Are they protected?
Immunization status of children at Kindergarten entry in Alberta

by

Manisha Dhungana

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Faculty of Nursing
University of Alberta

Abstract

Introduction: Immunization coverage for most childhood vaccines is measured and reported at 2 years and at 7 years of age in Alberta. There is currently a gap in knowledge regarding immunization coverage for children entering kindergarten (typically at age 5 years), as well as on factors associated with the incomplete immunization status of children at kindergarten entry in Alberta.

Objective: Objective #1 was to examine the immunization coverage of a cohort of Alberta children at the start of kindergarten, as compared to the end of grade 1, when immunization status as per the Alberta routine childhood immunization schedule is normally assessed. Objective #2 was to determine the risk factors for incomplete immunization status at the start of kindergarten.

Framework: This study was guided by the World Health Organization model of vaccine uptake/hesitancy.

Methods: This retrospective cohort study used administrative health services data held by the Alberta Ministry of Health. Immunization coverage was assessed at September 1, 2013, when the 2008 birth cohort of children were entering kindergarten, and again at June 30, 2015, when children were at the end of grade one. Maternal age, marital status, number of children in family, household moves, location of the birth, attendant at the birth, sex of the child, gestational age, income, and household moves were our exposure variables. Outcome variables were: immunization status for each individual vaccine and for all vaccines in the schedule combined. Immunization status of children for all vaccines was categorized as: complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1. Descriptive statistics and a multinomial logistic regression model were

used to determine the coverage rate and to assess the association between exposure variables and immunization status respectively.

Results: The final cohort included 41,515 children. We found higher immunization coverage at the end of grade 1 than at kindergarten entry for the vaccines that have doses scheduled for 4-6 years of age, i.e. diphtheria-tetanus-pertussis (DTaP)-containing vaccines and measles-mumps-rubella-varicella (MMRV) vaccine. For instance, 81.7% (95% CI 81.4-82.1) of the children were completely immunized at the end of Grade 1, whereas 47.5% (95% CI 47.0-48.0) were completely immunized at the start of kindergarten for DTaP-containing vaccines. For all vaccines combined, children at the end of grade 1 had higher immunization coverage than children entering kindergarten, i.e., 72.4%, 95% CI 72.0-72.8 versus 41.7%, 95% CI 41.2-42.2. The factors that were associated with incomplete immunization status at kindergarten entry were: single maternal marital status, large number of children in a household, young maternal age, and multiple household moves. Midwife delivery at hospital and home was strongly associated with still incomplete immunization status at the end of grade 1, i.e. OR 3.58 (95% CI 2.77-4.62) and 11.52 (95% CI 7.91-16.80) respectively.

Conclusion and Relevance: Immunization coverage of children at the start of kindergarten was lower than children at the end of grade 1. This identified gap in immunization coverage supports the need for policy review and shift of a school based catch-up immunization program from grade 1 to a kindergarten entry immunization program.

Implications & Recommendation: Public Health Nurses can play a significant role in increasing the immunization rate of children at kindergarten entry. Advocating for policy change, educating on immunization, and sending reminders to the caregiver are some of the strategies for increasing the immunization rates.

Preface

This thesis is an original work by Manisha Dhungana. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Health Research Ethics Board, under project title "Change in vaccination status over time in a population-based cohort: Coverage and determinants of immunization at pre-school and school entry", ID Pro00078832, January 2, 2017.

Chapter II of this thesis is planned to be submitted for publication at *JAMA Pediatrics* with authors Dhungana Manisha, Hoben Matthias, O'Brien Celine, and MacDonald Shannon. I was responsible for the data analysis and interpretation of the results as well as the manuscript composition. Hoben Matthias and O'Brien Celine contributed to the manuscript edits. MacDonald Shannon was the supervisory author and was involved with manuscript composition and oversaw data analysis.

Acknowledgements

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I am extremely grateful to my parents for their unconditional love and never-ending support, especially during this past one year when I needed them the most. I am truly blessed and lucky to have them here with me. I would not have made it this far without them. I am also thankful to my husband for always believing in me and supporting me to complete this research.

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Table of Contents

Chapter I: Introduction 1
Introduction and Overview 2
The Problem 2
Significance 3
Research Questions 3
Background 4
Importance of Immunization 4
Immunization Coverage 4
Determinants of Immunization 5
Measuring Immunization Coverage of Children at School Entry 6
Theoretical Framework for Study 8
Methods 9
Design 9
Setting 10
Study Cohort 11
Data Sources 12
Outcome Variables 13
Exposure Variables 14
Data Analysis 15
Summary 19
Chapter I References 21

Chapter II: Manuscript as prepared for submission to JAMA Pediatrics 27
Key Points 28
Abstract 29
Introduction 31
Methods 32
Study Design, Setting, & Population 32
Data Sources 33
Exposure Variables 33
Outcome Variables 34

Statistical Analysis 35
Results 36
Discussion 39
Conclusion 43
References 44

Chapter III: Discussion 52
Implications & Recommendations 53
Study Strengths & Limitations 55
Knowledge Translation (KT) Activities 56
Conclusion 57
Chapter III References 58
Full Thesis References 60

List of Tables

Table 1: Alberta recommended routine pre-school childhood immunization schedule that applies to a 2008 birth cohort 48
Table 2: Immunization coverage of children at the start of kindergarten and at the end of grade 1 49
Table 3: Characteristics of children according to their immunization status 50
Table 4: Multinomial logistic regression of factors associated with immunization status 51

Appendix

Appendix A: Sensitivity analysis for varicella immunization 65

Chapter I: Introduction

Introduction and Overview

This paper-based thesis examines the immunization coverage of a cohort of children in Alberta at the start of kindergarten and compares it to the coverage of the same cohort of children at the end of grade one. It also identifies the risk factors associated with the child's immunization status. This thesis is comprised of three chapters. Chapter I presents the problem, significance, background, guiding conceptual framework, and detailed methods of the study. Chapter II presents a manuscript prepared to be submitted to JAMA Pediatrics. Finally, chapter III provides strengths and limitations of the research, the knowledge translation plan, and general conclusions and recommendations.

The Problem

Measuring immunization coverage is critical to determining the susceptibility of a population to vaccine preventable diseases and as an important strategy to monitor the effectiveness of immunization programs.[1] For many children, kindergarten is the first time that they are surrounded by a lot of children, increasing their risk of acquiring a vaccine preventable disease if they are not fully immunized.[2] Thus, assessing immunization status at kindergarten school entry is critical to determine a child's risk for vaccine preventable diseases, as well as the school population's risk in case of potential outbreaks of disease.

In Alberta, immunization coverage for most routine childhood vaccines is measured and reported at 2 years and 7 years of age (approximately at the end of grade one). It is not assessed at school entry, i.e., at the start of kindergarten (when most children are 5 years of age).[2,3] Public Health Nurses (PHNs) review all grade one student records and undertake efforts to "catch-up" children on their vaccines during the grade one school year. There is currently a gap in knowledge regarding immunization coverage for kindergarten entry students in Alberta.

Moreover, there are numerous studies that have assessed risk factors for being incompletely immunized at 2 years of age,[4-7] but not for those who are incompletely immunized at the start of kindergarten or those whose immunization status remains incomplete at the end of grade 1.

Significance

The findings of the study help to determine the extent of the problem, i.e. the number and proportion of children who are incompletely immunized at the start of kindergarten, as well as those whose immunization status remains incomplete at the end of grade 1. This study also points out certain groups of children that are at particularly high risk for less than optimal immunization. This will be a prerequisite to improve childhood immunization coverage and to protect individual children from disease. Identifying the risk factors that make children particularly prone to sub-optimal immunization status supports tailored strategies to target these risk factors or population at risk.

Research Questions

Question 1: What is the immunization status (complete versus incomplete) of a 2008 birth cohort of children at the start of kindergarten (approximately 5 years of age) and again at the end of grade one (approximately 7 years of age) in Alberta?

Question 2: What are the factors associated with having an incomplete immunization status at the start of kindergarten but complete immunization status at the end of the grade 1 school year?

Question 3: What are the factors associated with having an incomplete immunization status at the start of kindergarten that remains incomplete at the end of the grade 1 school year?

Background

Importance of Immunization

To protect children from vaccine preventable diseases, routine childhood immunization programs are considered as one of the most successful public health interventions currently available.[2,3,8] According to the Public Health Agency of Canada (PHAC), immunization has saved more lives in the past fifty years than any other medical intervention.[9] It is estimated to save approximately three million lives per year globally.[3] Completion of recommended immunizations is a population health intervention that decreases the spread of vaccine preventable diseases.[2] Immunizations are also important for herd immunity, which happens when a sufficient proportion of a population is immunized such that the spread of infectious disease is minimal. As a result, the risk of infectious disease among unimmunized individuals is also minimized.[10]

Immunization Coverage

Immunization coverage is defined as the percentage of people who receive the recommended number of vaccine doses (the numerator) divided by the population eligible to receive the vaccine (the denominator).[11] It is one of the most common and important immunization indicators used in the research literature.[11] Measuring immunization coverage helps to quantify and evaluate the performance of immunization programs. Assessing immunization coverage can also help to identify the groups that are at high- risk of vaccine preventable diseases as well as the potential opportunities for enhancing immunization programs where coverage is lower.[11,12]

Determinants of Immunization

Socioeconomic status has been identified as one factor affecting immunization uptake.[13,14,15] Children from low income households are more likely to be incompletely immunized.[15] Similarly, children of parents who have less than a high school education are often under-immunized.[14,15] Being a young mother below 20 years old [5,7,16,17] is identified as a risk factor for a child's incomplete immunization status, with an adjusted Odds Ratio (aOR) of 9.5 as compared to more than 20 years old mother. Not married marital status of the mother and mothers who were divorced, separated, or widowed are risk factors to their children being incompletely immunized.[7,18,19] Single maternal marital status, as compared to not single maternal marital status, increases the odds of not completing immunization series among children, i.e., aOR of 1.58 in Alberta.[7] Certain household factors, such as a greater number of children in the family influences the likelihood of a child not being completely immunized.[4,7,19] The odds of not completing the immunization series increased in children who are from a household with a greater number of children (two or more) at the time of birth, as compared to being an only child, i.e., two children in a household at the time of birth has an aOR of 1.4;[7] three children in a household at the time of birth has aOR of 1.9; [4,7] and four or more children in a household at the time of birth has aOR of 3.2.[7] Multiple household moves have shown to be associated with incomplete immunization.[4,7,20] Children moving residence multiple times (i.e., two or more since birth), as compared to once or none, are likely to be incompletely immunized.[7,20] Furthermore, babies born before 37 weeks often experience incomplete as well as delayed immunization.[6,19,21] The odds of completing the immunization series decrease in preterm babies born at 33-36 weeks (aOR, 0.92) and in preterm babies born ≤ 32 weeks (aOR, 0.73).[6] Interestingly, a study done in the United States reported that male children are more likely to be non-immunized. Female

children have higher odds of being fully immunized than male children and have been documented as having an OR of 1.3.[22]

Parents' knowledge, attitudes, and beliefs regarding immunization have been identified as a key factor influencing immunization uptake.[13] Understanding the importance of immunization and risk perception of vaccine preventable diseases have been associated with higher immunization uptake.[13] Parents' negative attitudes towards immunization and lack of trust towards health professionals can result in lower immunization uptake.[23] Depending on the nature of the news, exposure to mass media can influence views on immunization in both positive and negative ways.[13] For instance, regular exposure to messages on benefits of immunization from the media have found to have positive effect on immunization uptake,[24] whereas exposure to negative news stories such as, threats and side effects of vaccines acted as a barrier to immunization uptake.[25] A study conducted in Edmonton revealed that children delivered by a midwife are more likely to have an incomplete immunization status.[17] Another study done in Alberta found that children delivered by a midwife at home are more prominently linked with total non-immunization status having an aOR of 51.7,[7] as compared to physician delivery in hospital. Some studies have stated that midwives' attitude and belief could influence parents' decision regarding immunization.[7,17,26]

Measuring Immunization Coverage of Children at School Entry

In Canada, the federal government makes vaccine recommendations for provincially funded immunization programs, however, the immunization policies and programs are the responsibility of the provincial/territorial governments. Almost every province/territory has their own immunization strategies and larger acts in isolation.[2] Data about vaccines administered also varies between provinces/territories and thus cross-provincial comparisons is challenging.

Alberta has a Public Health Nurse (PHN) led model for the administration of all childhood immunizations. In other provinces/territories, family doctors, pediatricians, or PHNs (or a mixed model that includes a combination of these) are responsible for administering childhood immunizations.[2,3] Out of the thirteen Canadian provinces/territories, only Ontario and New Brunswick require parents to provide a proof of immunization administered or provide a valid exemption of school aged children in order to attend school.[2,27,28]

Australia and the United States have made great advances in measuring immunization coverage of children at school entry. In Australia, ongoing monitoring and follow up on the immunization status of children at school entry has increased immunization coverage rates.[29] Part of this process is that parents are mandated to provide their child's immunization records at entry to the education system and the provided information on child's immunization is updated in school information system.[29] Furthermore in 2016, 'No Jab, No Pay' and 'No Jab, No Play' immunization policies have been introduced in Australia.[30] Under this policy, no other exemptions are accepted other than a medical exemption. Those parents who fail to fully immunize their children lose government subsidies (i.e., family tax benefit, child care benefit, and child care rebate reimburses) and access to kindergarten.[30,31]

Similarly, in all states of the USA, parents are required to provide their child's immunization records to be enrolled in school.[32,33] All states have school entry requirement for immunization, but the exemption on immunization requirements vary state to state.[34] Some states allow a religious, medical, and philosophical exemption; whereas, some states, such as California, West Virginia, and Mississippi only allow a medical exemption at school entry.[31,35] All children have to have documentation of their immunization status (complete/conditional/exempt) to be enrolled in school.[36]

Theoretical Framework for Study

There are various theoretical frameworks that have been used to understand individuals' behavior and decisions regarding uptake of childhood vaccines. One example is the "Model of vaccine uptake/hesitancy".[37] This model was developed by the Strategic Advisory Group of Experts (SAGE) on immunization for the World Health Organization (WHO). This human behavior of vaccine uptake/hesitancy is influenced by 3 components (3Cs), i.e. *complacency, confidence,* and *convenience* (See Figure 1). Vaccine *complacency* is defined as recognizing (or not) the risk of vaccine preventable diseases and perceiving (or not) the importance of vaccine. Vaccine *confidence* is defined as trust (or not) in the effectiveness and safety of vaccines, health services, health professionals, system, and policy makers. The third component, vaccine *convenience,* is defined as access to vaccines (e.g. physical availability, affordability, geographical accessibility, and language and health literacy).[37] This model helped guide the selection of variables to be included in our statistical model of factors affecting immunization uptake.

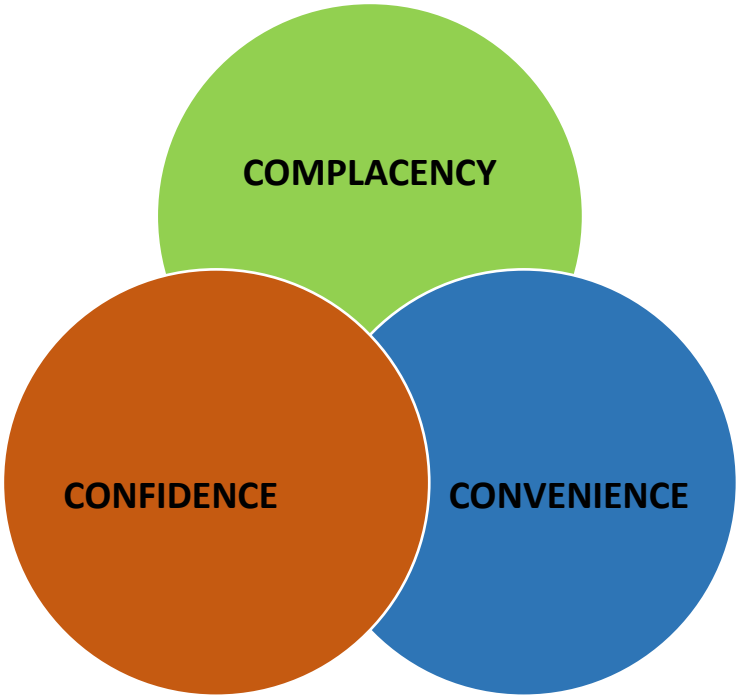

Figure 1. Adapted from the report of the SAGE working group on vaccine hesitancy "Model of Vaccine Hesitancy"

Methods

Design

This study was a retrospective cohort study examining population-based administrative data held by the Alberta Ministry of Health. This study assessed immunization status of a 2008 birth cohort children at the start of kindergarten and at the end of grade one when coverage is typically assessed. The study cohort of children were likely at the start of kindergarten at September 1, 2013 and were likely at the end of grade one at June 30, 2015 (see Figure 2).

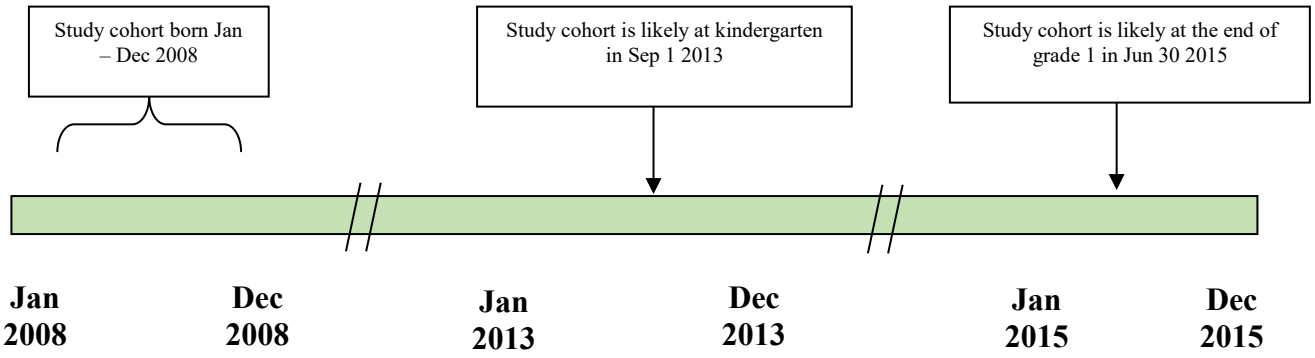

Figure 2. Study cohort timeline of the start of kindergarten and at the end of grade 1

Setting

This study took place in Alberta, which has a population of approximately 4.3 million.[38] All routine childhood immunizations in Alberta are covered by a universal provincially-funded health care insurance plan.[7] The recommended vaccines for children in the pre-school period are diphtheria, pertussis, tetanus, polio, *Haemophilus influenzae* type b (DTaP-IPV-Hib); meningococcal conjugate (Men C); pneumococcal conjugate (PCV); and measles, mumps, rubella (MMR) or MMR-varicella (MMRV) (see Table 1). Although the above-mentioned vaccines are offered as part of a primary series at 2, 4, 6, 12, and 18 months, the last booster doses are offered to children at 4-6 years of age, and it is recommended that immunizations are up to date prior to kindergarten school entry, in order to ensure full protection.

Table 1: Alberta recommended routine pre-school childhood immunization schedule that applies to a 2008 birth cohort

Vaccines	2 months	4 months	6 months	12 months	18 months	4 -6 years [b]	Total Doses
Diphtheria, Tetanus, Acellular Pertussis, Polio, *Haemophilus influenzae* type b (DTaP-IPV-Hib)	X	X	X		X	X (does not contain Hib)	5
Pneumococcal Conjugate (PCV)	X	X	X		X		4
Meningococcal Conjugate (Men C)	X	X		X			3
Measles, Mumps, Rubella (MMR)				X			1
Varicella [a]				X			1
MMR or MMRV [a]						X	1
							15

[a] This schedule reflects changes to the vaccine schedule that occurred in 2012 that applies to the 2008 birth cohort. Specifically, the 2nd dose of Varicella was added for 4-6 year old children in Aug 1, 2012. Therefore, children who turned 4 years old before Aug 1, 2012 would not be eligible to receive a second dose of varicella vaccine, and thus would have received MMR vaccine instead of MMRV

b Although these doses are offered to children at 4-6 years of age, it is recommended that they receive them before they begin school, in order to ensure that they are fully protected.

Study Cohort

The study population was a 2008 birth cohort of children in Alberta (N=50,149). This cohort has been previously created and analyzed to answer other research questions.[7,39]

First Nations children living on reserves and children living in the border town of Lloydminster were excluded from the sample, because they receive immunizations through federal programs and the province of Saskatchewan, respectively. We also excluded any children with health care cancellation by age 7 (death or migration). We included one child of any

multiple births (e.g. twin, triplets, and quadruplets), selected randomly, to ensure the independence of observations.

Data Sources

Three administrative data sources were combined to form this cohort. The first data source is the provincial immunization repository (*Immunization and Adverse Reaction to Immunization – Imm/ARI)*. Imm/ARI stores immunization information for all provincially funded vaccines administered in Alberta and contains some historical data for immunizations administered outside of the Province of Alberta. Public Health Nurses (PHNs) employed by Alberta Health Services (AHS) administer routine childhood immunizations in Alberta and record administration events in their point of service systems for submission to Imm/ARI (there are 5 zones in Alberta, each with their own point of service systems).[7] Imm/ARI has guidelines and business rules for data submission, increasing data integrity, data quality and data completeness. The second data source is the *Vital Statistics* database, which includes information on any infant born in Alberta and on newborn sex, maternal age, and number of live births. The third database is the *Alberta Health Care Insurance Plan Central Stakeholder Registry (AHCIP/CSR).* The database includes demographic information of all residents of Alberta, including information to identify First Nations status, death, people who migrated from Alberta to another province and non-Alberta residents. Individuals residing in Alberta register with AHCIP and are issued a Unique Lifetime Identifier (ULI). The ULI allows linkage of all the three databases.

Outcome Variables

The outcome variables for this study were:

Immunization Coverage for Each Individual Vaccine. We assessed the coverage of each individual vaccines (DTaP-containing vaccines, PCV, Men C, MMR/MMRV, and Varicella) for children in our birth cohort at the start of kindergarten and at the end of grade one. *Immunization coverage* is the number of children who have received the recommended number of vaccine doses as scheduled at the start of kindergarten and at the end of grade one, respectively, divided by the eligible population. For instance, complete immunization coverage for PCV according to the recommended schedule is the number of children receiving all 4 doses of PCV vaccine (see Table 1) divided by the number of children eligible to receive the vaccine.

Immunization Coverage for the Entire Vaccine Schedule. We assessed the coverage for the entire combined schedule of vaccines (15 doses, as shown in Table 1) for children in the 2008 birth cohort at the start of kindergarten and at the end of grade one. *Complete immunization* is defined as receiving all vaccine doses (i.e. 15 doses) by the scheduled age. *Incomplete immunization* is defined as receiving only some doses or no doses of the vaccines at the scheduled age.

We categorized immunization status for the entire vaccine schedule into three categories. Complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1. *Complete at kindergarten entry* is defined as the children who were completely immunized (received all vaccine doses) at the start of kindergarten. *Incomplete at kindergarten entry, but complete at the end of grade 1* are the children who were incompletely immunized at the start of kindergarten but were completely immunized at the end of grade 1. *Still incomplete at the end of grade 1* are the children who were

incompletely immunized at the start of kindergarten and were still incompletely immunized at the end of grade 1.

Exposure Variables

The exposure variables included in the study are maternal age, maternal marital status, number of children in the family, number of household moves, location of the birth, attendant at birth, sex of the child, gestational age, and income. Household moves was extracted from the AHCIP/CSR and all other variables included in the study were extracted from the Alberta Vital Statistics database.

The variables that we had in our dataset were able to measure some components of the theoretical framework (see Figure 3) chosen to guide this study. The variables, such as household moves, income and number of children in the family, measure one component, i.e. convenience. The variables location and attendant at birth are a proxy of acceptance of/trust in the health care system, as they identify individuals who prefer a less mainstream medical option to childbirth. Therefore, we think we are able to look at some part of another component, i.e. confidence. While the variables of our dataset have been shown in previous research to be associated with vaccine uptake, we recognize that we are unable to look at all aspects of this framework, or of many other theories or models found in the literature.

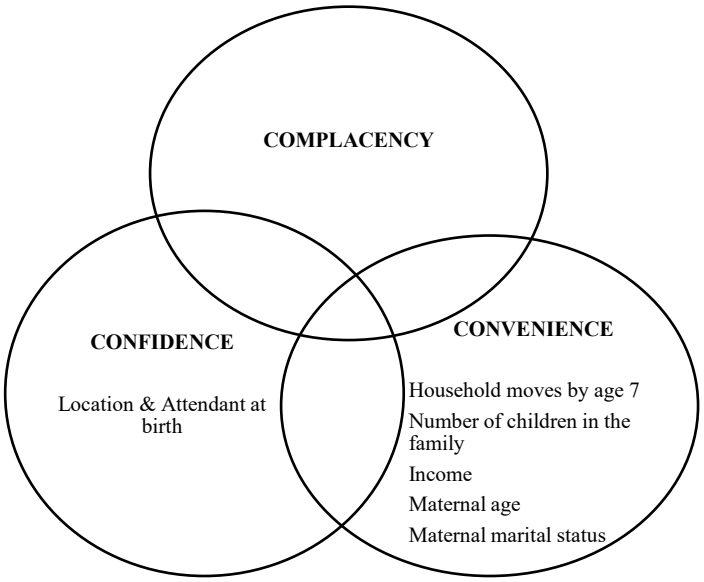

Figure 3. Model of Vaccine Hesitancy

Data Analysis

The minimum age and the minimum interval between vaccine doses is needed to ensure that the vaccine dose is optimally effective. Vaccine doses administered earlier than the minimum age or with a shorter time between doses than the minimum interval are not considered valid doses. Doses administered earlier than the minimum age and with less than minimum interval can lead to a sub-optimal vaccine response decreasing the level of protection. Thus, we determined the *valid dose* of each individual vaccine based on AHS recommendations for minimum age of receipt and minimum intervals between vaccine doses.[40] We used SPSS software V25 to perform the data analysis.

Analysis for Research Question 1: What is the immunization status (complete versus incomplete) of a 2008 birth cohort of children at the start of kindergarten (approximately 5 years of age) and again at the end of grade one (approximately 7 years of age) in Alberta? We performed descriptive analysis to assess the immunization coverage of children at the start of

kindergarten and again at the end of grade 1. We assessed immunization coverage at September 1, 2013 when the children were likely at the start of kindergarten and again assessed immunization coverage at June 30, 2015 when the children were likely at the end of grade one (see Figure 2). We classified immunization status for each individual vaccine listed in Table 1 into two categories (complete or incomplete immunization status). We then compiled these to determine whether each child's immunization status was complete or incomplete for *all vaccines in the recommended* schedule. We calculated and reported the proportion of children with complete immunization status at the start of kindergarten and at the end of grade 1 for each vaccine and for all vaccines in the recommended schedule, along with the 95% confidence intervals for each proportion.

Sensitivity Analysis. We performed a sensitivity analysis for varicella immunization (see Figure 4). The Alberta immunization schedule states that children should receive their second dose of MMR between 4 and 6 years of age. Effective August 1, 2012, the policy changed such that children should also receive a second dose of varicella vaccine, which is delivered in the form of MMRV between 4 and 6 years of age. Thus, children in our cohort who turned 4 years old and attended their immunization appointment between January 1, 2012 and August 1, 2012 would only have been offered 1 dose of varicella vaccine. In contrast, children who turned 4 years old between August 1, 2012 and December 31, 2012 (and those who turned 4 years old between January 1, 2012 and August 1, 2012, but who attended their appointment after August 1, 2012) would be offered 2 doses of varicella vaccine. It should be noted that the introduction of the second dose of varicella vaccine included a catch-up program so that children born as early as August 1, 2005 could return to receive a second dose of the varicella vaccine.

In our main analysis, we assumed that all children should have received two doses of varicella vaccine. In this analysis, children who only received one dose of varicella were classified as having *incomplete* immunization status. In order to determine whether this assumption had a substantial impact on our calculation of immunization coverage, we conducted a sensitivity analysis. We did so through the following steps:

- Main analysis: Assessed varicella immunization coverage for all the children in the cohort, with the assumption that all should have received 2 doses of varicella vaccine.
- Sensitivity analysis: Re-analyzed the data with the new assumption for the children born in between January 1, 2008 and August 1, 2008 only need one dose of varicella vaccine while children born after August 1, 2008 still need two doses of varicella vaccine.
- Compared and reported both the findings to determine if there was a significant change in coverage.

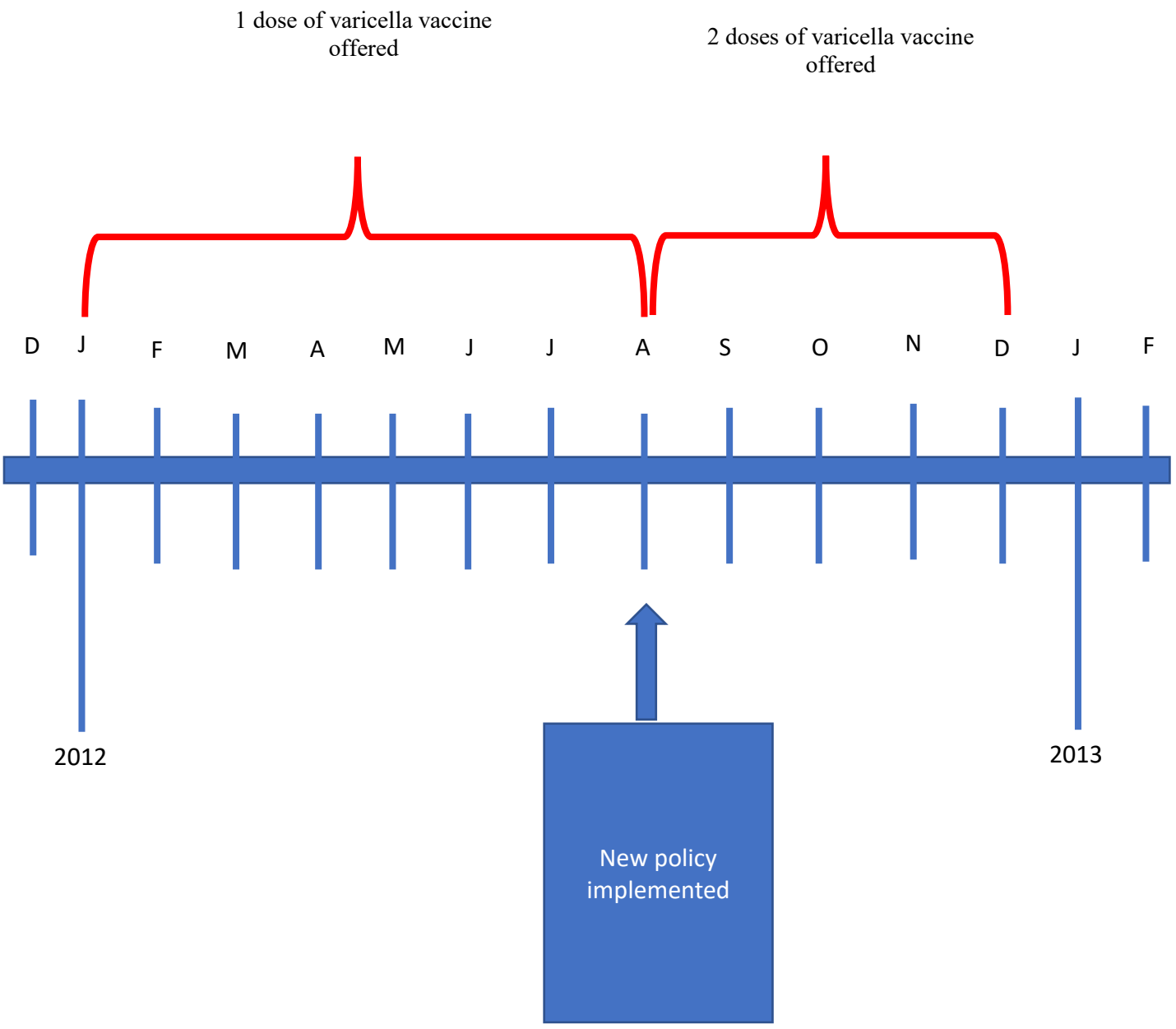

Figure 4. Sensitivity analysis for varicella vaccine

Analysis for Research Questions 2 and 3: Research Question 2-. What are the risk factors associated with having incomplete immunization status at the start of kindergarten but complete immunization status by the end of the grade 1 school year? Research Question 3- What are the factors associated with having an incomplete immunization status at the start of kindergarten that remains incomplete at the end of the grade 1 school year? We performed descriptive statistics to explore the characteristics of the exposure variables (listed previously). We also reported the number and percentage of each exposure variable according to the immunization status of children for the entire vaccine schedule (i.e., complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1).

We performed a multinomial logistic regression to look at the association between the exposure variables and our dependent variable, i.e. immunization status, which had three categories: complete at kindergarten entry (this was the reference category); incomplete at kindergarten entry, but complete at the end of grade 1 (comparison group 1); and still incomplete at the end of grade 1 (comparison group 2). We included all exposure variables in the multinomial logistic regression model, as previous literature has shown them to be associated with a child having an incomplete immunization status.[7,39] We reported aORs and 95% confidence intervals (CI).

Summary

Kindergarten is typically the first time children are surrounded by a lot of other children, increasing their risk of acquiring a vaccine preventable disease if they are not fully immunized. Assessing immunization status of children at kindergarten entry helps to determine a child's susceptibility to vaccine preventable diseases, as well as determining if schools are at risk of

vaccine preventable disease outbreaks. Assessing immunization status at kindergarten school entry also helps to identify opportunities for immunization program improvement.

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Chapter II: Manuscript as prepared for submission to JAMA Pediatrics
(using abstract/manuscript formatting and headings required by the journal)

Authors: Dhungana Manisha, Hoben Matthias, O'Brien Celine, MacDonald Shannon

Are they protected?

Immunization status of children at Kindergarten entry in Alberta.

Key Points

Question: What is the immunization coverage of children at kindergarten entry (before a catch-up immunization program) and at the end of grade 1 (after a catch-up immunization program)?

Findings: Using a retrospective cohort analysis of 41,515 children, this study found that the immunization coverage of children for all scheduled vaccines combined, was significantly higher at the end of grade 1 (72.4%, 95% CI 72.0-72.8) than at kindergarten entry (41.7%, 95% CI 41.2-42.2)

Meaning: This study highlights the need to provide a school based catch-up immunization programs for children at kindergarten entry, to reduce the risk of vaccine preventable disease outbreaks.

Abstract

Importance: Currently there is a gap in knowledge regarding immunization coverage in jurisdictions that do not mandate presentation of an immunization record at school entry, as well as the factors associated with incomplete immunization status at school entry.

Objectives: (1) To examine the immunization coverage of a cohort of Alberta children at the start of kindergarten, as compared to the end of grade 1, when immunization status is normally assessed. (2) To determine the risk factors for incomplete immunization status at the start of kindergarten.

Design: This study followed a retrospective cohort study design.

Setting: This study took place in Alberta.

Participants: This study assessed the immunization coverage of a 2008 birth cohort of Alberta children at September 1, 2013, when children were at the start of kindergarten, and again at June 30, 2015, when children were at the end of grade one.

Exposure: Maternal age, marital status, number of children in the family, household moves, location of the birth, attendant at the birth, sex of the child, gestational age, income, and household moves.

Main Outcomes and Measures: Immunization status for each individual vaccine and for all vaccines in the schedule combined. Immunization status of children for all vaccines was categorized as: complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1. Descriptive statistics were used to determine the coverage rate. Multinomial logistic regression was used to assess the association between exposure variables and immunization status, with adjusted Odds Ratios and 95% CI reported.

Results: The final cohort included 41,515 children. The vaccines that have doses scheduled for 4-6 years of age, i.e. diphtheria-tetanus-pertussis (DTaP)-containing vaccines and measles-mumps-rubella-varicella (MMRV), had significantly higher immunization coverage at the end of grade 1 as compared to children entering kindergarten. For instance, for DTaP-containing vaccines, 81.7% (95% CI 81.4-82.1) of the children were completely immunized at end of Grade 1, whereas only 47.5% (95% CI 47.0-48.0) were completely immunized at the start of kindergarten. For all vaccines combined, children at the end of grade 1 had higher immunization coverage compared to children at the start of kindergarten (72.4%, 95% CI 72.0-72.8; 41.7%, 95% CI 41.2-42.2) The factors that were associated with incomplete immunization status at the start of kindergarten were: single maternal marital status, young maternal age, and multiple household moves. Midwife delivery at hospital and home was strongly associated with still incomplete immunization status at the end of grade 1, i.e. 3.58 (95% CI 2.77-4.62) and 11.52 (95% CI 7.91-16.80) respectively.

Conclusion and Relevance: This study suggests that immunization coverage of children at the end of grade 1 is higher after catch-up immunization schedule than the children at the start of kindergarten. It also highlighted some of the significant factors associated with incomplete immunization at the start of kindergarten.

Introduction

Childhood immunization is one of the most cost-effective interventions to keep children safe and healthy from vaccine preventable diseases.[1] Measuring immunization coverage is critical to determining the susceptibility of a population to vaccine preventable diseases. It is also an important strategy to monitor the effectiveness of immunization programs.[2] For many children, kindergarten is the first time that they are surrounded by a lot of children, increasing their risk of acquiring a vaccine preventable disease if they are not fully immunized.[3] Thus, assessing immunization records at kindergarten school entry will determine a child's susceptibility to vaccine preventable diseases, as well as determining if the school population is protected from potential outbreaks of disease.

In Canada, only Ontario and New Brunswick require students to show proof of immunization in order to attend school.[3,4] In Alberta, immunization coverage for most routine childhood vaccines is measured and reported at 2 years and 7 years of age (approximately at the end of grade one). It is not assessed at school entry, i.e., at the start of kindergarten (when most children are 5 years of age).[1,3] It is noteworthy that Public Health Nurses (PHNs) review all grade one student records and undertake efforts to "catch-up" children on their vaccines during the grade one school year. There is currently a gap in knowledge regarding immunization coverage for kindergarten entry children in Alberta. Moreover, there are numerous studies that have assessed risk factors that are associated with under-immunization at 2 years,[5-8] but we don't know if these risk factors are associated with under-immunization at the start of kindergarten. Therefore, our study aimed to examine the immunization coverage of a cohort of children in Alberta at the start of kindergarten and compare them to the coverage rates of the

same cohort of children at the end of grade one. This study also identified the risk factors associated with incomplete immunization status at the start of kindergarten.

Methods

Study Design, Setting, & Population

This study followed a retrospective cohort study design examining the population-based administrative data held by the Alberta Ministry of Health. The study population was a 2008 birth cohort of children in Alberta (N=50,149). This study assessed the immunization coverage of a 2008 birth cohort of children at September 1,2013 when children were likely at the start of kindergarten and again assessed immunization coverage at June 30, 2015 when children were likely at the end of grade one. This study took place in Alberta, a Canadian province with a population of approximately 4.3 million.[9] All routine childhood immunizations are covered by a universal provincially-funded health care insurance plan.[8] The recommended vaccines for children in the pre-school period are diphtheria, pertussis, tetanus, polio, *Haemophilus influenzae* type b (DTaP-IPV-Hib); meningococcal conjugate (Men C); pneumococcal conjugate (PCV); and measles, mumps, rubella (MMR) or MMR-varicella (MMRV) (see Table 1).

We excluded any First Nations children living on reserves and children living in the border town of Lloydminster, because they receive immunizations through federal programs and the province of Saskatchewan, respectively. We also excluded any children with health care cancellation by age 7 (death or migration). We included one child of any multiple births (e.g. twin, triplets, and quadruplets), selected randomly, to ensure the independence of observations. The final cohort included 41,515 children.

Data Sources

Three administrative data sources, i.e., Immunization and Adverse Reaction to Immunization (Imm/ARI), vital statistics, and Alberta Health Care Insurance Plan Central Stakeholder Registry (AHCIP/CSR) were combined to form this study cohort. Imm/ARI stores immunization information for all provincially funded vaccines administered in Alberta and also contains some historical data for immunizations administered outside of the Province of Alberta. Imm/ARI has guidelines and business rules for data submission, increasing data integrity, data quality and data completeness.[8] Vital statistics database, includes information on any infant born in Alberta and on newborn sex, maternal age, and number of live births. Alberta Health Care Insurance Plan Central Stakeholder Registry (AHCIP/CSR) includes demographic information of all residents of Alberta, including information to identify First Nations status, death, people who migrated from Alberta to another province and non-Alberta residents. Individuals residing in Alberta register with AHCIP and are issued a Unique Lifetime Identifier (ULI). The ULI allows linkage of all the three databases.

Exposure Variables

The exposure variables obtained from the administrative dataset were: maternal age, marital status, number of children in the family, number of household moves, location of the birth, attendant at the birth, sex of the child, gestational age, and income. Household move was extracted from the AHCIP Central Stakeholder Registry and all other variables included in the study were extracted from the Alberta Vital Statistics database.

This study was guided by the "Model of vaccine hesitancy/uptake" [10] developed by the Strategic Advisory Group of Experts (SAGE) working group on immunization for the World Health Organization (WHO). According to this model, vaccine hesitancy /uptake is influenced

by three factors: complacency, confidence, and convenience.[10] From the available exposure variables obtained from the administrative dataset, we were able to assess some of the factors of vaccine uptake using this model.

Outcome Variables

Immunization coverage for each individual vaccine. We assessed the coverage of each individual vaccines (DTaP-containing vaccines, PCV, Men C, MMR/MMRV, and Varicella) for children in our birth cohort at the start of kindergarten and at the end of grade one. *Immunization coverage* is defined as the number of children who have received the recommended number of vaccine doses as scheduled at the start of kindergarten and at the end of grade one, respectively, divided by the eligible population. Each individual vaccine coverage is categorized as complete and incomplete.

Immunization coverage for the entire vaccine schedule. We assessed the coverage for the entire combined schedule of vaccines (15 doses, as shown in Table 1) for children at the start of kindergarten and at the end of grade one. *Complete immunization* is defined as receiving all vaccine doses (i.e. 15 doses) by the scheduled age. *Incomplete immunization* is defined as receiving only some doses or no doses of the vaccines at the scheduled age.

Furthermore, we categorized immunization status of children for the entire vaccine schedule into three categories. Complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1. Complete at kindergarten entry is defined as the children who were completely immunized at the start of kindergarten. Incomplete at kindergarten entry, but complete at the end of grade 1 are the children who were incompletely immunized at the start of kindergarten but were completely immunized by the end of grade 1. Still incomplete at the end of grade 1 are the children who

were incompletely immunized at the start of kindergarten and were still incompletely immunized at the end of grade 1.

Statistical Analysis

We determined the *valid dose* based on AHS recommendation for minimum age of receipt and minimum intervals between vaccine doses.[11] We calculated the proportion and 95% Confidence Intervals (CIs) for each proportion of immunization coverage at September 1, 2013 and again at the end of June 30, 2015 of each individual vaccine and for all vaccines in the vaccine schedule. To look at the association between each factor and immunization status we performed a multinomial logistic regression. The three categories of immunization status were: complete at kindergarten entry (this was the reference category); incomplete at kindergarten entry, but complete at the end of grade 1 (comparison group 1); and still incomplete at the end of grade 1 (comparison group 2). We reported adjusted Odds Ratio (OR) and 95% CI.

We performed a sensitivity analysis for varicella immunization (see Appendix A). The Alberta immunization schedule states that children should receive their second dose of MMR between 4 and 6 years of age. Effective August 1, 2012, the policy changed such that children should also receive a second dose of varicella vaccine, which is delivered in the form of MMRV between 4 and 6 years of age. Thus, we conducted the following steps: for the main analysis- we calculated the immunization coverage for all the children in the cohort with the assumption that all children should have received 2 doses of varicella vaccine. For *sensitivity analysis*- reanalyzed the varicella immunization coverage for the children born in between Jan 1, 2008 and Aug 1, 2008 based on the assumption that these children only need one dose of varicella vaccine, while children born after Aug 1, 2008 need two dose of varicella vaccine. This was due to a vaccine schedule change midway through the cohort year.

This study obtained ethics approval from the University of Alberta Health Research Ethics Board, under study title "Change in vaccination status over time in a population-based cohort: Coverage and determinants of immunization at pre-school and school entry", study ID Pro00078832. For the privacy and confidentiality of the individuals, no personal identifying information was provided to the researcher.

Results

Immunization coverage for each vaccine and for all vaccines combined were significantly higher at the end of grade 1 as compared to at the start of kindergarten (see Table 2). The vaccines that have doses scheduled for 4-6 years of age (i.e. DTaP-containing vaccine and MMRV) had significantly higher immunization coverage at the end of grade 1 compared to kindergarten entry. For DTaP-containing vaccine, 81.7% (95% CI 81.4-82.1) of the children were completely immunized at the end of Grade 1, whereas only 47.5% (95% CI 47.0-48.0) were completely immunized at kindergarten entry. Similarly, for MMR/MMRV, 82.8% (95% CI 82.5-83.2) of the children were completely immunized at the end of grade 1, while 49.1% (95% CI 48.6-49.5) were completely immunized at kindergarten entry. According to the main analysis for varicella vaccine, 78.4% (95% CI 78.0-78.8) of the children were completely immunized at the end of Grade 1, while 44.2% (95% CI 43.7-44.7) were completely immunized at kindergarten entry. Children at the end of Grade 1 saw slightly higher coverage for PCV vaccine than at the start of kindergarten, i.e. 85.2% (95% CI 84.8- 85.5) and 84.1% (95% CI 83.8-84.5) respectively. Only for Men C coverage, no significant difference was seen between children at the end of grade 1 (87.0%, 95% CI 86.7-87.3) and at the start of kindergarten (87.0%, 95% CI 86.6-87.3). For all vaccines combined, children at the end of grade 1 had statistically significantly higher immunization coverage compared to kindergarten entry children (main analysis: 72.4%, 95% CI

72.0-72.8 versus 41.7%, 95% CI 41.2-42.2) and (sensitivity analysis: 74.8%, 95% CI 74.3-75.2 versus 44.5%, 95% 44.0-45.0), respectively.

Table 3 presents the characteristics of study children according to their immunization status, categorized as complete at kindergarten entry; incomplete at kindergarten entry, but complete at the end of grade 1; and still incomplete at the end of grade 1. For all three groups, the majority of children had ≤1 household move, but the proportion was highest for children who were complete at kindergarten entry (84.4%); slightly lower for those who were incomplete at kindergarten entry, but complete at the end of grade 1 (82.9%); and lowest for children who were still incomplete at the end of grade 1 (79.5%). Similarly, for maternal marital status, most of the children had a married mother, but the proportion was highest for children who were complete at kindergarten entry (79.5%); slightly lower for those who were incomplete at kindergarten entry, but complete at the end of grade 1 (74.9%); and lowest for children who were still incomplete at the end of grade 1 (68.8%). Most of the children were the only child in the household at the time of birth, but the proportion was highest for children who were complete at kindergarten entry (48.1%); slightly lower for those who were incomplete at kindergarten entry, but complete at the end of grade 1 (42.4%); and lowest for children who were still incomplete at the end of grade 1 (39.6%).

Table 4 explores the factors associated with the immunization status categorized as: complete at kindergarten entry (reference group); incomplete at kindergarten entry, but complete at the end of grade 1 (group 1); and still incomplete at the end of grade 1 (group 2). As compared to children who were complete at kindergarten entry, the odds of being incomplete at kindergarten entry, but complete at the end of grade 1 increased with an aOR of 1.33 (95% CI 1.26-1.32) in children whose mother were not married than the children whose mother were

married. The odds of being still incomplete at the end of grade 1 increased even more in children whose mother's were not married than the children whose mother's were married with aOR of 1.58 (95% CI 1.49-1.68). As compared to children who were complete at kindergarten entry, the odds of being incomplete at kindergarten entry, but complete at the end of grade 1 increased with the increasing number of the children in a household, i.e., 2, 3, and >=4 with aOR of 1.26 (95% CI 1.19-1.32), 1.44 (95% CI 1.34-1.55), and 1.61 (95% CI 1.45-1.78), respectively. Likewise, the odds of being still incomplete at the end of grade 1 increased even more with an increasing number of children in a household, i.e., 2, 3, and >=4 with aOR of 1.33 (95% CI 1.26-1.41), 2.04 (95%CI 1.89-2.21), and 3.82 (95% CI 3.47-4.21), respectively. As compared to children who were complete at kindergarten entry, the odds of being incomplete at kindergarten entry, but complete at the end of grade 1 decreased in children from the lowest income (Q1) families compared to the children from the highest-income families with an OR of 0.87 (95% CI 0.81-0.93). In contrast, the odds of being still incomplete at the end of grade 1 increased in children from the lowest income families compared to the children from the highest-income families with an aOR of 1.12 (95% CI 1.04-1.21). Compared to children who were complete at kindergarten entry, the odds of being incomplete at kindergarten entry, but complete at the end of grade 1 slightly increased in children who had moved residence 2 times or more with aOR of 1.07 (95% CI 1.00-1.14) and P value of 0.04 than the children who had moved residence 1 time or less. The odds of being still incomplete at the end of grade 1 increased in children who had moved residence 2 times or more with aOR of 1.14 (95% CI 1.07- 1.22) than the children who had moved residence 1 time or less. Compared to physician delivery at a hospital, those with a midwife delivery at a hospital had 3.58 (95% CI 2.77-4.62) higher odds of being still incompletely immunized at the end of grade 1. This was even higher for midwife delivery at

home (aOR 11.52, 95% CI 7.91-16.80). Compared to children who were complete at kindergarten entry, the children who were incomplete at kindergarten entry, but complete at the end of grade 1 were more likely to have a mother under 21 years old than a mother over 40 years old (aOR 1.33, 95% CI 1.07-1.66). Likewise, the children who were still incomplete at the end of grade 1 were more likely to have a younger mother than a mother >40 years old; children of a mother <21 old had an aOR of 2.01 (95% CI 1.6-2.50), and children of mother 21-25 years old had an aOR of 1.48 (95% CI 1.20-1.81). Gestational age and sex of a child were not associated with the immunization status.

Discussion

This is the first study to assess the immunization coverage of children at kindergarten entry in Alberta, as well as to assess the factors associated with incomplete immunization status at the start of kindergarten and those who remain incompletely immunized at the end of grade 1.

Immunization coverage for each vaccine and for all vaccines combined

The immunization coverage rate for most individual vaccines and all vaccines combined was significantly increased at the end of grade 1 compared to kindergarten entry. The reason behind the increase in coverage rate at the end of grade 1 is likely because of the catch-up immunization program in which PHNs review immunization records of students in grade 1, send immunization consents home for missing immunizations, and administer immunizations in school in an effort to catch-up children on their vaccines. Any child who has an incomplete immunization record on file is contacted up to three times and are offered vaccines that they are missing.[12] Even though the coverage at the end of grade 1 increased compared to kindergarten entry, there were still some children that remained incompletely immunized at the end of grade 1.

The exception to this notable increase at the end of grade 1 was Men C and PCV vaccines. Specifically, there was no significant difference in coverage rate for Men C vaccine and there was a slightly higher coverage rate for PCV vaccine at the end of grade 1, as compared to kindergarten entry. This may be due to the fact that the last dose for Men C and PCV vaccines are due at 12 months and 18 months, respectively.

Factors associated with children having an incomplete immunization status

We identified that maternal characteristics (not married and young mothers) were associated with the child having an incomplete immunization status at kindergarten entry and the end of grade 1. These findings were consistent with previous studies that maternal characteristics (young and not married) are strongly associated with under-immunization among children.[6,8,13] Consistent with the previous studies,[5,8,14] we found a large number of children in a household and a greater number of household moves were also associated with incomplete immunization status at kindergarten entry. When many of these risk factors (i.e. young maternal age, single mother, multiple household moves, and a large number of children in a household) are present at the same time it can signal a chaotic life with many competing priorities.[8] These variables together create challenges for parents attending the immunization appointment. These variables are non-modifiable; however, interventions may be able to improve immunization access for this group by providing additional reminders and immunization outreach services.[8,15,16]

Midwife assisted home and hospital delivery were significantly associated with children who were still incomplete for immunization at the end of grade 1. In previous studies, births attended by a midwife were linked with total non-immunization status.[8] We are unable to draw any conclusion from this study about the direction of this effect. It is uncertain if the mother's decision was influenced by the midwife's attitude and beliefs or if mothers who are likely to

refuse vaccines seek out midwife-attended births.[8,17] Midwives usually stay neutral and do not give advice on immunization, while leaving the decision up to parents.[18,19] Further research is needed in order to fully understand the perspective of midwives on immunization, and perspective of mothers (who prefer midwife delivery) on immunization for their children.

Unexpectedly, children from the lowest income families were more likely to be completely immunized at the start of kindergarten. We are not sure why this finding occurred. Subsequently, children from the lowest income families were more likely to be still incompletely immunized at the end of grade 1. Previous studies have contradictory findings on this issue. Some previous studies[8, 20] found that a low level of income is associated with incomplete immunization status, whereas another study has found no association.[21]

Strengths & Limitations

This study assessed immunization status of a cohort of children at two-time points: kindergarten entry and at the end of grade 1 after a catch-up immunization program was offered. This gave insight on immunization coverage of the same cohort before and after the immunization catch-up program. This study used administrative health data for a population-based provincial birth cohort with a single immunization delivery and record-keeping system. This ensured that our dataset contained complete childhood immunization records.

There were some limitations of this study. The results are not generalizable to First Nations children, because Imm/ARI did not have complete immunization information for these children. There are various projects in progress with First Nation's communities for the sharing of immunization information.[22] Currently 8 of 44 First Nations communities are submitting immunization information using real time integration to Alberta Health. So hopefully in the future these children can be included in similar analyses.

Another limitation of this study was the children born between Jan 1. 2008 and the cut-off point for school entry (March 1, 2008) may have been in kindergarten a year ahead of the children born on or after March 1, 2008. We assessed immunization coverage of children at September 1, 2013, assuming that most of the children had started kindergarten at this point. However, children born in January and February 2008 may already be in grade 1 in September 1, 2013, and thus might have already been caught up on their vaccines by PHNs. Therefore, this study results may have overestimated coverage rate at kindergarten entry.

The dataset used for this study did not contain information regarding the history of varicella disease. This was important because children with previous disease history did not need varicella vaccine. Therefore, some children who were classified as incomplete for varicella vaccine might not actually need the vaccine. However, this was likely a small number of children, given that varicella disease was no longer circulating in the community due to the success of the immunization program.[23]

There were other exposure variables based on previous literature, such as maternal education, geographical location, residence[13,14] that we would like to examine, but we were limited to the variables available in the dataset. Even though we did not have all possible variables influencing immunization coverage, we had the ability to assess the immunization coverage and identify some key variables influencing immunization status.

Some specific events (e.g. awareness campaigns, outbreak and immunization campaigns, media campaigns) might have occurred between our first assessment (age 5) and second assessment (age 7). This event might have triggered a change in the immunization coverage between age 5 and age 7. Therefore, this study had the possibility of having historical effect which might have influenced immunization coverage.

Conclusion

Our study has highlighted that the immunization coverage of children at the end of grade 1 is higher after a school based catch-up immunization program was introduced than for the children at kindergarten entry. This suggests that the school-based catch-up immunization program that is ongoing in Alberta is very effective in increasing the immunization coverage among children. However, it also identifies that vaccine coverage at kindergarten entry is far below optimal levels to prevent spread of vaccine preventable diseases. Thus, we recommend that immunization policies and programs provide school based catch-up immunizations for children at the start of kindergarten, when children are at high risk. This study also highlighted some of the significant factors associated with a child having an incomplete immunization status at the start of kindergarten. Better understanding these factors allows for targeting of immunization strategies and programs to reach children most likely to be under-immunized. Due to the limited availability of exposure variables, we suggest the need of further research on many other exposure variables that were not included in this study.

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Table 1: Alberta recommended routine pre-school childhood immunization schedule that applies to a 2008 birth cohort

Vaccines	2 months	4 months	6 months	12 months	18 months	4 -6 years [b]	Total Doses
Diphtheria, Tetanus, Acellular Pertussis, Polio, *Haemophilus influenzae* type b (DTaP-IPV-Hib)	X	X	X		X	X (does not contain Hib)	5
Pneumococcal Conjugate (PCV)	X	X	X		X		4
Meningococcal Conjugate (Men C)	X	X		X			3
Measles, Mumps, Rubella (MMR)				X			1
Varicella [a]				X			1
MMR or MMRV [a]						X	1
						15	

[a] This schedule reflects changes to the vaccine schedule that occurred in 2012 that applies to the 2008 birth cohort. Specifically, the 2nd dose of Varicella was added for 4-6 year old children in Aug 1, 2012. Therefore, children who turned 4 years old before Aug 1, 2012 would not be eligible to receive a second dose of varicella vaccine, and thus would have received MMR vaccine instead of MMRV

b Although these doses are offered to children at 4-6 years of age, it is recommended that they receive them before they begin school, in order to ensure that they are fully protected.

Table 2: Immunization coverage of children at the start of kindergarten and at the end of grade 1

Immunization Type	Coverage Rate [a]	
	K No., % (95 CI)	G1 No., % (95 CI)
DTaP-containing vaccine	19,724, 47.5% (47.0- 48.0)	33,933, 81.7% (81.4-82.1)
MMR/MMRV	20,370, 49.1% (48.6- 49.5)	34,383, 82.8% (82.5-83.2)
Men C	36,106, 87.0% (86.6-87.3)	36,124, 87.0% (86.7-87.3)
PCV	34,932, 84.1% (83.8-84.5)	35,361, 85.2% (84.8-85.5)
Varicella (Main analysis)	18,340, 44.2% (43.7-44.7)	32,530, 78.4% (78.0-78.8)
Varicella (Sensitivity analysis)	28,163, 67.8% (67.4-68.3)	36,050, 86.8% (86.5-87.2)
All Vaccines (Main analysis)	17,308, 41.7% (41.2-42.2)	30,057, 72.4% (72.0-72.8)
All Vaccines (Sensitivity analysis)	18,478, 44.5% (44.0-45.0)	31,041, 74.8% (74.3-75.2)

[a] Denominator used to determine the coverage rate is 41,515 which includes all children in the cohort (i.e. those who received all doses, some doses, and no doses).

Table 3: Characteristics of children according to their immunization status

Variables	Category	Complete at K entry n (%) *N=17,308*	Incomplete at K entry, but complete at the end of G1 n (%) *N= 12,749*	Still incomplete at the end of G1 n (%) *N= 11,458*
Sex of child	Male	8826 (51.0)	6629 (52.0)	5914 (51.6)
	Female	8482 (49.0)	6120 (48.0)	5544 (48.4)
Number of children in a household (including index child)	1	8330 (48.1)	5400 (42.4)	4540 (39.6)
	2	6048 (34.9)	4705 (36.9)	3709 (32.4)
	3	2048 (11.8)	1800 (14.1)	1809 (15.8)
	>=4	882 (5.1)	844 (6.6)	1400 (12.2)
Household moves	<=1	14609 (84.4)	10567 (82.9)	9108 (79.5)
	>=2	2699 (15.6)	2182 (17.1)	2350 (20.5)
Income quantile	Q5 (highest)	4015 (23.2)	3057 (24.0)	2279 (19.9)
	Q4	3709 (21.4)	2709 (21.2)	2325 (20.3)
	Q3	3045 (17.6)	2326 (18.2)	2004 (17.5)
	Q2	3247 (18.8)	2347 (18.4)	2284 (19.9)
	Q1 (lowest)	3292 (19.0)	2310 (18.1)	2565 (22.4)
Maternal age	<21	1102 (6.4)	946 (7.4)	1286 (11.2)
	21-25	2810 (16.2)	2066 (16.2)	2309 (20.2)
	26-30	6125 (35.4)	4386 (34.4)	3746 (32.7)
	31-35	5028 (29.1)	3708 (29.1)	2857 (24.9)
	36-40	1982 (11.5)	1470 (11.5)	1066 (9.3)
	>40	261 (1.5)	173 (1.4)	194 (1.7)
Maternal marital status	Married	13751 (79.5)	9541 (74.9)	7849 (68.6)
	Not married	3550 (20.5)	3197 (25.1)	3585 (31.4)
Maternal term	Term or more	16054 (92.8)	11852 (93.0)	10626 (92.7)
	Pre-term	1254 (7.2)	897 (7.0)	832 (7.3)
Birth attendant _location	Physician at hospital/other & other at hospital/ en route	17162 (99.2)	12603 (98.9)	11014 (96.1)
	Midwife at hospital/en route	93 (0.5)	87 (0.7)	177 (1.5)
	Midwife at home/other	32 (0.2)	36 (0.3)	207 (1.8)
	Other at other	21 (0.1)	23 (0.2)	60 (0.5)

Table 4: Multinomial logistic regression of factors associated with immunization status

Complete at K entry (ref)	Incomplete at K entry, but complete at the end of G1 OR (95% CI)	P-value	Still Incomplete at the end of G1 OR (95% CI)	P-value
Not married (ref=Married)	1.33 (1.26-1.42)	<0.001	1.58 (1.49-1.68)	<0.001
No. of children in a household (including index child) (ref=1)				
2	1.26 (1.19-1.32)	<0.001	1.33 (1.26-1.41)	<0.001
3	1.44 (1.34-1.55)	<0.001	2.04 (1.89-2.21)	<0.001
>=4	1.61 (1.45-1.78)	<0.001	3.82 (3.47-4.21)	<0.001
Income (ref= Q5)				
Q4	0.95 (0.88-1.01)	0.11	1.07 (0.99-1.15)	0.08
Q3	0.97 (0.90-1.04)	0.36	1.03 (0.95-1.11)	0.48
Q2	0.91 (0.84-0.97)	0.007	1.08 (1.00-1.16)	0.06
Q1(lowest)	0.87 (0.81-0.93)	<0.001	1.12 (1.04-1.21)	0.03
Maternal term				
Pre-term (ref=term or more)	0.97 (0.89-1.06)	0.48	1.004 (0.91-1.10)	0.94
Sex of child				
Female (ref=male)	0.96 (0.92-1.01)	0.09	0.97 (0.92-1.02)	0.22
No. of moves (ref= <=1)				
>=2	1.07 (1.00-1.14)	0.04	1.14 (1.07-1.22)	<0.001
Attendant/Location (ref =Physician/Other at hospital & other/ hospital & en route)				
Midwife at hospital/en route	1.32 (0.98-1.77)	0.07	3.58 (2.77-4.62)	<0.001
Midwife at home/other	1.51 (0.94-2.44)	0.09	11.52 (7.91-16.80)	<0.001
Other at other	1.38 (0.75-2.54)	0.30	3.4 (2.38-6.68)	<0.001
Maternal age (ref= >40)				
<21	1.33 (1.07-1.66)	0.01	2.01 (1.6-2.50)	<0.001
21-25	1.19 (0.97-1.45)	0.10	1.48 (1.20-1.81)	<0.001
26-30	1.18 (0.97-1.43)	0.11	1.10 (0.90-1.34)	0.34
31-35	1.18 (0.97-1.44)	0.10	0.95 (0.78-1.16)	0.62
36-40	1.16 (0.95-1.42)	0.16	0.83 (0.68-1.02)	0.08

Chapter III: Discussion

This last chapter closes the thesis with a discussion of nursing implications and recommendations arising from this study, potential study strengths and limitations, followed by knowledge translation activities and a general conclusion.

Implications & Recommendations

The work we have carried out has clear nursing implications, new insight regarding policy, practice, and future direction for research.

Immunization Status of Children at the Start of Kindergarten

The first major significance of this study is that it has provided information on the proportion of children who are completely and incompletely immunized at the start of kindergarten. This information is important because, at kindergarten, children are surrounded by a lot of other children for the first time. This increases their risk of acquiring vaccine preventable diseases if they are not completely immunized.[1] This study showed that immunization coverage of children at entry to kindergarten is low, thus there are actions to be taken in order to address this problem. PHNs can advocate to improve this immunization coverage at an individual level. For instance, PHNs can educate parents on the importance of immunization and encourage parents to completely immunize their children at the start of kindergarten. This identified problem also provides a basis for consideration for adopting a model for mandating complete immunization of children at kindergarten entry in Alberta. In Australia and the USA, the mandatory childhood immunization model has increased coverage rates of children at school entry level.[2,3,4] It also provides a basis for consideration of adopting an incentive-based model. Based on a systematic review [5] monetary as well as non-monetary incentives results in an improvement in childhood immunization coverage.

Immunization Coverage of Children Before and After Catch-up Immunization Program

Based on the findings of the study, the school-based immunization catch-up program that is underway in Alberta is an effective strategy to increase immunization coverage among children in grade 1. It also identified that immunization coverage at entry to kindergarten is far below optimal levels to prevent the spread of vaccine preventable diseases. We recommend that immunization policies and programs provide school based catch-up immunization opportunities for children at the start of kindergarten, when children are at high risk. PHNs are the ones who review children and catch-up on their vaccines. Thus, PHNs could play a vital role in advocating for policy changes to shift the school based catch-up program from grade one to kindergarten

Characteristics of Children who are Incompletely Immunized at the Start of Kindergarten

This study also pointed out certain groups of children that are at particularly high risk for less than optimal immunization. This information allows targeting of programs to children most likely to be under-immunized. For instance, programs could be targeted for children whose mothers are young, unmarried, are from the lowest income families, move residence multiple times, and have many siblings. PHNs can take a leadership role and target these high-risk groups by sending reminders to the caregiver on their immunization appointment. Immunization reminder strategy has been found to be effective in improving immunization coverage rate.[6] For these high-risk groups, immunization access may be the barrier, thus some other strategies such as opening immunization clinics for longer hours, offering weekend hours for immunization, promoting immunization outreach teams, and developing immunization awareness campaigns might be effective in increasing access to immunization services.

Births attended by a midwife are linked with total non-immunization status. For this group PHNs can educate mothers as well as midwives on the importance of having an up-to-date

immunization status. Although an education campaign is not sufficient to increase immunization uptake,[7] it can be an initial step.

Study Strengths & Limitations

This is the first study to assess the immunization coverage for children at kindergarten entry in Alberta, as well as to assess the factors that contribute to children having an incomplete immunization status at the start of kindergarten and at the end of grade 1 after a school immunization catch-up program is offered. This study also used administrative health data with single immunization administration model for the infant/preschool and school immunization program and one immunization data submission mechanism to the provincial immunization administrative data system.

This study was guided by the WHO Model of vaccine uptake/hesitancy,[8] developed by the Strategic Advisory Group of Experts (SAGE) on immunization. It is important to assess all three components of the WHO model, in order to completely measure the model. Due to the limited availability of exposure variables in our dataset, we were not able to look at all components. Therefore, we suggest the need of further research on many other exposure variables [9,10,11] that were not examined by this study.

Our study design did not account for the non-independence of observations between the two-time points, i.e. the same children were being assessed at the start of kindergarten and again at the end of grade one. However, we performed two sets of cross-sectional analyses, i.e., at the start of kindergarten and at the end of grade one, thus independence of observations was not a necessary requirement.

In some immunization contexts, there is variation between immunization practice and record keeping between public health centers and between regions, in which case, analyses

would be expected to account for this clustering. This is not applicable in this study, as, in the Alberta context, there is minimal/no variation in immunization practice and record keeping across the province. The government of Alberta pays for all provincially funded vaccine as per the Alberta Childhood Immunization Schedule. Alberta Health develops the Alberta Immunization Policy and AHS develops immunization standards for all public health vaccination programs. There are immunization data submission guidelines with business rules to limit immunization data reporting errors.

In all our analyses, we excluded children who died or had health care cancellation by age 7. The total number of children who died before 7 years of age is minimal (i.e. approximately 300), so our study findings are likely not biased by excluding them. However, the total number of children who moved out of province before 7 years of age is approximately 3500, and we didn't know if these children received immunization from other provinces/countries. This introduces the potential for bias, as we don't know whether the immunization coverage of the excluded children is different from the included children. The immunization coverage of children may be underestimated, if the children who moved away received immunization from other provinces or countries; in contrast, the immunization coverage of children may be overestimated, if the children who moved away did not receive immunization from other provinces/countries.

Knowledge Translation (KT) Activities

At the end of this study, we will disseminate the findings using various KT strategies. For policy advisors, we will share findings via a written report and offer a presentation at the Ministry of Health staff. This process will help to spread study findings and aid policy advisors and policy makers in decision making and guide in policy development. For instance, given that the immunization coverage was low for children at the start of kindergarten compared to the

children at the end of grade one, we will recommend that school based catch-up immunizations be offered to students at the start of kindergarten rather than in grade one. Some of the identified risk factors to having an incomplete immunization status at kindergarten entry can be used to target interventions or strategies, and help shift the policy/program focus to these children and their parents (e.g. targeting programs for children whose mother's are young, children whose mother's are single/divorced, households with lots of children etc.). For medical professionals, PHNs, and researchers, we will share the findings through presentations such as grand rounds or inservices. We will disseminate findings by publishing in a peer-reviewed journal, and presenting at national and/or international conference(s). Thus, these dissemination strategies will help to spread the study findings to support potential policy and operational changes.

Conclusion

In this thesis it was determined that immunization coverage of children at the start of kindergarten is sub-optimal. It also highlighted the risk factors associated with the child's immunization status. Nurses have an important role in advocating for individuals regarding the importance of having an up to date immunization status at kindergarten entry. It emphasizes the need to review the timing of the school-based grade 1 catch-up immunization program. There may also be a need for implementing: an incentive-based model for encouraging parents to completely immunize their children at kindergarten entry; or a mandatory immunization model for mandating complete immunization of children at kindergarten entry. Moreover, further research is needed on many other exposure variables that were not examined by this study, in order to better understand other factors that result in children having an incomplete immunization status at kindergarten entry.

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Full Thesis References

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Appendix A: Sensitivity analysis for varicella immunization