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Patterns in COVID-19 vaccination among children aged 5–11 years in Alberta, Canada: Lessons for future vaccination campaigns

Shannon E. MacDonald [a,b,*], Laura Reifferscheid [a], Yuba Raj Paudel [a,b], Joan Robinson [c]

[a] Faculty of Nursing, University of Alberta, Edmonton, Alberta, Canada
[b] School of Public Health, University of Alberta, Edmonton, Alberta, Canada
[c] Department of Pediatrics, University of Alberta, Edmonton, Alberta, Canada

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ABSTRACT

Objectives: In Alberta, Canada, the COVID-19 vaccination program for children aged 5–11 years was launched on November 26, 2021. Our objectives were to determine the cumulative vaccine coverage, stratified by age, during the first thirteen months of vaccine availability, and investigate factors associated with vaccine uptake.
Study design: This retrospective cohort study used population-based administrative health data.
Methods: We determined cumulative vaccine coverage among 5–11 year olds, stratified by year of age, during the first thirteen months of vaccine availability and used a modified Poisson regression to evaluate factors associated with vaccine uptake.
Results: Of 377,103 eligible children, 44.8 % (n = 168,761) received one or more doses of COVID-19 vaccine during the study period (9.7 % received only one dose, while 35.1 % received 2 doses). Almost 90 % of initial doses were received within the first two months of vaccine availability. We found a step-wise relationship between increasing child age and higher vaccine coverage.
Conclusions: Plateaued vaccine uptake indicates a need to adapt programmatic efforts to encourage parents to act on positive vaccination intentions, and reach the large contingent of parents who have reported that they remain undecided. In order to promote vaccine uptake, messaging around vaccine safety and need should be tailored to child age, rather than uniformly applied across the 5–11 year age range.

1. Introduction

The success of childhood vaccination programs is dependent on the willingness of parents to obtain vaccines for their children, supported by acceptable and equitable vaccination delivery. Attitudes toward vaccination are commonly identified on a continuum, ranging from active demand for vaccines to complete refusal of all vaccines [1]. The large middle ground of this continuum consists of a varied group of individuals who are unsure about some or all vaccines, and may or may not refuse or delay vaccinations for their children [1,2]. Previous studies explored parental intentions toward COVID-19 vaccination for their children, in anticipation of vaccine offerings. A global pooled estimate compiled in December 2021 reported that approximately 60 % of parents intended to vaccinate their children, while approximately 22.9 % intended to refuse vaccination [3]. However, results varied widely, and studies that provided for uncertainty in decision making indicated approximately 26 % remained undecided about vaccinating their children [3]. Logistical or structural barriers caused by inaccessible or inconvenient vaccination delivery can exacerbate parental uncertainties, and also prevent parents with positive vaccination attitudes from acting on their intentions [4].

Health Canada approved the first COVID-19 vaccine product for use among 5–11 year old children in Canada on November 19, 2021 [5]. As of January 01, 2023, approximately 53 % of Canadian children aged 5–11 had received at least one dose [6]. Although COVID-19 vaccine coverage surveillance estimates are available from various government sources, there is little published research exploring uptake patterns among children aged 5–11 years, including variability in coverage across the age spectrum. Measuring age-specific COVID-19 vaccine coverage, and determining associated factors, are necessary to ensure vaccination programs are effectively tailored to population needs, and can provide insight for future vaccination campaigns. Thus, we sought to: 1) estimate coverage by age in years for COVID-19 vaccine among children aged 5–11 years in Alberta, 2) assess vaccine coverage over

* Corresponding author. Edmonton Clinic Health Academy, University of Alberta, 11405-87 Ave, Edmonton, Alberta T6G 1C9, Canada.
E-mail address: smacdon@ualberta.ca (S.E. MacDonald).

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time since vaccine availability, and 3) investigate factors associated with vaccination.

2. Methods

We conducted a retrospective cohort study of COVID-19 vaccine coverage and correlated factors using linked administrative health data in Alberta, Canada. Vaccination status was assessed between the start of the COVID-19 vaccine program for 5–11 year olds (November 26, 2021) and the end of the study period (December 31, 2022).

2.1. Setting

Alberta has a population of approximately 4.4 million, and is divided into five geographic health zones. In Alberta, routine childhood vaccines are provided by nurses working in public health centres. For the COVID-19 vaccine, doses were offered mainly through public health centres, and augmented by a small number of pharmacies and community physician offices in areas where public health centres were not nearby [7], in order to facilitate timely COVID-19 access. Although some vaccination requirements were put in place for children 12–17 years in some Canadian jurisdictions (e.g. some youth extracurricular activities required vaccination) [8], no such restrictions were placed on younger children [9].

2.2. Cohort and data sources

More than 99 % of Albertans are registered with the province's universal healthcare insurance program. Once registered, each individual is provided a personal healthcare number, which acts as a unique lifetime identifier. Using this identifier, we deterministically linked administrative databases available through the Alberta Ministry of Health. Through the school registration database (Provincial Student Immunization Repository [PSIR]), we identified all children enrolled in Alberta schools during the 2021/2022 school year, as well as individual birth date, sex, and postal code of residence. Children were included in the cohort if they were eligible for vaccination when vaccines became available to this age group on November 26, 2021 (i.e. date of birth between January 01, 2010 and November 26, 2016, aged 5–11 years; children born in 2009 were already eligible for vaccination as a 12 year old [10]). We used a Postal Code Conversion File to link postal codes to Statistics Canada's 2016 census information, to determine place of residence (by population density) and neighborhood income quintile. Individual vaccination status was retrieved from the provincial Immunization and Adverse Reaction to Immunization (Imm/ARI) repository, which includes all COVID-19 vaccine doses administered, regardless of provider. Children who left the province (i.e. cancelled provincial healthcare) or died between September 01, 2021 (the start of the school year) and December 31, 2022 (end of study period) were excluded from the analysis. We excluded children with a residential postal code from outside Alberta, or in the city of Lloydminster (where vaccinations are provided by the neighboring province). Children with a two-dose interval less than the minimum recommendation of 21 days [10] were excluded, as either dose may have represented a data entry error. Finally, those who received a COVID-19 vaccine dose before the vaccine was available in Alberta (November 26, 2021) were excluded, as doses may represent a data entry error, and to ensure uniform follow-up time for all children to calculate cumulative coverage (Supplementary Fig. 1).

2.3. Measures and analysis

To identify vaccine uptake trends over time, we calculated cumulative one- and two-dose vaccine coverage overall, and by age, for the study period. To calculate cumulative coverage, we divided the daily number of children who received a first or second vaccine dose by the total population of children. We calculated the absolute difference in cumulative coverage between two time points to measure increase in coverage. Vaccine delivery location was categorized into public health centres, pharmacies, physician clinics, and others.

We calculated frequencies and percentages for no dose, one dose, and two doses of COVID-19 vaccine received by end of study period for six exposure variables of interest: age as of November 26, 2021; sex; place of residence by population density (metro, moderate metro, urban, moderate urban, rural centre, rural, and rural remote [11]); geographic health zone (South, Calgary, Central, Edmonton, and North); neighborhood income quintile; school authority type (Public, Publicly-funded Catholic, Private, Charter, Francophone, and early childhood services [ECS] private operator [education programs for children under the age of 6]). Children who are homeschooled are registered with the relevant school authority in Alberta; thus, are included in these groups [12]. A sub-group analysis was conducted among children aged 11 years at the start of the study period, comparing the vaccinated proportion of those who turned 12 during the study period to those who remained 11.

Using a modified Poisson regression analysis, we determined the adjusted risk ratio (ARR) and 95 % confidence interval (CI) for the relationship between each exposure variable of interest (age, sex, place

Table 1
Cohort characteristics (N = 377,103).

Characteristic	n	%
Age (years)[a]		
5	50,867	13.5
6	54,994	14.6
7	55,712	14.8
8	54,652	14.5
9	55,407	14.7
10	55,200	14.6
11	50,271	13.3
Sex		
Female	183,675	48.7
Male	193,257	51.3
Missing	171	0.1
Neighborhood income quintile[b]		
Q1 (lowest income)	60,582	16.1
Q2	66,012	17.5
Q3	68,310	18.1
Q4	86,604	23.0
Q5 (highest income)	95,595	25.4
Place of residence[b]		
Metro	197,807	52.5
Moderate metro influence	59,890	15.9
Urban	35,556	9.4
Moderate urban influence	11,360	3.0
Rural centre area	12,846	3.4
Rural	51,545	13.7
Rural remote	8099	2.2
Geographic health zone		
Calgary	144,179	38.2
Edmonton	123,963	32.9
South	27,563	7.3
Central	38,277	10.2
North	43,121	11.4
School authority type		
Public	252,320	67.2
Publicly-funded Catholic	88,289	23.5
Private School	21,984	5.9
Charter	5756	1.5
Francophone	5537	1.5
ECS Private Operator	1576	0.4
Missing	1641	0.4

ECS, early childhood services.
[a] Age at start of study period (Nov 26, 2021).
[b] Based on Statistics Canada 2016 Census.

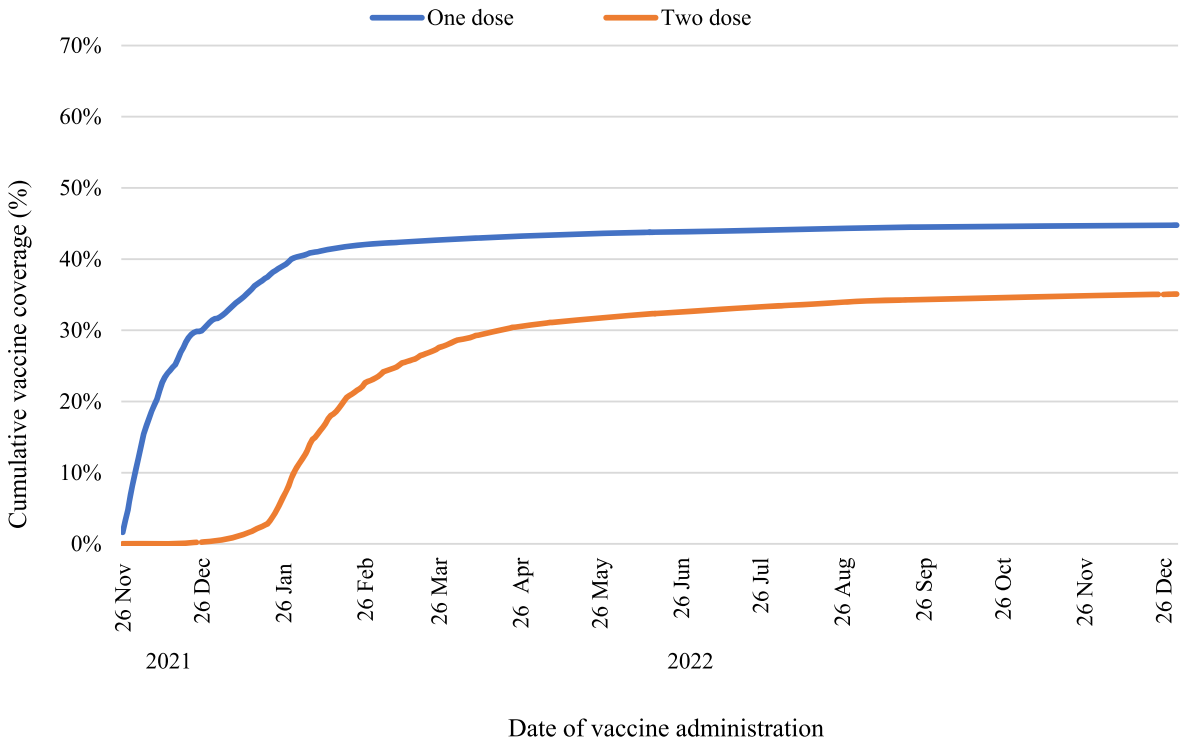

Fig. 1. Cumulative percent of children who have received one and two doses of COVID-19 vaccine.

of residence, health zone, neighborhood income quintile, and school authority type) and our outcome variable of vaccination status, comparing those who received one or more doses of vaccine during the study period with those who received none. Missing data were assumed to be missing completely at random, thus all the cases with data, including observations with missing values on some variables, were included in the analysis. Data analysis was completed using SAS version 9.4. Ethics approval for this work was obtained from the University of Alberta's Health Research Ethics Board.

3. Results

A total of 377,103 children were included in our cohort. Demographic characteristics of the cohort are provided in Table 1.

3.1. Vaccine coverage

A total of 44.8 % (n = 168,761) of the cohort had received at least one dose during the first 13 months of vaccine availability (9.7 % received only one dose, while 35.1 % received 2 doses) (Fig. 1, Supplementary Table 1). First dose vaccine coverage reached 30 % within the first month of vaccine availability (by December 26, 2021) and increased another 9.1 % in the second month (by January 26, 2022). During the third month of availability, first dose coverage increased by 3 %, reaching 42.1 % on February 26, 2022. For the remaining ten months of follow-up, first dose vaccine coverage increased by less than one percent per month. Among those who received two doses, the median interval between dose 1 and dose 2 was 62 days (range: 21–397 days; Supplementary Table 1, Table 1). The majority of vaccine doses were distributed by public health centres (94.4 %), with only 4.2 % distributed by pharmacies, and remaining doses (1.4 %) distributed from other sources (including First Nations clinics and physician clinics).

We observed a similar pattern of increasing coverage with time across the specific age groups, but with a stepwise increase in vaccine coverage with increasing age (Fig. 2). Within two months of vaccine availability, first dose coverage had reached more than 87 % of end-of-study coverage for all age groups except the oldest (11 years of age at the start of the study period) (Fig. 2, Supplementary Table 2). Coverage in the oldest age group increased at a faster rate throughout the remainder of the study period, though the increase was less than 4 % during the third month of vaccine availability (between January 26 and February 26), and less than 1 % in subsequent months for all age groups. Subgroup analysis among children aged 11 years at the start of the study revealed receipt of one or more doses of vaccine was significantly higher among those who turned 12 during our study period, compared to those who remained 11 (56.9 % *vs* 51.5 %, $p < 0.0001$; Supplementary Table 3). Receipt of two doses was also significantly higher among those who turned 12 during our study period, compared to those who remained 11 (45.5 % *vs* 41.2 %, $p < 0.0001$).

3.2. Factors associated with vaccination

No dose, one dose, and two dose coverage by study characteristics are presented in Table 2. In the multivariable analysis, factors positively associated with receiving at least one dose of COVID-19 vaccination were older age (e.g. 11 years *vs* 5 years ARR 1.40 [1.38–1.42]; 10 years *vs* 5 years ARR 1.25 [1.23–1.26]); and living in a higher income neighborhood (e.g. highest quintile *vs* lowest quintile [ARR 1.77 [1.75–1.79]) (Table 3). By contrast, living in a moderate urban region (ARR 0.61 [0.59–0.64]), rural (ARR 0.62 [0.61–0.64]) or rural remote areas (ARR 0.68 [0.65–0.72]) were associated with lower vaccination compared to living in a metro areas. Similarly, living in the South (ARR 0.88 [0.85–0.91], Central (ARR 0.71 [0.69–0.73]), and North health zones (ARR 0.60 [0.58–0.62]) were associated with lower vaccination, compared to the Calgary zone. In comparison to those attending Public schools, children attending a Charter (ARR 1.18 [1.16–1.21]), or publicly-funded Catholic school (ARR 1.03 [1.03–1.04]) were more likely to be vaccinated, while those attending Francophone (ARR 0.95 [0.92–0.98]), Private (ARR 0.66 [0.64–0.67]), and ECS private Operators (ARR 0.87 [0.82–0.93]) were less likely to be vaccinated. No appreciable differences in coverage were observed by sex.

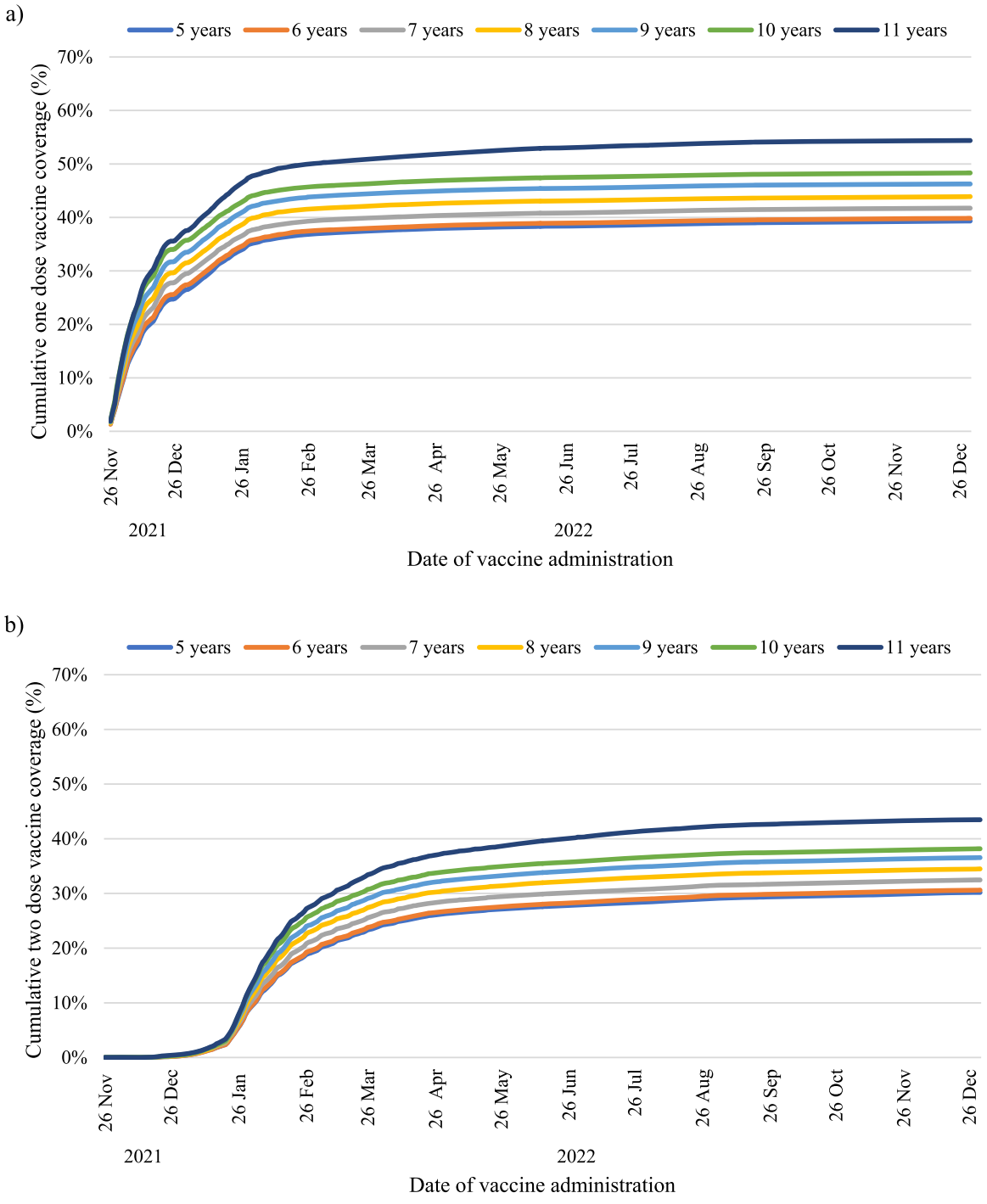

Fig. 2. Cumulative coverage of COVID-19 vaccine by age category: a) one dose b) two doses. Recommended interval between first and second dose was 8 weeks.

4. Discussion

We used school enrollment records and a population-based immunization repository to determine COVID-19 vaccine coverage among children aged 5–11 years during the first thirteen months of vaccine availability in Alberta, Canada, from November 26, 2021 through December 31, 2022. Our results indicate that less than half had received a dose of COVID-19 vaccine by the end of our study period (December 31, 2022), and most had received their initial dose within the first two months of vaccine availability (by January 26, 2022). Similar patterns in vaccine uptake have been noted in other Canadian provinces [6], and other countries [13], despite different levels of coverage. Our coverage level was lower than previously reported parental intentions for similar age groups in Canada (56 % intended, 33 % undecided for children 5–11 years [14]) and Alberta (60 % intended, 31 % undecided for children aged 9–12 years [15]). This suggests that a significant portion of parents with unvaccinated children may still be open to COVID-19 vaccination, but may have experienced logistical or structural barriers to acting on those intentions. Conversely, survey results may have overestimated vaccination intentions, or intentions may have changed over time.

Notably, coverage among 5–11 year olds in Alberta is lower than other Canadian provinces and territories, which are estimated to range from 50.1 to 88.8 % (as of January 01, 2023 [6]). This discrepancy is not apparent for other childhood vaccines [16], indicating that regional

Table 2
Proportion of children who received no doses, one dose, or two doses of COVID-19 vaccine during study period by selected background characteristics.

Variables	No doses		One dose		Two doses	
	n	% (95%CI)	n	% (95%CI)	n	% (95%CI)
Age (years)						
5	30,869	60.7 (60.3–61.1)	4645	9.1 (8.9–9.4)	15,353	30.2 (29.8–30.6)
6	33,097	60.2 (59.8–60.6)	5064	9.2 (9.0–9.5)	16,883	30.6 (30.2–31.0)
7	32,465	58.3 (57.9–58.7)	5156	9.3 (9.0–9.5)	18,091	32.5 (32.1–32.9)
8	30,670	56.1 (55.7–56.5)	5142	9.4 (9.2–9.7)	18,840	34.5 (34.1–34.9)
9	29,773	53.7 (53.3–54.2)	5386	9.7 (9.5–10.0)	20,248	36.5 (36.1–37.0)
10	28,530	51.7 (51.3–52.1)	5604	10.2 (10.0-10.4)	21,066	38.2 (37.8–38.6)
11	22,938	45.6 (45.2–46.1)	5479	10.9 (10.6–11.2)	21,854	43.5 (43.0–43.9)
Sex						
Female	101,056	55.02 (54.8–55.3)	17,586	9.6 (9.4–9.7)	65,033	35.4 (35.2–35.6)
Male	107,219	55.5 (55.3–55.7)	18,870	9.8 (9.6–9.9)	67,168	34.8 (34.5–35.0)
Neighborhood income quintile						
Q1 (lowest income)	41,010	67.7 (67.3–68.1)	5854	9.7 (9.4–9.9)	13,718	22.6 (22.3–23.0)
Q2	40,769	61.8 (61.4–62.1)	6403	9.7 (9.5–9.9)	18,840	28.5 (28.2–28.9)
Q3	37,431	54.8 (54.4–55.2)	6889	10.1 (9.9–10.3)	23,990	35.1 (34.8–35.5)
Q4	45,245	52.2 (51.9–52.6)	8239	9.5 (9.3–9.7)	33,120	38.2 (37.9–38.6)
Q5 (highest income)	43,887	45.9 (45.6–46.2)	9091	9.5 (9.3–9.7)	42,617	44.6 (44.2–44.9)
Place of residence						
Metro	92,282	46.7 (46.4–46.9)	20,598	10.4 (10.3–10.6)	84,927	42.9 (42.7–43.2)
Metro Influence	31,480	52.6 (52.2–53.0)	6046	10.1 (9.9-10.3)	22,364	37.3 (36.9–37.7)
Urban	22,381	63.0 (62.4–63.5)	3552	10.0 (9.7–10.3)	9623	27.1 (26.7–27.5)
Moderate urban	8616	75.9 (75.1–76.6)	781	6.9 (6.4-7.3)	1963	17.3 (16.6–18.0)
Rural centre area	8572	66.7 (65.9–67.5)	1122	8.7 (8.3–9.2)	3152	24.5 (23.8–25.3)
Rural	38,785	75.2 (74.9–75.6)	3751	7.3 (7.1–7.5)	9009	17.5 (17.2–17.8)
Rural remote	6226	76.9 (76.0–77.8)	626	7.7 (7.2–8.3)	1247	15.4 (14.6–16.2)
Geographic health zone						
Calgary	68,353	47.4 (47.2–47.7)	15,188	10.5 (10.4–10.7)	60,683	42.1 (41.8–42.3)
Edmonton	27,827	72.7 (72.3–73.1)	3074	8.0 (7.8–8.3)	7376	19.3 (18.9–19.7)
South	61,953	50.0 (49.7–50.3)	12,360	10.0 (9.8–10.1)	49,650	40.0 (39.8–40.3)
Central	18,549	67.3 (66.7–67.9)	2401	8.7 (8.4–9.0)	6613	24.0 (23.5–24.5)
North	31,660	73.4 (73.0–73.8)	3453	8.0 (7.8–8.3)	8008	18.6 (18.2–18.9)
School authority type						
Public	140,158	55.6 (55.4–55.7)	24,991	9.9 (9.8–10.0)	87,171	34.6 (34.4–34.8)
Publicly-funded Catholic	45,617	51.7 (51.3–52.0)	8842	10.0 (9.8–10.2)	33,830	38.3 (38.0–38.6)
Private School	15,525	70.6 (70.0–71.2)	1313	6.0 (5.7–6.3)	5146	23.4 (22.9–24.0)
Charter	2089	36.3 (35.1–37.5)	642	11.2 (10.3–12.0)	3025	52.6 (51.3–53.4)
Francophone	3105	56.1 (54.8–57.4)	412	7.4 (6.8-8.1)	2020	36.5 (35.2–37.8)
ECS Private Operator	981	62.3 (59.9–64.6)	148	9.4 (7.8–10.1)	447	28.4 (26.1–30.6)

CI, confidence interval; ECS, early childhood services.

efforts that have been used to promote COVID-19 vaccine uptake should be explored. For example, school-based delivery of COVID-19 vaccines has been used in Quebec, Saskatchewan, and British Columbia [14]. School-based programs have been used effectively in Canada to achieve high and equitable coverage for other childhood vaccines [17,18]; in fact, simply encouraging vaccination in school may promote uptake among this age group [19]. Our results also indicate that prioritizing vaccination interventions by school type may be useful for targeting areas of low coverage. However, lower vaccine coverage among those attending private schools has been consistently reported for other routine vaccines [20,21], and, while Canadian parents who support COVID-19 vaccination for their children are largely in favor of school-based delivery, those who are undecided may be less supportive [14]. The province of Alberta did expand delivery options in March 2022, increasing availability through pharmacies and primary care physician offices, and offering walk-in appointments and extended hours at select public health centres [22,23]. These efforts did not appear to impact provincial-level vaccine coverage; however, as interventions were applied only in specific areas, there may have been significant localized impacts. In addition, these efforts may have been more effective if implemented earlier in the vaccine roll-out, when parent interest was high. More information about the challenges and successes of regional programs, school-based and otherwise, is required.

Nearly 10 % of children who received an initial dose of COVID-19 vaccine did not receive a second dose within the study timeframe. These children reflect a missed opportunity to increase vaccine series completion, which is crucial to ensure protection is maximized. Reminders for upcoming vaccination doses, and recalls for overdue vaccinations, have been identified as effective strategies for increasing routine vaccination rates among children [24]; implementation of this approach may be both particularly useful and difficult for COVID-19 vaccines and future pandemic vaccines, due to frequently changing guidelines. Tailoring these interventions to the local population may be particularly effective [25]. Additionally, techniques to alleviate first dose pain and anxiety may promote second dose vaccine compliance, particularly in this age group [26]. Given the variable rate in follow-up time after first dose receipt, we did not explore factors associated with delaying or not receiving a second dose. Future research should recognize this group as a unique population, and determine factors associated with incomplete and/or delayed vaccination.

In our study, younger ages within the 5–11 year old range were significantly associated with lower vaccine coverage. This pattern persisted throughout the age range, with higher coverage even noted among children who turned 12 years during the study time period compared to those who remained 11. However, coverage among those who turned 12 was still below coverage for the 12–17 year old age group in Alberta (82 % [6]), indicating that the relationship between age and uptake may extend to older children. Previous survey results indicate mixed results on the impact of child age on parental vaccination intention [3]; however, studied age ranges varied. Our findings are

Table 3
Proportion of children who received at least one dose of COVID-19 vaccine, with unadjusted and adjusted risk ratios for factors associated with vaccination status.

Characteristic	Coverage (≥ 1 dose), % (n)	Unadjusted risk ratio (95 % CI)	Adjusted risk ratio (95 % CI)	p-value
Age (years)				
5	39.3 (19,998)	Ref	Ref	
6	39.8 (21,897)	1.01 (1.00-1.03)	1.03 (1.01-1.04)	0.0004
7	41.7 (23,247)	1.06 (1.05-1.08)	1.08 (1.06-1.09)	<.0001
8	43.9 (23,982)	1.12 (1.10-1.13)	1.13 (1.12-1.15)	<.0001
9	46.3 (25,634)	1.18 (1.16-1.19)	1.19 (1.18-1.21)	<.0001
10	48.3 (26,670)	1.23 (1.21-1.25)	1.25 (1.23-1.26)	<.0001
11	54.4 (27,333)	1.38 (1.36-1.40)	1.40 (1.38-1.42)	<.0001
Sex				
Male	45.0 (82,619)	Ref	Ref	
Female	44.5 (86,038)	1.01 (1.00-1.02)	1.01 (1.00-1.02)	0.0078
Neighborhood income quintile				
Q1 (lowest income)	32.3 (19,572)	Ref	Ref	
Q2	38.2 (25,243)	1.18 (1.17-1.20)	1.23 (1.21-1.25)	<.0001
Q3	45.2 (30,879)	1.40 (1.38-1.42)	1.43 (1.41-1.45)	<.0001
Q4	47.8 (41,359)	1.48 (1.46-1.50)	1.55 (1.53-1.57)	<.0001
Q5 (highest income)	54.1 (51,708)	1.67 (1.65-1.70)	1.77 (1.75-1.79)	<.0001
Place of residence				
Metro	53.4 (105,525)	Ref	Ref	
Moderate metro influence	47.4 (28,410)	0.89 (0.88-0.90)	0.80 (0.80-0.82)	<.0001
Urban	37.1 (13,175)	0.69 (0.68-0.70)	0.91 (0.88-0.94)	<.0001
Moderate urban influence	24.2 (2744)	0.45 (0.44-0.47)	0.61 (0.59-0.64)	<.0001
Rural centre area	33.3 (4274)	0.62 (0.61-0.64)	0.75 (0.72-0.77)	<.0001
Rural	24.8 (12,760)	0.46 (0.46-0.47)	0.62 (0.61-0.64)	<.0001
Rural Remote	23.1 (1873)	0.43 (0.42-0.45)	0.68 (0.65-0.72)	<.0001
Geographic health zone				
Calgary	52.6 (75,826)	Ref	Ref	
Edmonton	50.0 (62,010)	0.95 (0.94-0.96)	0.95 (0.94-0.95)	<.0001
South	32.7 (9014)	0.62 (0.61-0.63)	0.88 (0.85-0.91)	<.0001
Central	27.3 (10,450)	0.52 (0.51-0.53)	0.71 (0.69-0.73)	<.0001
North	26.6 (11,461)	0.50 (0.50-0.51)	0.60 (0.58-0.62)	<.0001
School authority type				
Public	44.5 (112,162)	Ref	Ref	
Publicly-funded Catholic	48.3 (42,672)	1.09 (1.08-1.10)	1.03 (1.03-1.04)	<.0001
Private	29.4 (6459)	0.66 (0.65-0.67)	0.66 (0.64-0.67)	<.0001
Charter	63.7 (3667)	1.43 (1.40-1.46)	1.18 (1.16-1.20)	<.0001
Francophone	43.4 (2432)	0.99 (0.96-1.02)	0.95 (0.92-0.98)	0.0005
ECS Private Operator	37.8 (595)	0.85 (0.80-0.91)	0.87 (0.82-0.93)	<.0001

CI, confidence interval; ECS, early childhood services.

consistent with a Canadian survey that reported parents of 8–11 year olds were more likely to report positive vaccination intentions than those of 5–7 year olds (58.1 % *vs* 54.8 %) [14]. Murthy et al. [27] found a similar relationship between age and coverage during the first two months of vaccine availability in the US; our results indicate that this pattern persists. Therefore, treating 5-11-year-olds as one homogeneous group for messaging and vaccine delivery may not be appropriate for optimizing vaccine coverage for COVID-19 and other vaccines. Instead, age-specific information on vaccine safety and effectiveness should be provided, including greater efforts to publicize the growing number of children worldwide who have been safely vaccinated. This may be particularly important for the large portion of parents who have stated they wish to "wait and see" [3,28,29].

We found that vaccine coverage increased with both income and population density and varied by geographic health zone. These relationships are consistent with patterns noted for adult COVID-19 vaccine intention and uptake [30,31], which is not surprising given that parental vaccination status is highly predictive of vaccination intention for their children [32]. However, the vaccination rate for children in this age group is much lower than that reported for adults (greater than 85 % [6]). This disparity has also been noted for childhood vaccination intentions among parents [14,32], with lower intentions associated with perceptions of lower risk of severe COVID-19 disease in children [3] and greater concern over unknown or potential side effects related to vaccination [29]. This means that trusted healthcare providers must have the information and training required to have effective conversations in their communities [33]. Efforts to promote COVID-19 vaccination for children 5–11 as a social norm by leveraging informal social connections may also be effective [28,34].

4.1. Strengths and limitations

This study benefited from timely population-based data, using individual-level school enrollment and immunization records. By using school enrollment records to identify our cohort, we were able to accurately identify children who are current residents of Alberta. In addition, our overall coverage estimates were similar to those posted by the Alberta Ministry of Health, who apply population weights to measure coverage. For those children who were vaccinated, we used age at start of study period as an estimate for age at vaccination; thus, the positive association between increasing age and vaccine coverage may be underestimated. Although all vaccine-eligible 5 year olds were also eligible for school enrollment [35], this age group may have been underrepresented in this study as kindergarten enrollment is not mandatory in Alberta [36]. Some of the children recorded as having only received 1 vaccine dose may not have been yet eligible for a second vaccine dose during our study period; however, this represents less than 0.1 % of vaccinated children in the study.

5. Conclusions

Our results indicate that parents either sought vaccination for their 5-11-year-old children soon after it was available or not at all. Thus, having a well-developed vaccine roll-out plan promptly after vaccine

availability may result in higher coverage, and innovative messaging and delivery options will be required to increase uptake in this age group over the longer term. Although this uptake pattern is consistently noted across Canadian provinces, lower coverage levels in Alberta indicate that understanding regional differences in COVID-19 vaccination efforts is required. We found that specific child age was significantly related to vaccine coverage, even after correcting for sociodemographic and regional variability, suggesting that the 5–11-year-old age group should not be treated as one homogeneous group. Rather, tailored messaging to parents of younger children within this age group should be used. We also found some indication that efforts to promote timeliness of two-dose series completion are required. These important lessons should be used to guide ongoing COVID-19 vaccine programming for children, as well as introduction of new vaccines in the future.

Ethical approval

Ethics approval for this work was obtained from the University of Alberta's Health Research Ethics Board.

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Data sharing statement

No data are available. The steward of the data used in this study is the Alberta Ministry of Health, who maintains the data for the purpose of health system administration. Thus, the authors are not at liberty to make the data publicly available.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhip.2024.100467.

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