public Health clinics | Public Health clinics | Public Health (at schools) | Public health clinics, some doctor and nurse practitioner offices, many pharmacies | Public health clinics, some doctor and nurse practitioner offices, pharmacies | Public health clinics, some doctor and nurse practitioner offices, pharmacies | Public health clinics, some doctor and nurse practitioner offices, many pharmacies (≥5 years) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Manitoba** | Public health offices, nursing stations, doctor's offices, QuickCare clinics, and ACCESS Centres | Public health offices, nursing stations, doctor's offices, QuickCare clinics, and ACCESS Centres | Public health (at schools) | Public health offices, nursing stations, doctor's offices, pharmacies, QuickCare clinics, and ACCESS Centres | Public health offices, nursing stations, doctor's offices, pharmacies, QuickCare clinics, and ACCESS Centres | Public health offices, nursing stations, doctor's offices, pharmacies, QuickCare clinics, and ACCESS Centres | Local public health office, nursing station, doctor's office, pharmacy (≥7 years), ACCESS Centre, or the nearest immunization clinic |
| **Ontario** | Primary care providers- PHUs in select instances (see note1) | Primary care providers- PHUs in select instances (see note1) | Public health (at schools) | See notes below re universal influenza immunization program (UIIP) providers | Primary care providers- PHUs in select instances | Public health units, community health centres, health care provider offices, pharmacies | Public health units, primary care providers (e.g., physician officers, community health centres, nurse practitioners), occupational health services, pharmacies (≥5 years) |
| **Quebec** | Local community service centres (CLSCs), some doctor's offices | Local community service centres (CLSCs), some doctor's offices | Public health (at schools) | Local community service centres (CLSCs), some doctor's offices, pharmacies | Local community service centres (CLSCs), some doctor's offices, pharmacies | Local community service centres (CLSCs), some doctor's offices, pharmacies | Local community service centres (CLSCs), some doctor's offices, pharmacies (age 6+) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Nova Scotia** | Public health offices, some local primary care providers | Public health offices, some local primary care providers | Public health (at schools) | Public health offices, some local primary care providers, pharmacies | Public health offices, some local primary care providers, pharmacies | Public health offices, some local primary care providers, pharmacies | Public health offices, some local primary care providers, pharmacies |
| **Newfoundland** | Local health units | Local health units | Public health (at schools) | Public health nursing clinics only | Public health | Public health | Public health, healthcare occupational health services and physician's offices |
| **New Brunswick** | Public health clinics | Public health clinics | Public health (at schools) | Family physicians, nurse practitioners, pharmacists, midwives | Public health clinics, family physicians, nurse practitioners | Family physicians, nurse practitioners, pharmacists | Public Health Offices (children 6-59 months), some pharmacies (5+ years), family physicians, midwives (pregnant women) and other health care providers |
| **Prince Edward Island** | Public health nursing offices | Public health nursing offices | Public health (at schools) | Public Health Nursing office | Local Health PEI Public Health Nursing office, family doctor or nurse practitioner's office or a | Local Health PEI Public Health Nursing office, family doctor or nurse practitioner's office or a | Family physicians, nurse practitioners, pharmacies, and Health PEI Flu Clinics |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | pharmacy, depending on the vaccine | pharmacy, depending on the vaccine | |
| **Yukon** | Community health centres | Community health centres | Public health (at schools) | Community health centres | Community health centres | Community health centres | Flu clinics at community health centres |
| **Northwest Territories** | Health centre, public health unit | Health centre, public health unit | Public health (at schools) | Health centre, public health unit | Health centre, public health unit | Health centre, public health unit | Health centre, public health unit |
| **Nunavut** | Community health centres and public health offices | Community health centres and public health offices | Public health (at schools) | Community health centres and public health offices | Community health centres and public health offices | Community health centres and public health offices | Community health centres and public health offices |

# Chapter Three: School immunization coverage in Alberta, Canada during the COVID-19 pandemic

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The work presented in this Chapter will be submitted to a peer-reviewed journal. This work has not yet been published publicly.

## Introduction

The COVID-19 pandemic has greatly impacted health care systems worldwide via the influx of COVID-19 patients in ICUs, the establishment of testing and tracing programs, and the introduction of mass immunization campaigns against COVID-19. As a result, many routine health services may have been overlooked, including immunization. There has been mounting concern among public health experts and health care providers regarding global declines in routine childhood immunization coverage during the pandemic (World Health Organization, 2020f).

Existing literature has quantified the impact of the COVID-19 pandemic on child and adolescent immunization outside of Canada. Data from Colorado showed an 82% decrease in the mean immunization rate of adolescents aged 10-17 years immediately following the release of social distancing guidelines in mid-March 2020 (O'Leary et al., 2021). Similarly, DeSilva et al. (2022) reported lower weekly immunization rates in the early pandemic period (March-May 2020) compared to the same months in 2019 among children aged 11 to 13 years (relative risk [RR]=0.16, 95% CI: 0.14-0.17) in multiple large jurisdictions across the United States.

In Canada, many provinces, including Alberta, implemented public health restrictions beginning in mid-March 2020, including physical distancing measures, school and clinic closures, and re-allocation of public health staff (Alberta Government, 2021b). These restrictions may have disrupted routine immunization programs, leaving many Canadian children with missed immunization doses (National Advisory Committee on Immunization, 2020; Ontario Ministry of Health, 2020). Immunizations for school-aged children have likely been significantly disrupted as national recommendations have prioritized infant vaccines, while school-based immunization programs were suspended due to school closures (National Advisory Committee

on Immunization, 2020; Sell et al., 2021). A Canadian survey of pediatricians and family physicians in Ontario conducted during the pandemic (May-June 2020) found that 26% of respondents only provided immunizations to children of a specific age, and of this group most postponed immunizations for preschool-aged children (77%) and teenagers (97%) (Piché-Renaud et al., 2021). As such, there is concern that the reduction in coverage for vaccines such as MenC-ACYW or HPV will increase Canadian children's susceptibility to VPDs (Canadian Pediatric Society, 2020; National Advisory Committee on Immunization, 2020).

Currently, the impact of the COVID-19 pandemic on immunization coverage for school children in Canada is unknown. It is essential to quantify the impact of the pandemic on routine immunization coverage as this information can assist public health in identifying populations of children with missed immunizations and devising strategies for catch-up to prevent future VPD outbreaks. As such, the objective of this study was to assess the change in immunization coverage for two school-based vaccines (HPV and MenC-ACYW) in Alberta before and during the COVID-19 pandemic and ascertain whether coverage has returned to pre-pandemic levels. Additionally, we sought to determine whether immunization coverage during the pandemic differed by factors such as school zone and type.

## Methods

### Study design

This was a retrospective cohort study of immunization coverage for two school-based vaccines in Alberta conducted using administrative health data.

## Setting

Alberta is a western Canadian province with a population of approximately 4.5 million (Alberta Government, 2022a). The province is divided into five geographical zones (North, South, and Central, which are predominantly rural zones, and Calgary and Edmonton, which are large urban zones) for delivery of publicly funded health services by Alberta Health Services (Alberta Health Services, 2021a). School-based immunizations are usually delivered by public health nurses in schools (Alberta Health Services, n.d.-a). Table B1 in the appendix provides more information on the number and timing of doses for school-based immunizations in Alberta.

## Data sources

The cohorts were created by linking population-based administrative databases from the Alberta Ministry of Health, including Alberta Health Care Insurance Plan (AHCIP), Provincial School Immunization Record (PSIR), and Immunization and Adverse Reaction to Immunization (Imm/ARI). Almost all Albertans are registered in the AHCIP, which assigns them a unique lifetime identifier that was used to link administrative health records for each individual, including their immunization records. During the period of this study, the Imm/ARI database included all publicly funded childhood vaccines administered in Alberta, except those described in exclusions below. The PSIR database contains individual-level records of student enrollment information in each school year, including grade, age, and gender, as well as school-level information such as school zone and authority type.

### *Exclusions*

Exclusions included those who died or migrated out of Alberta during each respective school year, identified as First Nations (as data is not consistently submitted to Imm/ARI and

PSIR), or were from Lloydminster (as vaccines are delivered by a neighbouring province). Additionally, schools that offer online or distance education (not due to COVID-19), post-secondary, continuing education, summer, or evening/weekend schools were also excluded. To be consistent with previous coverage analyses (Alberta Government, 2021f), age limitations were also applied for each grade. Specifically, for grade 5, those <9 years of age and >11 years were excluded from the analysis. For grade 6, those <10 years and >12 years were excluded. Finally, for grade 9, those <13 years and >15 years were excluded. Figures B1 and B2 in the appendix provide further details on cohort exclusions.

**Analysis**

Immunization coverage (MacDonald et al., 2019) was defined as the proportion of age- and grade-eligible children who received a complete vaccine series on or prior to July 31 of each school year for two vaccines, HPV and MenC-ACYW. Currently, a complete vaccine series for HPV consists of two doses given in grade 6, while MenC-ACYW is a single dose given in grade 9. There was no school program for HPV immunization in the 2018-2019 school year due to a change in delivery from three doses in grade 5 to two doses in grade 6 (Alberta Health Services, 2021b), so the 2017-2018 school year was used as the pre-pandemic comparison year. As a three-dose program was in the place throughout 2017-2018, receipt of at least three doses was used to define a complete HPV series for this cohort. As some students may have received more doses than required, a complete series was defined as receiving the number of required doses as a minimum. Coverage was calculated as the number of children in Imm/ARI who had received a complete dose series of HPV (at least two doses in 2019-2020 or 2020-2021 and at least three doses in 2017-2018) or MenC-ACYW (at least one dose) vaccines divided by the number of

children who had a record of attending grade 5, 6, or 9 in PSIR between September 1 and July 31. Absolute differences in coverage between the pre-pandemic (2017-2018 school year) and pandemic (2019-2020 and 2020-2021 school years) cohorts for each vaccine and associated 95% confidence intervals (CIs) were calculated and compared using Pearson's chi-square tests. Coverage was also stratified by each school's provincial zone (i.e., Calgary, Edmonton, Central, North, South), and authority type (i.e., public, publicly-funded Catholic, private, charter, francophone). Crude RRs and 95% CIs were calculated for the analysis stratified by zone (reference: Calgary) and authority type (reference: public). The zone and authority type with the largest populations were chosen as reference categories.

To assess catch-up over time for both HPV and MenC-ACYW, children who were due to be vaccinated in the 2019-2020 school year were followed until September 1, 2021. Absolute differences in coverage and 95% CIs were calculated using coverage for the pre-pandemic (2017-2018) cohort at July 31, 2018 (which represented coverage at the end of a 'typical' school year) and coverage for the 2019-2020 cohort at September 1, 2021 for each vaccine. Differences were compared using Pearson's chi-square tests. Coverage for HPV and MenC-ACYW for the 2019-2020 cohort over the follow-up period was also stratified and presented by zone and authority type. This analysis excluded any individual from the 2019-2020 cohort who died or left the province before September 1, 2021. Individuals from the 2020-2021 cohort were not followed due to the short period of time between assessment of coverage for this cohort and the end of the follow-up period (July 31, 2021 and September 1, 2021, respectively). SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used for all analyses.

## Results

For the HPV vaccine, there were 50,127 students in the 2017-2018 cohort, 51,760 in the 2019-2020 cohort, and 52,770 in the 2020-2021 cohort, for a total of 154,657 students.

For the MenC-ACYW vaccine, there were 42,442 students in the 2017-2018 cohort, 45,376 in the 2019-2020 cohort, and 46,945 in the 2020-2021 cohort, for a total of 134,763 students. Table 5 describes the sociodemographic characteristics of each cohort.

**Table 5.** Sociodemographic characteristics of the Albertan student cohorts.

| | **HPV cohorts (grades 5 & 6)[a]** | | | **MenC-ACYW cohorts (grade 9)** | | |
|---|---|---|---|---|---|---|
| | **Pre-pandemic** | **Pandemic** | | **Pre-pandemic** | **Pandemic** | |
| **Characteristic** | ***2017-2018*** | ***2019-2020*** | ***2020-2021*** | ***2017-2018*** | ***2019-2020*** | ***2020-2021*** |
| ***N*** | 50,127 | 51,760 | 52,770 | 42,442 | 45,376 | 46,945 |
| **Age, mean (SD)** | 9.70 (0.50) | 10.70 (0.49) | 10.70 (0.49) | 13.69 (0.46) | 13.68 (0.46) | 13.67 (0.47) |
| **Gender, *n* (%)** | | | | | | |
| **Female** | 24,463 (48.80) | 25,215 (48.71) | 25,624 (48.55) | 20,858 (49.14) | 22,196 (48.91) | 22,880 (48.74) |
| **Male** | 25,662 (51.19) | 26,536 (51.27) | 27,122 (51.40) | 21,581 (50.85) | 23,163 (51.05) | 23,996 (51.11) |
| **Other** | 2 (0.01) | 9 (0.02) | 24 (0.05) | 3 (0.01) | 17 (0.04) | 69 (0.15) |
| **School zone, *n* (%)** | | | | | | |
| **Calgary** | 19,734 (39.37) | 20,629 (39.86) | 21,270 (40.31) | 16,899 (39.82) | 17,920 (39.49) | 19,176 (40.85) |
| **Edmonton** | 16,020 (31.96) | 16,665 (32.20) | 17,136 (32.47) | 13,471 (31.74) | 14,697 (32.39) | 15,312 (32.62) |
| **Central** | 5,204 (10.38) | 5,172 (9.99) | 5,220 (9.89) | 4,529 (10.67) | 4,642 (10.23) | 4,677 (9.96) |
| **North** | 5,086 (10.15) | 5,249 (10.14) | 5,233 (9.92) | 4,407 (10.38) | 4,685 (10.32) | 4,624 (9.85) |
| **South** | 3,678 (7.34) | 3,641 (7.03) | 3,772 (7.15) | 2,809 (6.62) | 3,068 (6.76) | 3,007 (6.41) |
| **Missing** | 405 (0.81) | 404 (0.78) | 139 (0.26) | 327 (0.77) | 364 (0.80) | 149 (0.32) |
| **School authority type, *n* (%)** | | | | | | |
| **Public** | 34,175 (68.18) | 35,176 (67.96) | 35,388 (67.06) | 28,873 (68.03) | 31,074 (68.48) | 31,874 (67.90) |
| **Catholic** | 12,050 | 12,632 | 12,936 | 10,814 | 11,400 | 11,908 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (24.04) | (24.40) | (24.51) | (25.48) | (25.12) | (25.37) |
| **Private** | 2,253 | 2,309 | 2,750 | 1,611 | 1,727 | 1,863 |
| | (4.49) | (4.46) | (5.21) | (3.80) | (3.81) | (3.97) |
| **Charter** | 982 | 978 | 988 | 828 | 812 | 842 |
| | (1.96) | (1.89) | (1.87) | (1.95) | (1.79) | (1.79) |
| **Francophone** | 650 | 665 | 708 | 315 | 363 | 458 |
| | (1.30) | (1.28) | (1.34) | (0.74) | (0.80) | (0.98) |

*Notes.* HPV = human papillomavirus; MenC-ACYW = meningococcal A, C, Y, W-135; SD = standard deviation.
[a]Starting in the 2018-2019 school year, there was a change in delivery for HPV vaccine from three doses given in grade 5 to two doses in grade 6, so there was no school program for HPV in the 2018-2019 school year. As such, the 2017-2018 school year was used as the pre-pandemic comparison year.

## HPV coverage

Full coverage (i.e., two or more doses in 2019-2020 and 2020-2021, three or more doses in 2017-2018) for the HPV vaccine on July 31 of each respective school year was 66.4% in the 2017-2018 pre-pandemic cohort, 5.6% in the 2019-2020 pandemic cohort, and 6.6% in the 2020-2021 pandemic cohort (Figure 4). In comparison to 2017-2018, coverage for HPV was significantly lower in 2019-2020 (5.6% vs. 66.4%; absolute difference: 60.8%; 95% CI: 60.4-61.3%; $p < 0.001$) and 2020-2021 (6.6% vs. 66.4%; absolute difference: 59.9%; 95% CI: 59.4-60.3%; $p < 0.001$) cohorts.

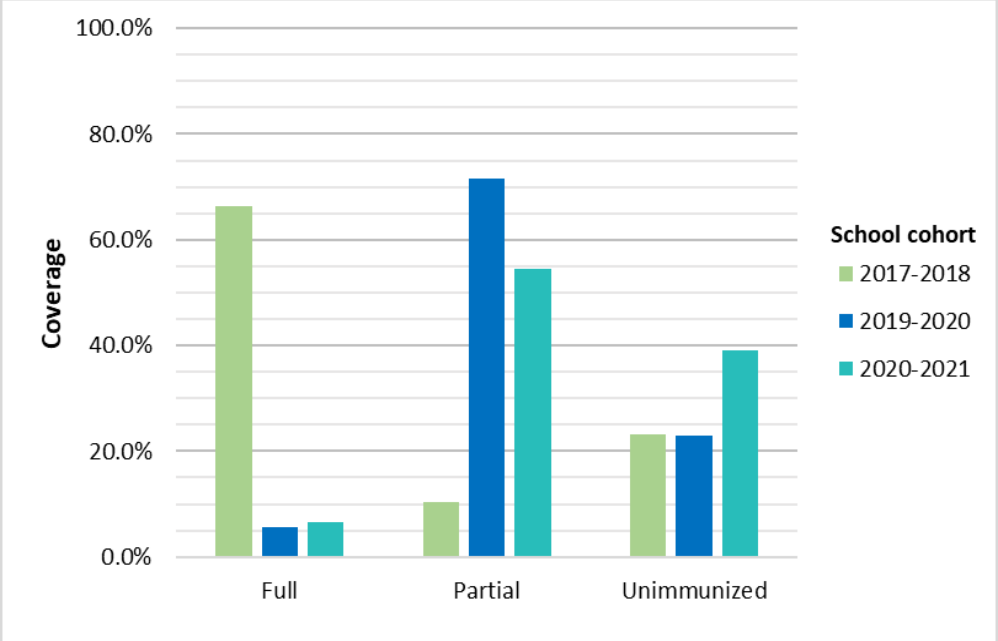


**Figure 4.** Coverage (full[a], partial[b], or unimmunized) for HPV vaccine in the pre-pandemic (2017-2018) and pandemic (2019-2020, 2020-2021) school cohorts at July 31 of each respective school year.

*Notes.* HPV = human papillomavirus.

The HPV school immunization program in Alberta changed from a three-dose schedule given in grade 5 to a two-dose schedule given in grade 6 in the 2018-2019 school year. As such, no immunization data were available for the 2018-2019 school year, so 2017-2018 was used as the pre-pandemic comparison year.

[a]Full coverage defined as the percentage of children who received all scheduled doses of HPV vaccine by July 31 of each respective school year (i.e., at least two doses for the 2019-2020 and 2020-2021 cohorts, at least three doses for the 2017-2018 cohort).

[b]Partial coverage defined as the percentage of children who received some but not all scheduled doses of HPV by July 31 of each respective school year (i.e., one dose for the 2019-2020 and 2020-2021 cohorts, one or two doses for the 2017-2018 cohort).

During the pandemic, HPV immunization coverage at July 31 of each respective school year differed by school zone and school type (Table 6). Across school zones, coverage ranged from 1.1% (Edmonton) to 24.7% (Central) in the 2019-2020 cohort and 0.3% (South) and 11.9% (Edmonton) in the 2020-2021 cohort. When analyzed by school type, public schools had the highest HPV coverage in both pandemic cohorts (6.6% and 7.4%), while charter and private schools had the lowest coverage in 2019-2020 and 2020-2021, respectively.

**Table 6.** Immunization coverage for HPV and MenC-ACYW vaccines in the 2019-2020 and 2020-2021 cohorts by school zone and school authority type.

| | **HPV (grade 6)** | | | | **MenC-ACYW (grade 9)** | | | |
|---|---|---|---|---|---|---|---|---|
| **School year** | **2019-2020** | | **2020-2021** | | **2019-2020** | | **2020-2021** | |
| | **Coverage (%)** | **RR (95% CI)** | **Coverage (%)** | **RR (95% CI)** | **Coverage (%)** | **RR (95% CI)** | **Coverage (%)** | **RR (95% CI)** |
| **School zone** | | | | | | | | |
| Calgary | 4.87 | ref | 1.50 | ref | 83.06 | ref | 62.83 | ref |
| Edmonton | 1.08 | **0.22 (0.19, 0.26)** | 11.93 | **7.96 (7.09, 8.94)** | 81.06 | 0.99 (0.98, 1.00) | 51.92 | **0.83 (0.82, 0.85)** |
| Central | 24.73 | **5.10 (4.72, 5.50)** | 11.61 | **7.74 (6.79, 8.83)** | 78.31 | **0.96 (0.94, 0.97)** | 64.04 | 1.02 (1.00, 1.05) |
| North | 5.35 | 1.10 (0.97, 1.26) | 9.25 | **6.17 (5.37, 7.08)** | 79.42 | **0.97 (0.96, 0.99)** | 52.70 | **0.84 (0.82, 0.87)** |
| South | 3.98 | **0.82** | 0.29 | **0.19** | 78.65 | **0.96** | 5.79 | **0.09** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **(0.69, 0.97)** | | **(0.11, 0.35)** | | **(0.94, 0.98)** | | **(0.08, 0.11)** |
| **School authority type** | | | | | | | | |
| Public | 6.56 | ref | 7.38 | ref | 80.85 | ref | 54.48 | ref |
| Catholic | 4.20 | **0.64 (0.58, 0.70)** | 6.10 | **0.83 (0.76, 0.89)** | 83.56 | **1.03 (1.02, 1.04)** | 57.24 | **1.05 (1.03, 1.07)** |
| Private | 1.73 | **0.26 (0.19, 0.36)** | 0.80 | **0.11 (0.07, 0.16)** | 54.78 | **0.68 (0.65, 0.71)** | 39.99 | **0.73 (0.69, 0.78)** |
| Charter | 0.31 | **0.05 (0.02, 0.15)** | 1.42 | **0.19 (0.11, 0.32)** | 90.02 | **1.11 (1.09, 1.14)** | 54.99 | 1.01 (0.95, 1.07) |
| Francophone | 3.61 | **0.55 (0.37, 0.82)** | 4.10 | **0.55 (0.39, 0.79)** | 82.37 | 1.02 (0.97, 1.07) | 53.93 | 0.99 (0.91, 1.08) |

*Notes.* CI = confidence interval; HPV = human papillomavirus; MenC-ACYW = meningococcal A, C, Y, W-135; ref = reference category; RR = relative risk.
Coverage values calculated as the percentage of children fully vaccinated (i.e., received at least two doses of HPV or one dose of MenC-ACYW by July 31 of each respective school year.
Bolded indicates significant difference from reference category.

*Cumulative coverage*

After removing those who died or left the province before the end of the follow-up period (September 1, 2021), the total number of children from the 2019-2020 cohort included in the cumulative coverage analysis was 51,494. As shown in Figure 5, HPV full coverage in the 2019-2020 cohort improved over the approximately one-year follow-up period, from 5.6% on July 31, 2020 to 50.2% on September 1, 2021. However, in comparison to the 2017-2018 pre-pandemic cohort, HPV coverage remained significantly lower in the 2019-2020 pandemic cohort even after the one-year follow-up (50.2% vs. 66.4%; absolute difference: 16.2%; 95% CI: 15.6-16.8%; $p < 0.001$).

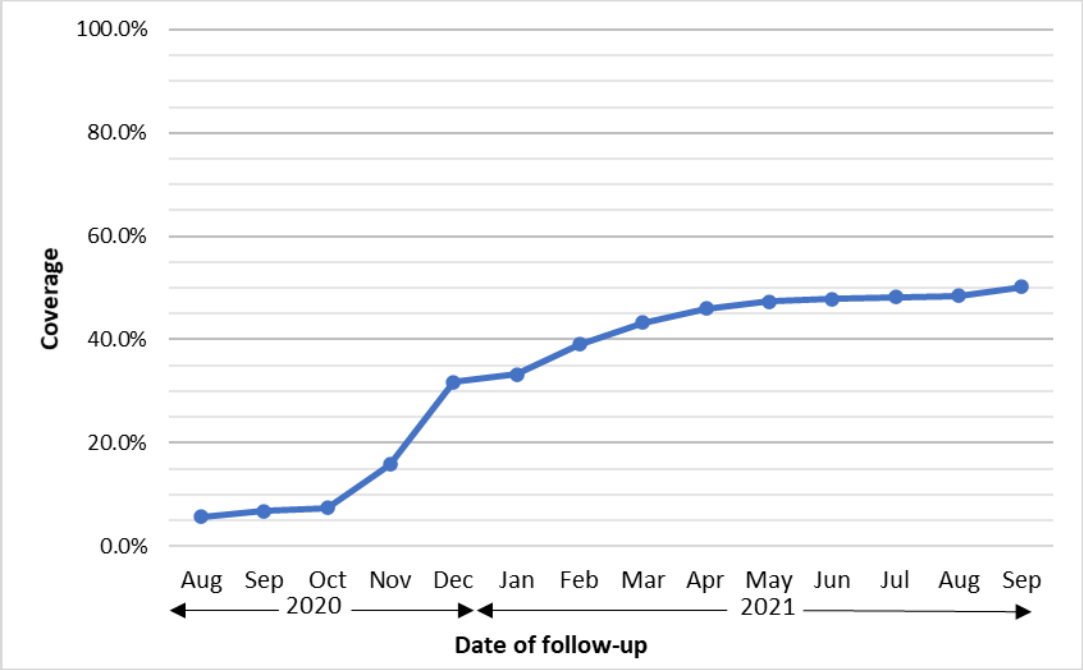



**Figure 5.** Cumulative coverage graph displaying HPV full coverage[a] for grade 6 children from the 2019-2020 school cohort during the follow-up period (July 31, 2020 to September 1, 2021).
*Notes.* HPV = human papillomavirus.
[a]Full coverage defined as the percentage of children who received all scheduled doses of HPV vaccine by the follow-up date (i.e., at least two doses).

When stratified by school zone (Figure 6a), Central zone had the highest HPV coverage at the beginning of the follow-up period, but by December 2020 Calgary had surpassed Central zone and had the highest coverage until the end of follow-up. Most zones, other than South zone, had a sharp increase in coverage around October-December 2020, and steady increases in coverage throughout 2021. South zone did not display a large increase in coverage until the end of the follow-up period, but still had the lowest coverage.

Based on school authority type (Figure 6b), all of the school types had similar coverage for HPV throughout follow-up, except for private schools which had the lowest coverage from November 2020 to the end of follow-up. All school types exhibited a sharp increase in coverage around October-December 2020 and had steady increases in coverage throughout 2021. Francophone and charter schools had the highest HPV coverage at the end of follow-up.

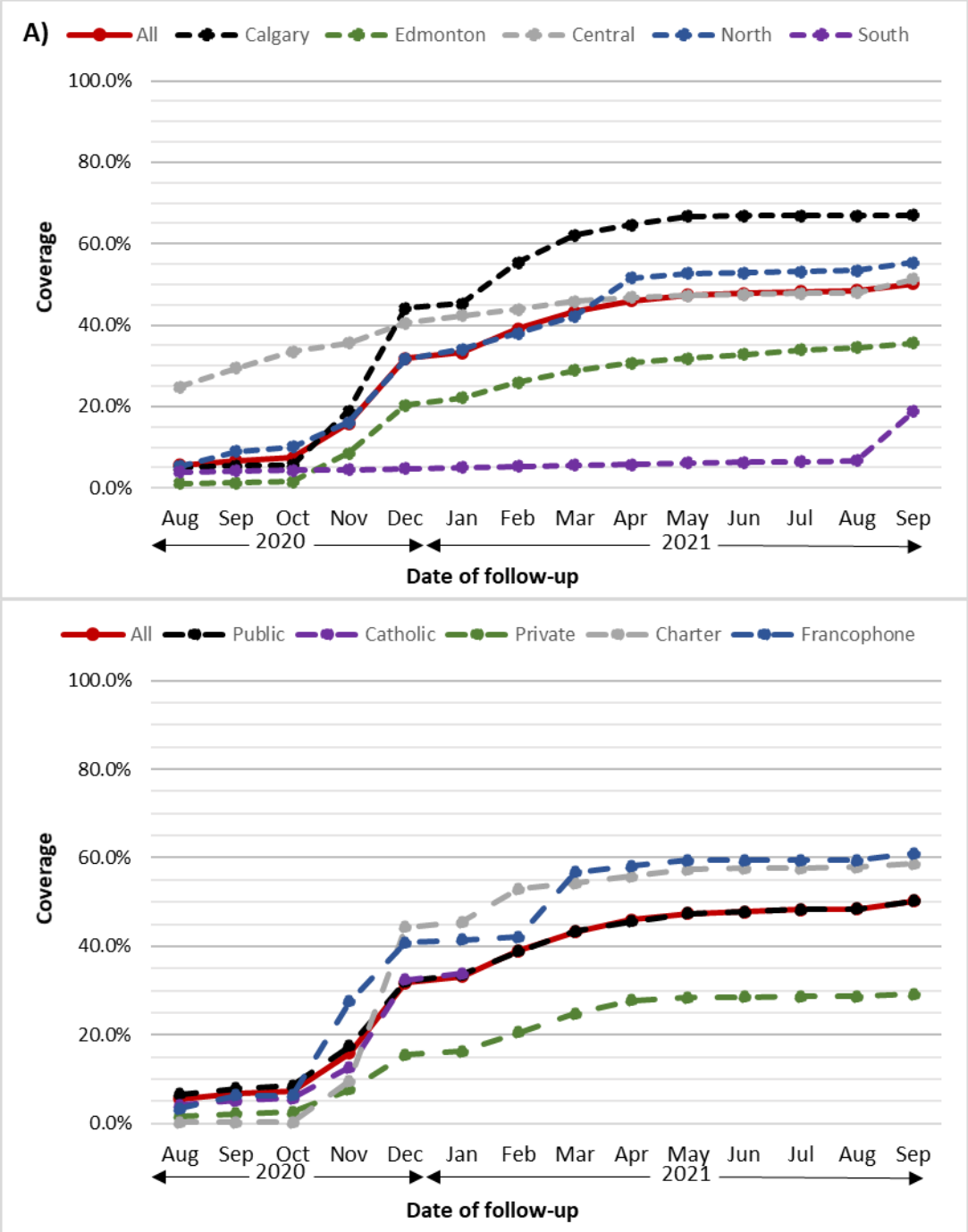



**Figure 6.** Cumulative coverage graph displaying HPV full coverage[a] for grade 6 children from the 2019-2020 school cohort during the follow-up period (July 31, 2020 to September 1, 2021) stratified by school a) zone (top) b) authority type (bottom).

*Notes.* HPV = human papillomavirus.

[a]Full coverage defined as the percentage of children who received all scheduled doses of HPV vaccine by the follow-up date (i.e., at least two doses).

**MenC-ACYW coverage**

Full coverage (i.e., at least one dose) for the MenC-ACYW vaccine on July 31 of each respective school year was 86.8% in the 2017-2018 cohort, 80.7% in the 2019-2020 cohort, and 54.6% in the 2020-2021 cohort (Figure 7). In comparison to the 2017-2018 pre-pandemic cohort, coverage for MenC-ACYW was significantly lower in the 2019-2020 pandemic cohort (80.7% vs. 86.8%; absolute difference: 6.1%; 95% CI: 5.6-6.5%; $p < 0.001$) and the 2020-2021 pandemic cohort (54.6% vs. 86.8%; absolute difference: 32.2%; 95% CI: 31.6-32.7%; $p < 0.001$).

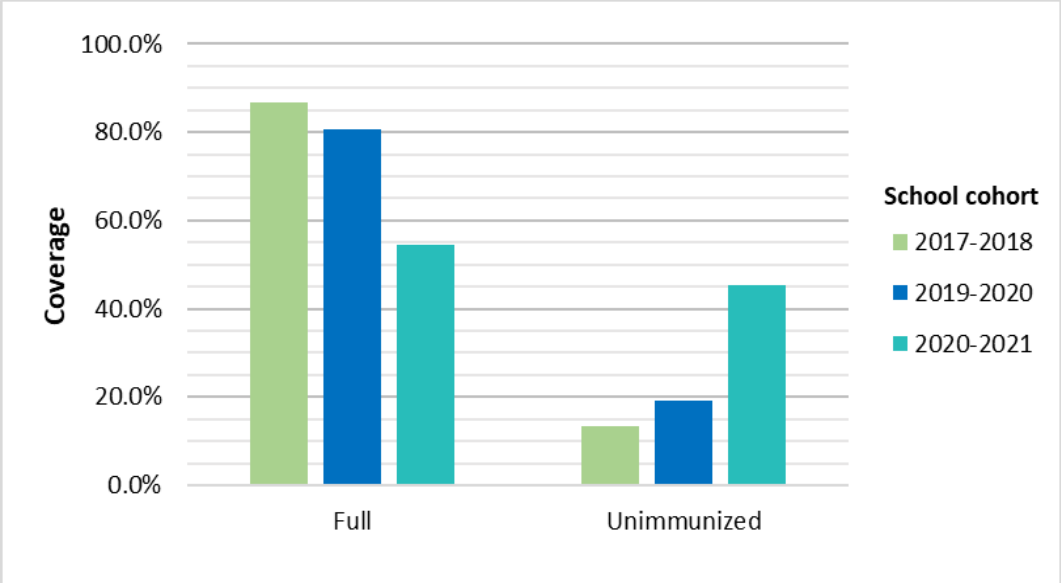



**Figure 7.** Coverage (full[a], unimmunized) in the pre-pandemic (2017-2018) and pandemic (2019-2020, 2020-2021) school cohorts at July 31 of each respective school year for the MenC-ACYW vaccine.

*Notes.* MenC-ACYW = meningococcal A, C, Y, W-135.

The HPV school immunization program in Alberta changed from a three-dose schedule given in grade 5 to a two-dose schedule given in grade 6 in the 2018-2019 school year. As no immunization data were available during the 2018-2019 school year for HPV vaccine, 2017-2018 was also used as the pre-pandemic comparison year for MenC-ACYW vaccine to be consistent across both vaccines.

[a]Fully immunized defined as the percentage of children who received all scheduled doses of MenC-ACYW vaccine by July 31 of each respective school year (i.e., at least one dose).

MenC-ACYW coverage also differed by school zone and school type, but slightly less than for HPV (Table 6). Across school zones, coverage ranged from 78.3% (Central) to 83.1% (Calgary) in 2019-2020 and 5.8% (South) to 64.0% (Central) in 2020-2021. When analyzed by

school type, coverage was significantly lower in private schools in both the 2019-2020 and 2020-2021 school years (54.8% and 40.0%), and highest in charter schools in 2019-2020 (90.0%) and publicly-funded Catholic schools in 2020-2021 (57.2%).

*Cumulative coverage*

After removing those who died or left the province before the end of the follow-up period (September 1, 2021), the total number of children from the 2019-2020 cohort included in the cumulative coverage analysis was 45,183. As shown in Figure 8, MenC-ACYW vaccine coverage in the 2019-2020 cohort slightly improved over the approximately one-year follow-up period, from 80.7% on July 31, 2020 to 83.0% on September 1, 2021. However, in comparison to the 2017-2018 pre-pandemic cohort, MenC-ACYW coverage remained significantly lower in the 2019-2020 pandemic cohort even after the one-year follow-up (83.0% vs. 86.8%; absolute difference: 3.7%; 95% CI: 3.3-4.2%; $p < 0.001$).

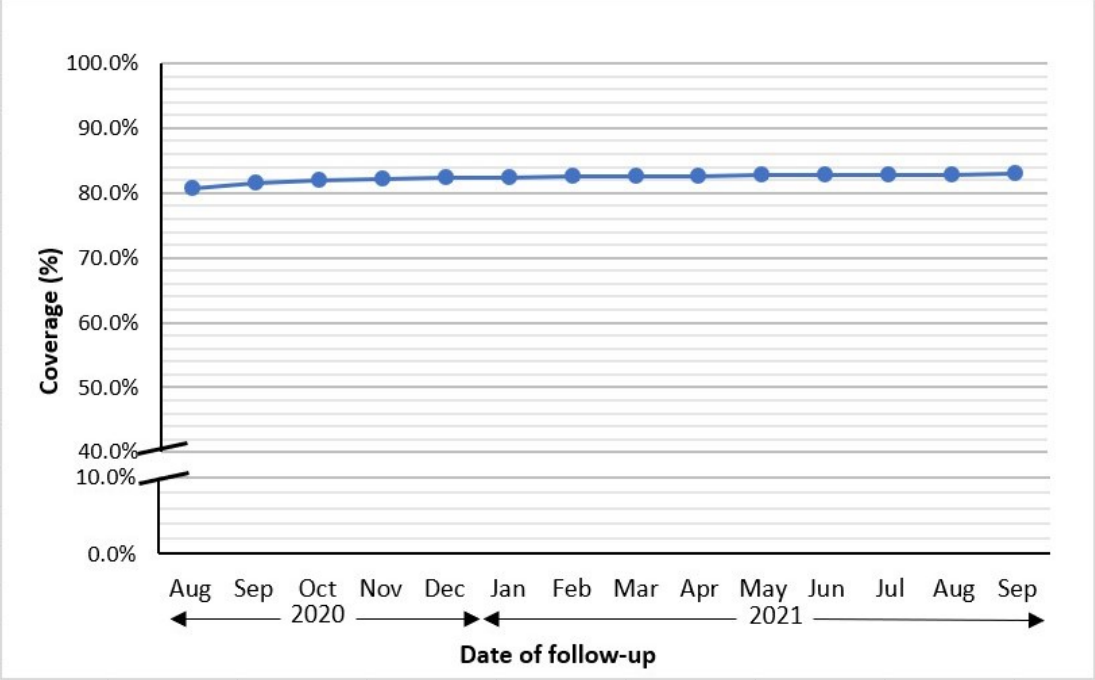
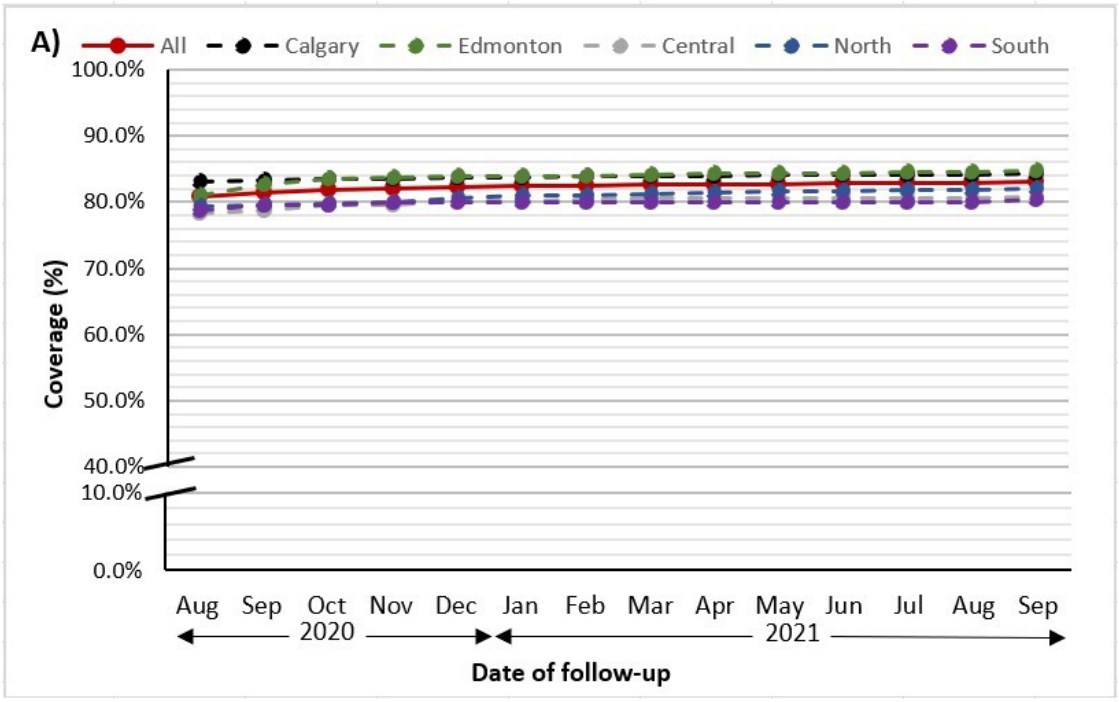


**Figure 8.** Cumulative coverage graph displaying MenC-ACYW full coverage[a] for grade 9 children from the 2019-2020 school cohort during the follow-up period (July 31, 2020 to September 1, 2021).
*Notes.* MenC-ACYW = meningococcal A, C, Y, W-135.
[a]Full coverage defined as the percentage of children who received all scheduled doses of MenC-ACYW vaccine by the follow-up date (i.e., at least one dose).

When stratified by school zone (Figure 9a), all zones had steady MenC-ACYW coverage throughout the follow-up period, with Calgary having slightly higher coverage at the beginning of follow-up, and Edmonton having highest coverage at the end of follow-up.

Based on school authority type (Figure 9b), private schools had the lowest coverage for MenC-ACYW throughout the entire follow-up period, while charter schools had the highest. Public, publicly-funded Catholic, and francophone schools had similar coverage during follow-up. Coverage was steady for all school types throughout the follow-up period.



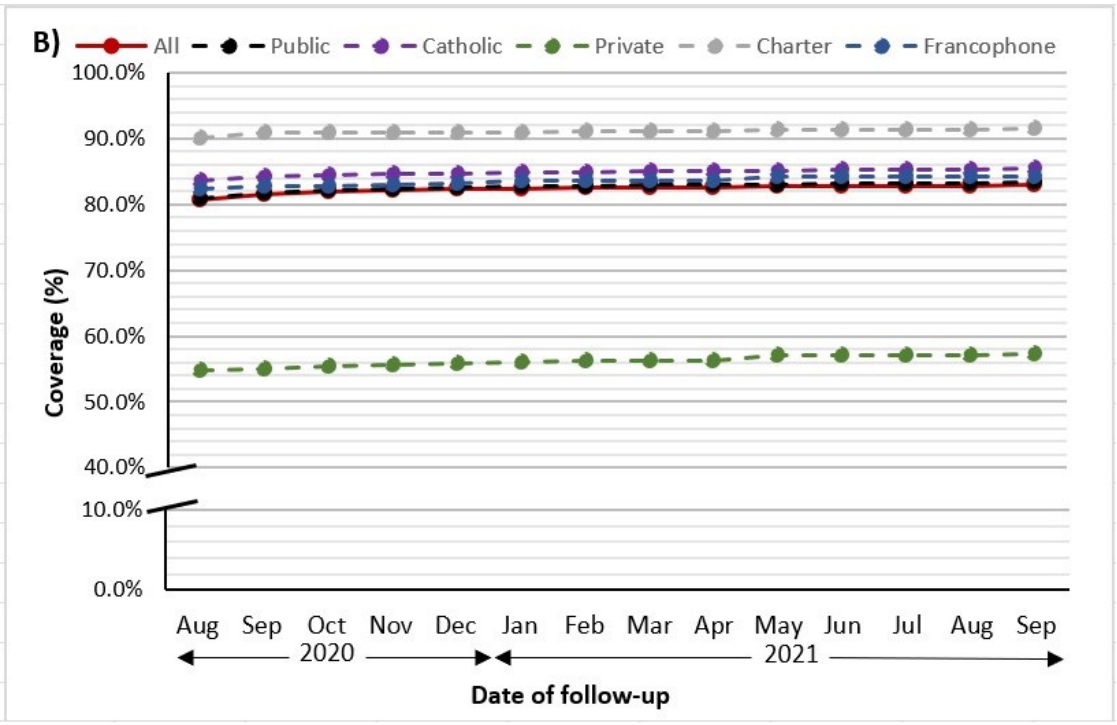



**Figure 9.** Cumulative coverage graph displaying MenC-ACYW full coverage[a] for grade 9 children from the 2019-2020 school cohort during the follow-up period (July 31, 2020 to September 1, 2021) stratified by school a) zone (top) b) authority type (bottom).
*Notes.* MenC-ACYW = meningococcal A, C, Y, W-135.
[a]Full coverage defined as the percentage of children who received all scheduled doses of MenC-ACYW vaccine by the follow-up date (i.e., at least one dose).

## Discussion

### Summary of findings

The COVID-19 pandemic has significantly impacted health care systems worldwide, including routine immunization programs. We found that HPV and MenC-ACYW immunization coverage was significantly lower in cohorts of schoolchildren who were eligible for immunization during the pandemic in comparison to before the pandemic. This decline in coverage seen during the pandemic is consistent with previous literature on other routine immunizations internationally, including infant (Bramer et al., 2020; DeSilva et al., 2022; McDonald et al., 2020), preschool (Bramer et al., 2020; DeSilva et al., 2022), and adolescent (DeSilva et al., 2022; Murthy et al., 2021; O'Leary et al., 2021; Saxena et al., 2021). Declines are

likely explained by factors such as school closures across Canada during the pandemic (Piché-Renaud et al., 2021; Sell et al., 2021) and re-allocation of public health staff to COVID-19-related activities (Sell et al., 2021), which meant that public health nurses were unable to deliver immunizations to children at school.

Coverage for HPV was below that of MenC-ACYW. This finding is likely explained by the fact that MenC-ACYW is a single-dose vaccine so it may have been easier to complete this series before the COVID-19-related school closures, whereas the HPV series requires two doses, six months apart. Many students in both pandemic cohorts had received a single dose of HPV by the end of the school year (71.5% in 2019-2020 and 54.5% in 2020-2021), therefore additional follow-up efforts are needed to ensure that these partially immunized children complete the series to maximize protection against HPV.

Coverage also differed by school zone. Specifically, South zone had low coverage for both vaccines in the 2020-2021 school year, and the lowest HPV coverage in the 2019-2020 cohort at the end of follow-up, while Edmonton had lower HPV coverage in the 2019-2020 cohort at the end of follow-up than the other large urban zone, Calgary. Discrepancies in coverage across school zones likely reflects the epidemiology of COVID-19 in each region and the available resources to provide immunizations to schoolchildren. An AHS news report from July 2021 showed that school immunizations were delayed in South zone due to the COVID-19 pandemic response, and would resume at the end of July 2021, which may explain the lower coverage in this zone (Alberta Health Services, 2021e). Personal communication with public health officials from Edmonton zone revealed that school immunization teams were redeployed from March 2020 to August 2020 for COVID-19 testing and returned to immunization work from January 2021 to August 2021 and again in January 2022. Additionally, grade 9 MenC-

ACYW immunizations were prioritized to try catch-up students before they entered high school, which may explain the lower HPV coverage in this zone. On the other hand, Central zone had higher HPV coverage (24.7%) than all other zones at the end of the 2019-2020 school year. In speaking with public health officials from this zone, we found that additional immunization clinics were held at community health centres throughout June-August 2020 to catch-up students with missed doses, particularly in smaller rural sites that were not overwhelmed by COVID-19 testing.

Similarly, private schools had low coverage for all vaccines in both school years in comparison to the other school types. Previous literature from Canada and the U.S. has found that private schools have lower immunization coverage even prior to the pandemic (Carpiano & Bettinger, 2016; Lai et al., 2014). The differing coverage across school zones and types has important implications for catch-up planning and implementation. Stratifying coverage by school zone and type may be useful for identifying where to focus catch-up immunization programs.

The cumulative coverage analysis found that coverage for both HPV and MenC-ACYW improved over a one-year period in individuals from the 2019-2020 cohort who missed immunizations in the first year of the pandemic, although the improvement was not as large for MenC-ACYW. For HPV, sharp increases in coverage were seen throughout October-December 2020, suggesting the implementation of fall catch-up programs. Although this is an encouraging finding, coverage still remained below pre-pandemic levels at the end of follow-up, necessitating further catch-up for this group. The 2020-2021 cohort had low coverage for both HPV and MenC-ACYW vaccines on July 31, 2021, meaning that catch-up for this group is urgently needed.

**Strengths and limitations**

To our knowledge, this study is one of the first to assess school-based immunization program coverage during the COVID-19 pandemic in Canada. A strength of our study was the use of a population-based registry that contains complete and timely information on all childhood immunizations, as well as complete denominator data. Data were included over a one-year period to determine whether coverage was recovering to pre-pandemic levels, which was previously unknown.

A limitation is that there was a change in programming for the HPV vaccine during the 2018-2019 school year, moving from three doses in grade 5 to two doses in grade 6. As there were no HPV immunizations provided in this school year, we could not use this year for comparison. Furthermore, this meant that our definition of fully vaccinated was three or more doses for the 2017-2018 cohort, but two or more doses for the 2019-2020 and 2020-2021 cohorts. However, the percentage of individuals with two or more doses of HPV vaccine in the 2017-2018 cohort was 74.3%, so our difference in coverage estimates based on three dose coverage are conservative and with the same direction of effect (i.e., coverage is significantly lower in the pandemic cohorts in comparison to the pre-pandemic cohort). Additionally, as this study focused on immunization coverage for Albertan schoolchildren, findings may not be generalizable to other jurisdictions. Finally, as this is a descriptive analysis, we cannot be certain whether the differences in coverage seen across zones and school type can be attributed to individual, school, or zone-level factors. Further analyses are needed to understand the relationship between these factors and immunization coverage during the COVID-19 pandemic.

**Implications and future directions**

This study provides valuable information for policymakers and program planners regarding the state of school-based immunization coverage in Alberta but may also apply to other jurisdictions where school immunization programs have been disrupted by the COVID-19 pandemic.

Routine childhood immunizations are important to prevent outbreaks of VPDs, which have occurred in Alberta within the past decade. In 2013, 42 cases of measles were identified among an unimmunized population (Kershaw et al., 2014). Additionally, individuals who miss immunizations at the scheduled time may be less likely to catch-up later (National Advisory Committee on Immunization, 2020). Although our findings show that some catch-up has occurred, additional efforts will be needed to ensure children are fully protected against VPDs. This will require a multi-pronged approach, utilizing existing strategies such as holding additional catch-up clinics at public health centres or schools, as well as possible new strategies including providing missing routine vaccine doses at other vaccine appointments (e.g., COVID-19, influenza) (Centers for Disease Control and Prevention, 2022; National Advisory Committee on Immunization, 2021) or any contact with the health system (e.g., visits at primary care practices, pharmacies, or hospitals) (MacDonald et al., 2020).

This was a preliminary analysis of coverage for school-based immunizations. Further analyses could be conducted with additional data using multivariable or multilevel regression modelling to determine factors at the individual (e.g., parental employment status, ethnicity, income) and school (e.g., zone, authority type) levels that are associated with routine immunization status during the pandemic. This may be useful in determining populations of focus for immunization catch-up planning and programming.

## Conclusion

Coverage analyses showed that coverage for HPV and MenC-ACYW vaccines in cohorts of schoolchildren eligible for immunization during the COVID-19 pandemic declined in comparison to pre-pandemic. Coverage also differed by school zone and type. Cumulative coverage analyses of the 2019-2020 cohort showed that coverage for both school-based vaccines during the pandemic increased over time but has not yet returned to pre-pandemic levels. Additional catch-up is needed to protect Canadian schoolchildren from VPDs. To date, the 2020-2021 cohort had the lowest immunization coverage, suggesting that this group may be a priority for catch-up programs.

# Appendix B

**Table B1**. Number and timing of doses for school-based vaccines in Alberta, Canada.

| Vaccine | Number and timing of doses | Minimum interval between doses |
|---|---|---|
| Hepatitis B | 2019-2020 school year and beyond:<br>2 doses in Grade 6 | Minimum interval between doses 1 & 2: 6 months |
| | 2017-2018 school year and prior:<br>3 doses in Grade 5 | 2nd dose: 1 month after dose 1<br>3rd dose: 6 months after dose 1 |
| Human papillomavirus (HPV) | 2018-2019 school year and beyond:<br>2 doses in Grade 6<br>(3 doses if first dose is at age 15 years or older) | Minimum age dose 1: 9 years<br>Minimum interval between doses 1 & 2: 6 months |
| | 2017-2018 school year and prior:<br>3 doses in Grade 5 | Minimum age dose 1: 9 years<br>2nd dose: 2 months after dose 1<br>3rd dose: 4 months after dose 1 |
| Diptheria-tetanus-acellular pertussis (dTap) | 1 dose in Grade 9 | Minimum age: 12 years<br>Minimum interval: N/A |
| Meningococcal Conjugate A, C, Y, W-135 (MenC-ACYW) | 1 dose in Grade 9 | Minimum age: 12 years<br>Minimum interval: N/A |

*Notes.* dTap: diphtheria-tetanus-acellular pertussis; HPV: human papillomavirus; MenC-ACYW: meningococcal conjugate A, C, Y, W-135; N/A: Not Applicable.
Source: (Alberta Government, 2021b)

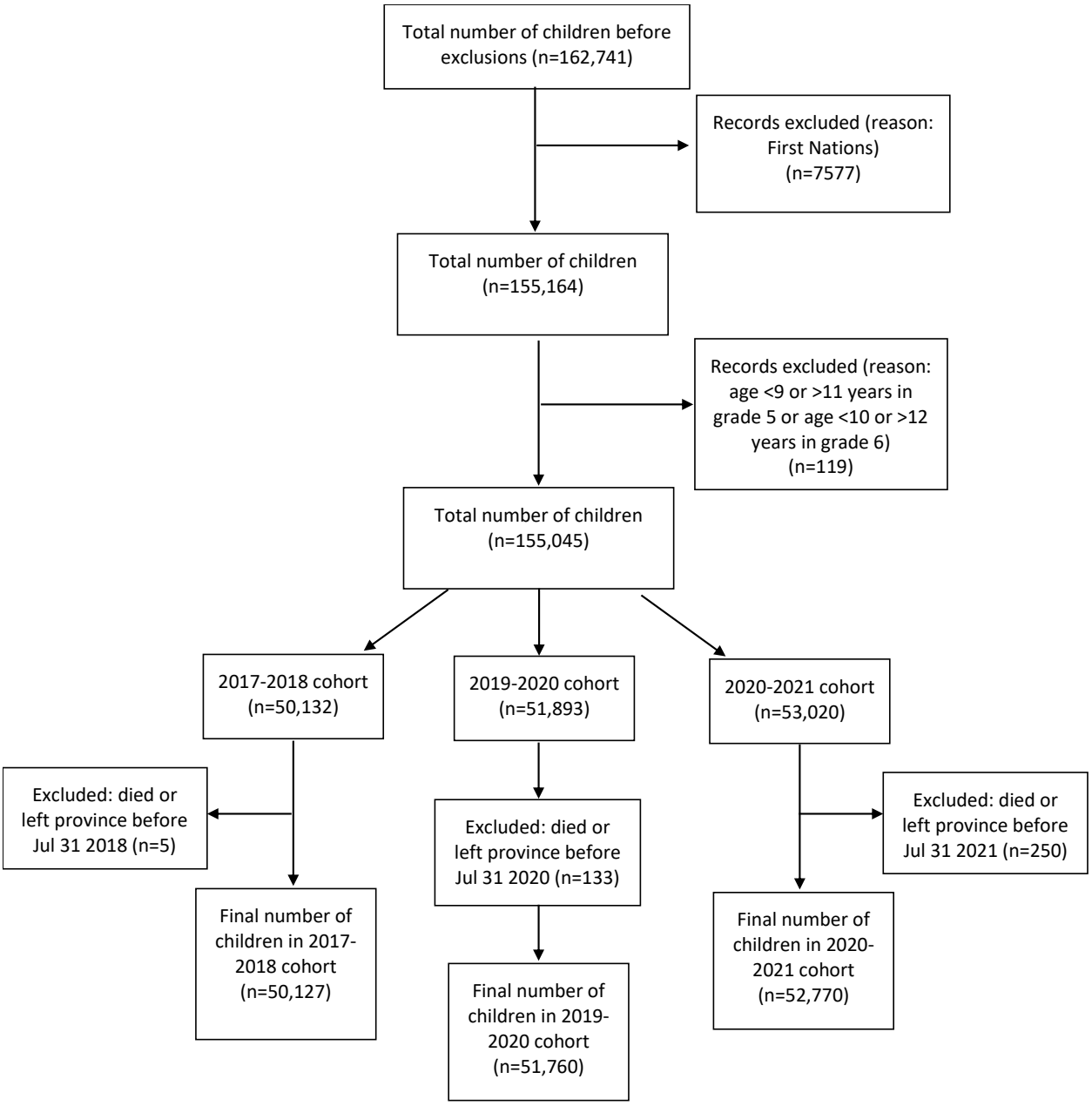



**Figure B1.** Flowchart of exclusion criteria for the HPV immunization cohorts for the 2017-2018, 2019-2020, and 2020-2021 school years.

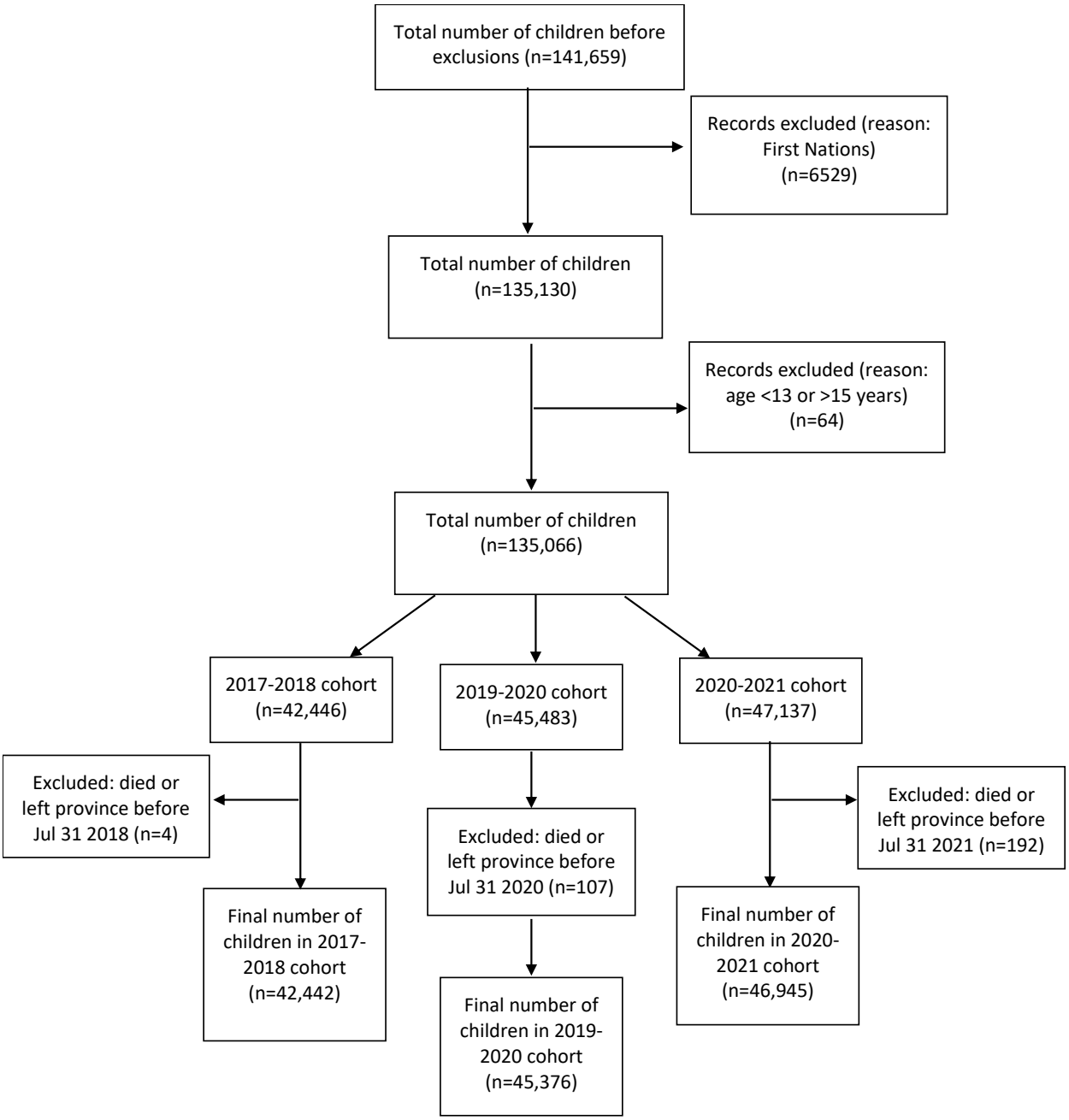



**Figure B2.** Flowchart of exclusion criteria for MenC-ACYW immunization cohorts for the 2017-2018, 2019-2020, and 2020-2021 school years.

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# Chapter Four: Discussion and Conclusion

## Overview of findings

The overall objective of this thesis was to examine the impact of the COVID-19 pandemic on routine immunization programs across Canada and assess the impact of the pandemic on school-based immunization coverage in Alberta.

The environmental scan study presented in Chapter 2, which involved interviews with public health leaders from across Canada, aimed to synthesize information about the actions that have been taken to maintain routine immunizations during the pandemic, including changes to immunization programs and plans to catch-up any missed immunizations. This study found that routine immunization programs were suspended during the initial lockdown period (March-April 2020) but eventually resumed with adaptations for COVID-19 restrictions. In this study, P/Ts reported many challenges in continuing routine immunization programs during the pandemic, including resource shortages (e.g., staff, PPE, infrastructure), public health restrictions (e.g., increased infection control measures, school and clinic closures), and public hesitancy to attend health appointments due to COVID-19. Following NACI guidelines (National Advisory Committee on Immunization, 2020), most P/Ts prioritized infant and preschool appointments and did not implement active catch-up for adult and older adult immunizations missed early in the pandemic. Notably, school immunization programs were identified as most impacted by the pandemic, as due to school closures, public health nurses were unable to provide immunizations to children at school in the spring of 2020. As such, all P/Ts except one reported holding summer catch-up clinics to reach students who had missed their school-based immunizations, and all had plans for fall catch-up programs. However, at this point in time, the impact of the pandemic on

immunization coverage and to what extent the catch-up programs improved coverage was unclear.

As such, the retrospective cohort study presented in Chapter 3 aimed to assess the impact of the COVID-19 pandemic on school-based immunization coverage in Alberta, including whether coverage has returned to pre-pandemic levels, and whether it differed by provincial zone or school type. This study found that coverage for both HPV and MenC-ACYW vaccines was lower in the two pandemic school cohorts (2019-2020 and 2020-2021 school years) in comparison to the pandemic cohort (2017-2018 school year). After more than a year of follow-up (July 31, 2020 to September 1, 2021), coverage remained below pre-pandemic levels in the 2019-2020 school cohort. These findings are consistent with studies of other routine childhood immunizations during the pandemic, such as infant (Ackerson et al., 2021; Bramer et al., 2020; MacDonald et al., 2022; Middeldorp et al., 2021; Murthy et al., 2021), preschool (Ackerson et al., 2021; Murthy et al., 2021), and adolescent (Ackerson et al., 2021; Murthy et al., 2021), which have found that routine immunization coverage declined during the pandemic and remained below pre-pandemic coverage. However, the remaining differences in immunization coverage for older children as reported in this study and others (Ackerson et al., 2021; MacDonald et al., 2022; Middeldorp et al., 2021) differs from what has been reported for infants. For example, Middeldorp et al. (2021) found that MMR coverage was only 1-2% below prior years for each monthly birth cohort after a follow-up period >1 year. In Alberta, the difference in coverage after one year of follow-up for the MMR/MMRV vaccine was 5% for cohorts due for immunization in March and April 2020 compared to 2019, and only 1-2% for pertussis-containing (i.e., DTaP-IPV-Hib-HB, DTaP-IPV-Hib) and rotavirus vaccines (MacDonald et al., 2022). In contrast, in this study, the difference in coverage between the 2019-2020 cohort after

one year of follow-up and the 2017-2018 cohort was 16.2% for HPV and 3.8% for MenC-ACYW. This likely reflects the recommendations by public health bodies to prioritize children <2 years to ensure that they remain up to date on their immunizations (National Advisory Committee on Immunization, 2020; World Health Organization, 2020b). Although the focus on younger children is very important, the observed gap between older and younger children should also be recognized to ensure that older children do not get left behind.

There were some differences in coverage in the two pandemic cohorts. The 2019-2020 school year was only impacted by pandemic-related school closures towards the end of the school year (i.e., March 2020). The study in Chapter 2 revealed that schools were closed in all interviewed P/Ts and as a result school immunization programs were suspended during the initial lockdown period (March-April 2020). Conversely, the pandemic resulted in shifts to online learning (Alberta Government, 2021d) and multiple rounds of school closures throughout the entire 2020-2021 school year (Alberta Government, 2020e, 2021m), which may have resulted in additional disruption to school-based immunizations and lower coverage for both HPV and MenC-ACYW as compared to 2017-2018 and 2019-2020. This suggests that the 2020-2021 cohort is an important population of focus for future catch-up programs. Additional efforts are needed to ensure that this cohort can receive their missed doses.

Furthermore, coverage was different across provincial zones and school authority types. As noted in Chapter 3, this is likely due to the epidemiology of COVID-19 cases in each region, and whether there was capacity for public health nurses to visit schools and provide immunizations or hold catch-up clinics at public health centres or community locations. Indeed, the findings from the study in Chapter 2 revealed that some regions, particularly smaller regions with lower numbers of COVID-19 cases, were able to catch-up missed doses more quickly in

comparison to larger regions with higher numbers of COVID-19 cases, which may partially explain the low coverage for HPV in Edmonton and Calgary at the end of the 2019-2020 school year.

These findings build on a publicly available data report from the Alberta Government, which reported immunization coverage in Alberta for all school vaccines in the 2019-2020 school year using data drawn from the same databases included in this thesis (Alberta Government, 2021f). Specifically, the current study analyzed coverage for the 2020-2021 school cohort, which is not currently available in the Alberta Government data, and also included an assessment of coverage over a one-year follow-up period in the 2019-2020 school cohort. The Alberta Government report estimated grade 6 HPV full coverage in the 2019-2020 school year to be 46.4%, and grade 9 MenC-ACYW full coverage in the same year to be 81.1% (Alberta Government, 2021f). The Alberta Government analysis, done on June 8, 2021, reported coverage as of June 2021 to reflect the catch-up that had occurred since the end of the 2019-2020 school year (July 31, 2020). These estimates are similar to the coverage estimates for HPV (47.8%) and MenC-ACYW (82.8%) measured in this study at June 1, 2021 in the cumulative coverage analysis. The slight differences in the two estimates likely reflect differences in denominator data and the exclusions that were applied to create the school cohorts. However, as the number of children included in the numerator and the denominator and were not publicly available, we were not able to investigate these slight differences more thoroughly.

**Strengths and limitations**

There are various strengths of the studies included in this thesis. First, this thesis presented novel information regarding the state of routine immunization programs during the COVID-19 pandemic. Specifically, the study in Chapter 2 provided a variety of perspectives

from most P/Ts, and comprehensive information regarding routine immunization program changes during the pandemic was collected via the semi-structured interview method used.

However, a limitation of the study in Chapter 2 is that we were not able to obtain perspectives from two P/Ts due to non-response (i.e., New Brunswick and Yukon), and only a few select individuals were interviewed from each P/T, so perspectives may not represent entire P/Ts. We were also unable to determine how successful each P/Ts strategies for continuing routine immunization programs were, as at the time of the study immunization coverage during the pandemic had not yet been assessed in most P/Ts.

The study in Chapter 3 provided an assessment of immunization coverage in Alberta for two school-based vaccines, HPV and MenC-ACYW. To our knowledge, this study is the first to assess school-based immunization program coverage during the COVID-19 pandemic in Canada. The population-based registry used in the study contained complete and timely information on all childhood immunizations given in Alberta during the study time period, as well as complete denominator data. This builds on previous studies that have only looked at vaccine doses administered (Murthy et al., 2021). Another strength was the ability to follow-up one of the pandemic school cohorts over a one-year period to determine whether coverage for HPV and MenC-ACYW recovered to pre-pandemic levels. This extends current knowledge of how coverage has changed over time during the pandemic, as COVID-19 case numbers and public health restrictions fluctuated. This study also provided a breakdown of coverage by school zone and authority type to determine whether there were differences across the province.

Although this study provided some clarity around the state of school-based immunization coverage in Alberta, we did not assess all school-based vaccines (e.g., Tdap, hepatitis B), and we could not make cross-Canadian comparisons as not all P/Ts have publicly available coverage

data for immunizations during the pandemic. Additionally, as this study focused on coverage for Albertan schoolchildren, findings may not be generalizable to other jurisdictions, especially as COVID-19 restrictions varied across Canada and globally. This study also did not include data from First Nations children attending schools on-reserve, as immunization data for this group are not consistently submitted to the Imm/ARI database. Lastly, we were unable to assess all possible individual, school, or community factors that may have contributed to the trends in immunization coverage seen during the pandemic. Untangling the impacts of these factors would require additional data and the use of more complex statistical modelling techniques (e.g., multilevel modelling).

**Future directions**

Future research could consider exploring the impact of the pandemic on coverage for other school-based vaccines, such as Tdap or hepatitis B, or adult immunizations, which were not examined in this thesis. Immunizations for adults and older adults have likely been largely impacted by the pandemic, as noted in the study in Chapter 2, but have been understudied in comparison to childhood immunizations. Furthermore, coverage for routine childhood immunizations should continue to be assessed over time as further catch-up occurs to re-evaluate whether coverage eventually returns to pre-pandemic levels, and to determine if children eligible for immunization later in the pandemic (e.g., during the 2021-2022 school year) are continuing to miss doses, thus necessitating additional catch-up.

Additionally, for future pandemic preparedness, it would be useful to compare each P/T's strategies for continuing routine immunizations with their respective coverage estimates to determine which strategies were the most successful in maintaining routine immunizations

during the pandemic. As this thesis mainly focused on immunization coverage in Alberta, we were unable to make comparisons to other P/Ts. Therefore, this work could be expanded to other jurisdictions to gain insight into the impact of the pandemic on routine immunization coverage across Canada.

As previously noted, assessing individual, school, or community factors using multivariable or multilevel regression modelling may help to further explain variations in routine childhood immunization coverage during the pandemic, subject to data availability (e.g., attending school online vs. in-person, individual or neighbourhood income, rural or urban residence, parental employment status, ethnicity). This type of work may help to further clarify any differences seen in coverage across schools, communities, or jurisdictions during the pandemic.

**Implications for policy and practice**

The findings from this thesis have various implications for public health policy and practice. First, the observation that school immunization coverage continues to remain below pre-pandemic levels is concerning and will need to be addressed to ensure that Albertan children are adequately protected from VPDs, such as HPV and MenC-ACYW. HPV is one of the most common sexually transmitted infections, and it is estimated that 70% of sexually active individuals will be infected with HPV in their lives (Government of Canada, 2020a). Although most infections resolve without treatment, persistent infection with a cancer-causing strain can result in the development of cervical or anal cancer (Government of Canada, 2020a). Thus, vaccinating children before they become sexually active is critical for optimum HPV protection. Research has found that receiving even one dose of the HPV vaccine may offer some protection

against infection and HPV-related cancers (Markowitz et al., 2013). Specifically, data from the United States National Health and Nutrition Examination Surveys found that the vaccine effectiveness against HPV infection of receiving at least one dose was 82% (95% CI: 53-93%) (Markowitz et al., 2013). Additionally, outbreaks of meningococcal disease have been reported in various school settings over the past decade (elementary, junior high, high schools, and universities), often occurring in previously unimmunized individuals, and have resulted in severe outcomes such as hospitalization and death (Centers for Disease Control and Prevention, 2012; Mbaeyi et al., 2019). Therefore, timely MenC-ACYW immunization is also essential to prevent future outbreaks of meningococcal disease among Canadian schoolchildren.

It is likely that future school immunization programs will need to include other grades to ensure that those who were in grade 6 or 9 during the 2019-2020 and 2020-2021 school years and missed doses can be caught up. Although some catch-up for missed doses is normally provided in later grades, it is likely that these programs will need to be expanded to address the larger number of students who have missed doses due to the COVID-19 pandemic. While the recent expansion of eligibility for free HPV immunization until age 26 in Alberta (Alberta Health Services, 2021b) is reassuring to ensure that those who missed doses in school have a large period of time to be caught up, it would be more ideal to catch-up students before they exit the school system. Conversely, students only remain eligible for the publicly funded MenC-ACYW program until grade 12 (Alberta Health Services, 2021c), so catch-up is urgently needed to ensure that these students do not age out of eligibility for MenC-ACYW. High school catch-up immunization programs may be needed to catch-up these students, even in zones that do not currently offer these programs.

Currently in Alberta, most routine immunization delivery is done by public health nurses at clinics or schools (Alberta Health Services, n.d.-b), whereas provinces such as Ontario use physician delivery as well as public health centre clinics (Government of Ontario, 2021). Thus, to facilitate the large amount of catch-up needed, it may be prudent to consider alternative delivery strategies to immunization in schools, such as holding additional catch-up clinics at public health centres or community locations, physician or pharmacist delivery, or providing missing doses at other vaccine appointments (e.g., COVID-19, influenza).

## Conclusion

In the two studies presented in Chapters 2 and 3, we found that routine immunization programs in Canada were largely impacted by the COVID-19 pandemic and the related public health restrictions implemented to control the spread of COVID-19 disease, especially for older children and adults. Coverage for two school-based immunizations (HPV, MenC-ACYW) in Alberta significantly declined in the pandemic period as compared to the pre-pandemic period and have not yet returned to pre-pandemic levels. Additional catch-up is needed to ensure that Canadian schoolchildren are fully protected from VPDs. To improve pandemic preparedness, future research should consider comparing strategies for continuing routine immunizations with coverage estimates across P/Ts to determine which strategies were most successful in maintaining immunization coverage.

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