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SYSTEMATIC REVIEW

Vaccine hesitancy among parents of preschoolers in Canada: a systematic literature review

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Abstract

Objectives The purpose was to synthesize the available literature on what factors influence vaccine hesitancy of parents of preschoolers in Canada.

Methods Databases (e.g., CINAHL, PubMed, OVID, Proquest) were searched for relevant research articles produced between January 2009 and October 2019. Articles were required to examine vaccine uptake in children aged 0–7, in the English language, and focused within a Canadian context. Articles were excluded if they focused on uptake of the influenza vaccine and if the study population was children with chronic health conditions. A total of 367 articles were reviewed and 12 met the criteria for inclusion in this review.

Synthesis This review found that between 50% and 70% of children are completely vaccinated at 2 years old, with up to 97% having received at least one vaccine, and 2–5% receiving no vaccines. This review found that trust and access to health care providers is significantly associated with vaccine uptake, likely more important than parents' vaccine knowledge, and may compensate for challenges related to socio-economic status and family dynamics.

Conclusion Vaccine programs need to be created that are accessible to all families, with an awareness of the significant impact of trust on vaccine uptake. Future research should include consistent measures of vaccine uptake, and data from First Nation communities, and should examine how increased trust between health care providers and parents of preschool children would increase vaccine uptake in Canada.

Résumé

Objectifs Synthétiser la documentation disponible sur les facteurs qui influent sur l'hésitation vaccinale des parents d'enfants d'âge préscolaire au Canada.

Méthode Des bases de données (CINAHL, PubMed, OVID, Proquest) ont été interrogées pour recenser les articles de recherche pertinents produits entre janvier 2009 et octobre 2019. Les articles devaient porter sur les taux de vaccination des enfants de la naissance à 7 ans, être rédigés en anglais et se concentrer sur le contexte canadien. Ont été exclus les articles portant sur les taux de vaccination contre l'influenza et ceux dont la population étudiée était constituée d'enfants atteints de problèmes de santé chroniques. Sur les 367 articles examinés, 12 répondaient aux critères d'inclusion dans notre revue systématique.

Synthèse Selon la revue, entre 50 et 70 % des enfants sont entièrement vaccinés à l'âge de 2 ans, jusqu'à 97 % ont reçu au moins un vaccin, et entre 2 et 5 % n'en ont reçu aucun. La confiance envers les professionnels de santé et l'accès à ces professionnels présentent une corrélation significative avec les taux de vaccination; cette confiance et cet accès sont probablement plus importants que les connaissances des parents sur les vaccins, et ils pourraient compenser les difficultés liées au statut socioéconomique et aux dynamiques familiales.

Electronic supplementary material The online version of this article (https://doi.org/10.17269/s41997-020-00390-7) contains supplementary material, which is available to authorized users.

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Conclusion Il faudrait créer des programmes de vaccination accessibles à toutes les familles en tenant compte de l'effet significatif de la confiance sur les taux de vaccination. Les études futures devraient inclure des mesures cohérentes des taux de vaccination et des données provenant des communautés des Premières Nations, et elles devraient chercher à déterminer si une confiance accrue entre les professionnels de santé et les parents d'enfants d'âge préscolaire ferait augmenter les taux de vaccination au Canada.

Keywords Vaccine hesitancy · Acceptance · Uptake · Preschool immunizations · Canada · Systematic review

Mots-clés Hésitation vaccinale · acceptation des vaccins · taux de vaccination · immunisations préscolaires · Canada · revue systématique

Introduction

Vaccines are a safe and effective way to prevent communicable and infectious diseases (Public Health Agency of Canada 2007). In Canada, vaccines have nearly eradicated diseases such as measles, polio, rubella, diphtheria, tetanus, mumps, invasive meningococcal diseases, and haemophilus influenza B (Public Health Agency of Canada 2017). These diseases predominantly affect young children, infants, and unborn children (Public Health Agency of Canada 2007) and vaccines are therefore an essential part of a global strategy to reduce child mortality and morbidity (Andre et al. 2008). Worldwide, vaccinations prevent an estimated 2–3 million deaths annually from infectious diseases (World Health Organization 2018). However, it is estimated that a further 1.5 million deaths per year could be prevented with improved global vaccination coverage (World Health Organization 2019).

One prominent issue in the uptake of vaccines is "vaccine hesitancy", defined as "a delay in acceptance or refusal of vaccines despite availability of vaccination services" (SAGE Working Group 2014). As a result, children whose parents refuse vaccines and other members of their community are at risk of acquiring highly contagious vaccine-preventable diseases (VPDs) (Siddiqui et al. 2013). While vaccine hesitancy has been present in Canada since the 1800s (MacDougall and Monnais 2017), there has been an increase reported in the last few years by parents and health care providers (Wilson et al. 2015; Dubé et al. 2016a).

Vaccine hesitancy in Canada has contributed to a resurgence of pertussis and measles. While pertussis has not been completely eliminated in Canada (Public Health Agency of Canada 2014), outbreaks are more significant in under-immunized areas (Wierzbowski 2017) and continue to cause one to four infant deaths each year in Canada (Public Health Agency of Canada 2014). Endemic measles in Canada was eliminated in 1998 but imported cases continue to prompt outbreaks, affecting those who are under-immunized or immunocompromised (Public Health Agency of Canada 2016b). Between 2002 and 2006 there were fewer than 20 measles cases per year; however, this has increased to more than 60 cases annually in seven of the last twelve years (De Serres et al. 2015; Public Health Agency of Canada 2019, 2020b).

Declining immunization rates provide additional evidence of vaccine hesitancy in Canada. While most preschool children in Canada receive vaccinations, the number of children who have not received any vaccinations by age two increased between 2013 and 2017 from 1.5% to 2.3% (Health Canada 2019; Public Health Agency of Canada 2016a). The results from the 2013 and 2017 Childhood National Immunization Coverage Survey (CNICS) show an 89–90% vaccination uptake by children at age two for measles, mumps, and rubella (MMR) and a 76–77% uptake for diphtheria, pertussis, and tetanus (Health Canada 2019; Public Health Agency of Canada 2016a). The number of children who have received the recommended vaccines by age seven is 87% for measles and 80% for diphtheria, pertussis, and tetanus (Public Health Agency of Canada 2020a). This is well below the 95% target to achieve community or herd immunity and shows a nearly 5% decrease in 2-year-old measles coverage from 2002 (Health Canada 2019; Public Health Agency of Canada 2004, 2007), leaving thousands of Canadian children potentially vulnerable to VPDs.

Canadian parents may be hesitant to have their children vaccinated for various reasons, including contextual, individual/group, and vaccine-specific influences (MacDonald 2015; SAGE Working Group 2014). International reviews of vaccine hesitancy, which include some Canadian data, indicate that parental socio-economic status (SES), education, finances, social and media influences, beliefs about vaccines, complacency, and perception of safety can all influence vaccine uptake (Bocquier et al. 2017; Dubé et al. 2013; Larson et al. 2014), but they represent a broad range of international factors and cannot be extrapolated to Canada. Our publicly funded health care and social welfare systems make discussions on vaccine hesitancy unique from American or European counterparts due to geographical, cultural, and demographic differences. Without understanding more about what makes parents in Canada hesitant to accept vaccines, it is impossible to address this growing concern. Although there are a few studies in Canada on vaccine hesitancy, there has not been a synthesis

of the literature to date. The purpose of this paper is to synthesize the available literature on what factors influence vaccine hesitancy of parents of preschoolers in Canada.

Methods

Search strategy

Articles published between January 2009 and October 2019 were searched using the following databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Public Health Database (Proquest), Medline (Ovid), and Scopus. Search terms were developed in conjunction with a Public Health librarian at the University of Saskatchewan, and each term was truncated to elicit variations. The search terms included were vaccine, immuniz(s)e, shot, jab, hesitant, reluctant, confidence, acceptance, reject, delay, comply, and uptake (further details shown in supplementary file). The inclusion criteria required articles to: be published in English; be focused within a Canadian context; report vaccination status (e.g., measles, mumps, rubella, varicella, diphtheria, tetanus, pertussis, haemophilus influenza B, meningococcal C, pneumococcal disease, rotavirus, hepatitis B) in children aged 0–7 according to provincial schedules; and examine independent risk factors for vaccine hesitancy, such as demographics, socio-economic indicators, and parental knowledge, attitudes, and beliefs regarding vaccines. Articles were excluded if they were qualitative or were focused on the influenza vaccine due to the seasonal nature of the vaccine program, or if the study populations were children with chronic health concerns, because vaccine requirements may be different than the routine recommendations for the general population.

Citations from the search results were imported into Zotero, a citation management program. The first search resulted in 367 articles (see Fig. 1). Two reviewers reviewed titles and abstracts; 84 duplicates were removed, as were 243 articles that did not meet the inclusion criteria. After reviewing the full texts of 40 articles, 31 were removed that did not meet the inclusion criteria. A review of the bibliographies of the remaining 9 articles resulted in 3 additional articles that met the inclusion criteria, resulting in a total of 12 articles.

Results

Study descriptions

As shown in Table 1, three studies used data from the CNICS (Carpiano et al. 2019; Gilbert et al. 2017; Perinet et al. 2018). This survey is administered every two years by Statistics Canada, asking parents to provide vaccine data, which is then verified by medical records (Statistics Canada 2019). This survey is stratified to represent the Canadian population but excludes children living on First Nation reserves and institutionalized children (Statistics Canada 2019). Three studies sampled provincial birth cohorts using medical records and socio-demographic data (Bell et al. 2015) or a combination of medical records, parental vaccine records, and surveys (Dummer et al. 2012; Kiely et al. 2018). However, Bell et al. (2015) excluded babies living on First Nation reserves in Alberta and Kiely et al. (2018) excluded data from the two northern regions in Quebec. One study used medical records and a parental survey data from Edmonton (MacDonald et al. 2014) and another used medical records and socio-demographic data from Winnipeg (Martens et al. 2014). Two studies sampled children who were accessing health services; one study used parental vaccine records for the sibling of a child with autism spectrum disorder (ASD) in Toronto, Halifax, and Hamilton (Kuwaik et al. 2014), and the other study used medical records and a parental survey in children who visited the emergency room in Quebec for gastritis (O'Donnell et al. 2017). Another study conducted an online survey of the Canadian population asking parents for vaccination status without vaccine details (Greenberg et al. 2017). Similarly, Dubé et al. (2016c) conducted a cross-sectional survey in Quebec asking parents about their children's vaccination status.

Sample sizes ranged from 200 to more than 170,000. The CNICS sample (Carpiano et al. 2019; Gilbert et al. 2017; Perinet et al. 2018) consisted of 52% male respondents; 24% had secondary education or less, 31.5% post-secondary, 42.2% university graduate; 19.7% had an income of less than $39,000, 44% between $40,000 and $99,999, 34.6% greater than $100,000; and 87% reported being married/common-law. The remainder of the studies had similar distributions with three studies reporting ethnicity as being largely Caucasian (Bell et al. 2015) with a smaller proportion of non-Caucasian respondents (24%) in one study (Kuwaik et al. 2014) and Aboriginal status (4.4%) in another study (MacDonald et al. 2014).

Vaccination status

Studies used various indicators to assess vaccine status. Studies whose samples were within one province assessed vaccine status according to the provincial recommendations (Bell et al. 2015; Dubé et al. 2016c; Dummer et al. 2012; Kiely et al. 2018; Kuwaik et al. 2014; MacDonald et al. 2014; Martens et al. 2014; O'Donnell et al. 2017). Studies using national-level data assessed vaccine status using specific vaccines that are routinely provided across Canada (i.e., measles or MMR) (Greenberg et al. 2017; Perinet et al. 2018) or a combination of measles and pertussis vaccines (Carpiano et al. 2019; Gilbert et al. 2017).

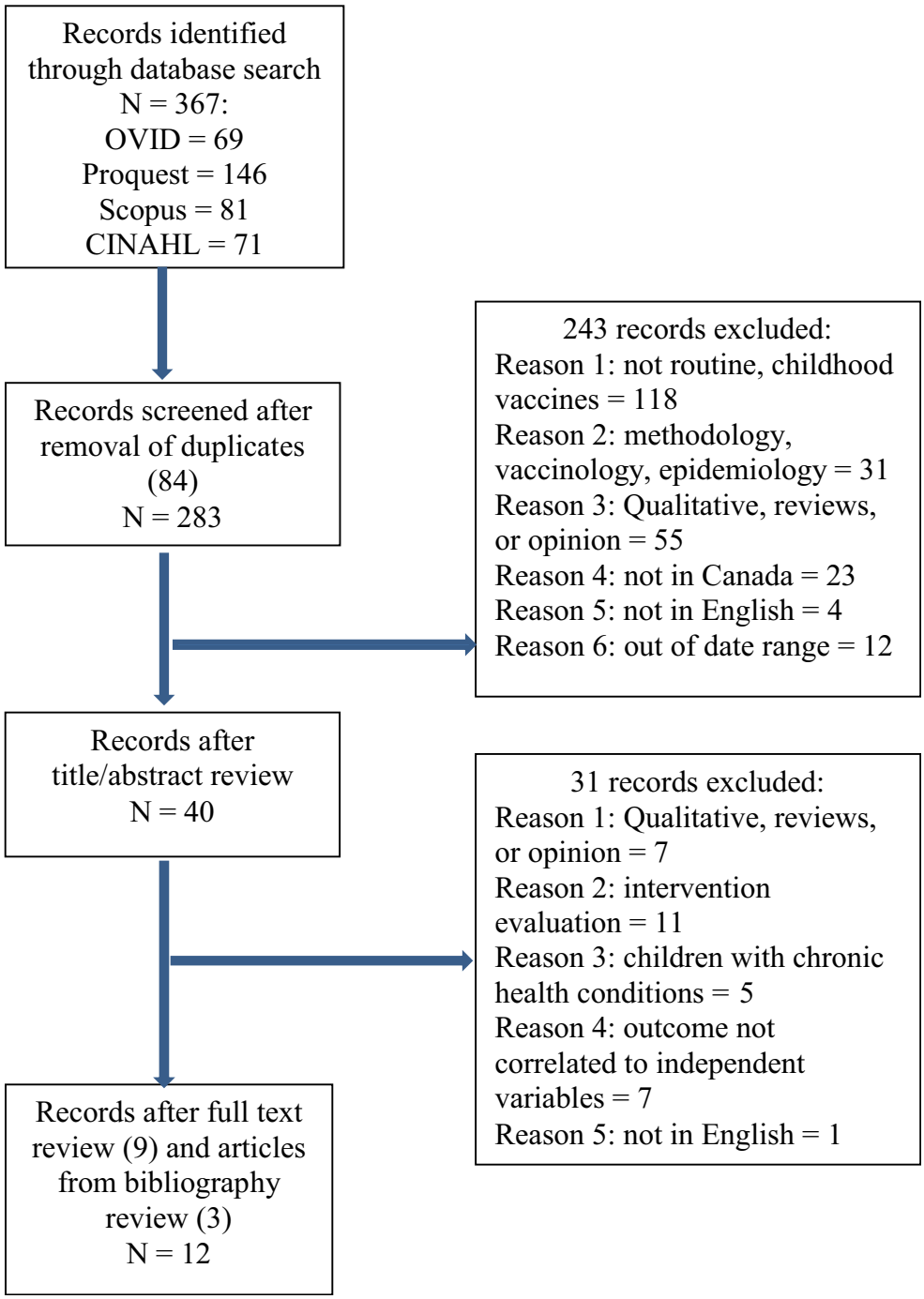

Fig. 1 Article search and screening process

Four articles found that complete vaccination status according to the full provincial vaccine schedule ranged from 50% to 71% at 2 years old (Bell et al. 2015; Dummer et al. 2012; Kiely et al. 2018; Martens et al. 2014). One additional study reported a complete vaccination rate of 80.4% in children; however, 59.8% of this sample were children 5–17 years old (Dubé et al. 2016c) which would allow more time to receive vaccines.

Studies using national-level data reported that 69% had complete vaccinations for measles (Perinet et al. 2018), 89.7–93% had at least one measles vaccine (Carpiano et al. 2019; Gilbert et al. 2017; Greenberg et al. 2017), and 95.3% had at least one pertussis vaccine (Gilbert et al. 2017) with 74% receiving all recommended pertussis vaccines by 7 years old (Carpiano et al. 2019).

Vaccine refusals ranged from 2.7% to 5.1% in 2-year-old children (Bell et al. 2015; Gilbert et al. 2017), 2.9% in 5-year-olds (Greenberg et al. 2017), and less than 2% in a sample with children from 1 to 17 years old, though vaccine refusal rates were not provided for those between 0 and

Table 1 Studies examining the association between independent variables on vaccine uptake

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
Bell et al. 2015 Exploring the heterogeneity among partially vaccinated children in a population-based cohort Alberta (AB)	$N = 43,965$ 2008 Alberta birth cohort	Data extraction from provincial vaccination repository, vital statistics registry, insurance plan database, and Alberta hospital discharge abstracts database for cohort at age 2	- Maternal age - Marital status - Gestational age - Family size - Household moves - Household income (quintiles) - Urban/rural residence - Birth attendant and location - NICU admission - Delivery type	Vaccination status: - Complete (all doses of all recommended vaccines for AB) - Incomplete (began but did not complete multi-dose series) - Selective (completed all doses of ≥ 1 vaccine, but no doses of others) - Non-vaccination (no doses of any vaccine)	71.1% completely immunized Incomplete vaccination (21.9%) predicted by: - Single mother (OR 1.58, 95% CI 1.49–1.67, $p < 0.001$) - Maternal age (odds of incomplete decrease with increased age, i.e.: 21–25 years (OR 0.71, 95% CI 0.64–0.79); 36–40 years (OR 0.40, 95% CI 0.35–0.45)) - ≥ 3 household moves (OR 1.69, 95% CI 1.35–2.10, $p < 0.001$) - ≥ 4 children in family (OR 3.24, 95% CI 2.95–3.54, $p < 0.001$) - Rural residence (OR 1.16, 95% CI 1.09–1.24, $p < 0.001$) - Midwife delivery at home (OR 4.66, 95% CI 3.21–6.76) Selective vaccination (2.0%) - 81.7% of selective vaccinators opted out of only 1 vaccine, usually varicella (88.2%) or MMR (24.2%) - Predicted by midwife delivery at home (OR 6.77, 95% CI 3.42–13.4, $p < 0.001$) - ≥ 4 children in family (OR 1.46, 95% CI 1.12–1.9, $p < 0.001$) Non-vaccination (5.1%) predicted by: - Midwife delivery at home (OR 51.7, 95% CI 37.1–72.1, $p < 0.001$) - Rural residence (OR 2.14, 95% CI 1.92–2.38, $p < 0.001$) - ≥ 4 children in family (OR 5.8, 95% CI 5.02–6.71, $p < 0.001$)
Carpiano et al. 2019 Socioeconomic status differences in parental immunization attitudes and child immunization in Canada: Findings from the 2013 Childhood National	$N = 3620$ Parents of 2-year-old children assessed for measles, mumps, and rubella (MMR) $N = 3465$	2013 Childhood National Immunization Coverage Survey (NICS) data analysis Response rate = 63.5% Immunization history confirmed by health care record for 33.1% of respondents	- Household income ($0–$19,999, $20k–$39,999, $40k–$59,999, $60k–$79,999, $80k–$99,999, $100k–$119,999, and ≥ $120k)	Vaccination status measured by: - 1 MMR dose at 2 years old OR - 5 doses of diphtheria, pertussis, and tetanus (DPT) by age 7	2-year-old/MMR subsample: - 7% had no MMR vaccine - Some post-secondary education predicted more MMR safety concerns (OR 2.06, 95% CI 1.43–2.98)

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
Immunization Coverage Survey (NCIS) Canada (national)	Parents of 7-year-old children assessed for diphtheria, pertussis, and tetanus (DPT)		- Parental education level (secondary or less, post-secondary, university graduate) - Knowledge, attitudes and beliefs (KABs) about vaccination (measured by assessing perceived importance of vaccinating and concern about side effects)	Mediation of KAB and SES or education level with vaccine outcomes	- Secondary education or less predicted 75% higher odds of vaccine side effect concerns, and 62% higher odds of concerns about MMR safety - Middle income had higher odds of MMR vaccine safety concerns ($60K: OR 1.7, 95% CI 1.02–2.83; $119K: OR 2.25, 95% CI 1.30–3.90) - Secondary education or less predicted not receiving minimum vaccine doses (measles: OR 1.78, 95% CI 1.02–3.10) - Concern about vaccine side effects predicted not receiving minimum MMR dose (125–130% higher for "very concerned" than "somewhat concerned" or "concerned") - Belief that MMR vaccine not important predicted not receiving minimum MMR dose (OR 1.19, 95% CI 1.03–1.38) Mediation: - Some post-secondary education (vs. university degree) associated with not receiving minimum MMR dose via strong side effect concerns - Middle income ($60k–$119k) associated with not receiving minimum dose via side effect concerns - Income $40k–$79K associated with not receiving minimum dose via belief in unimportance of MMR vaccination Age 7 DPT subsample: - 26% had < 5 doses of DPT vaccine - Vaccine safety concerns higher among lower income ($0–$19,999: OR 2.11, 95% CI

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					0.97–4.59; $40–$59,999: OR 2.42, 95% CI 1.32–4.41) - Secondary education or less predicted not receiving minimum doses (diphtheria: OR 1.45, 95% CI 1.00–2.09) - Some post-secondary education predicted not receiving minimum doses (diphtheria: OR 1.55, 95% CI 1.14–2.10) - Lack of confidence in vaccines predicted not receiving minimum DPT doses (OR 1.23, 95% CI 1.10–1.37) Mediation: none found
Dubé et al. 2016 Parental Vaccine Hesitancy in Quebec Quebec	$N = 589$ Parents (50.8% female): 18–34 years: 39.4% 35–44 years: 42.8% 45–49 years: 12.6% 50+ years: 5.2% Children's ages: - 1–4 (40.2%) - 5–17 (59.8%)	Telephone survey of parents Response rate = 35%	Knowledge, attitude, and beliefs toward vaccinations	- Self-reported immunization status of child ("all vaccines", "some vaccines" or "no vaccines") - Self-reported hesitation during vaccination decision ("yes", "no", "I do not know")	80.4% (95% CI 72.5–88.4) of sample fully immunized Not hesitant parents: - 95.3% (95% CI 91.2–99.4%) fully immunized - Trust vaccine information ($p < 0.023$) - Believe vaccines will prevent disease in their child ($p = 0.0111$) and in the community ($p = 0.006$) Hesitant parents (40.2% (95% CI 30.7–49.6) of sample): - 58.2% (95% CI 42.9–73.5) fully immunized - 39% accepted some vaccines - 2% refused all vaccines - 88% hesitant for only some vaccines: most frequently influenza, varicella, HPV, and rotavirus vaccine - Believe too many vaccines given ($p = 0.0242$) and vaccines weaken immune system ($p = 0.034$) - Feel pressure to vaccinate ($p = 0.0105$) - Fearful about vaccines ($p = 0.0111$) Incomplete vaccination status predicted by:

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					- Female survey respondent (OR 4.4, 95% CI 1.9–10.0, $p = 0.0005$) - Survey respondent 45 years or older (OR 4.8, 95% CI 1.8–12.9, $p = 0.0018$) - Household of 5 people or more (OR 6.1, 95% CI 2.1–18.2, $p = 0.0011$)
Dummer et al. 2012 Immunization Completeness of Children Under Two Years of Age in Nova Scotia, Canada Nova Scotia	$N = 8245$ 2006 Nova Scotia birth cohort	Data from provincial medical insurance physician billing data, public health records - Telephone survey of parent-held record to validate administrative data	- Unemployment rate - Parent education (quintiles) - Sex of child - Urban/rural residence - Household income (quintiles)	Immunization status calculated at 12, 18, and 24 months (mo.) (MMR=measles, mumps, rubella; DaPTP=diphtheria, pertussis, tetanus, and polio) - Up-to-date (UTD) - All vaccines given within 1 month of due date - Not UTD (> 1-month delay) - No immunizations	UTD - 12 mo.: MMR 66.4%; DaPTP-Hib 82.4% - 18 mo.: MMR 84.6%; DaPTP-Hib 49.4% - 24 mo.: MMR 85.9%; DaPTP-Hib 69.3% Not UTD: - 12 mo.: MMR 0.4%; DaPTP-Hib 14.4% - 18 mo.: MMR 0.4%; DaPTP-Hib 48% - 24 mo.: MMR 0.4%; DaPTP-Hib 28.5% No immunizations: - 12 mo.: MMR 33.1%; DaPTP-Hib 3.3% - 18 mo.: MMR 15.0%; DaPTP-Hib 2.6% - 24 mo.: MMR 13.7%; DaPTP-Hib 2.2% Completeness at 24 mo. predicted by ($p < 0.001$): - Region where PHNs and GPs provide vaccines (OR 2.1, 95% CI 1.9–2.4) - Communities with lower education (OR 2.0, 95% CI 1.7–2.3) and higher unemployment (OR 1.7, 95% CI 1.4–2.0) No variation in completeness for: - Child's sex - Urban/rural residence - Household income

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
Gilbert et al. 2017 Determinants of non-vaccination and incomplete vaccination in Canadian toddlers Canada (national)	$N = 5477$ Children $N = 5512$ Parents of 2-year-old children	2013 Childhood National Immunization Coverage Survey (CNICS) data analysis Response rate = 63.5% Immunization history confirmed by health care record for 33.1% of respondents	- Sex of child - Province - Child's place of birth - Parent education (secondary/trade certificate or less, post-secondary, university graduate) - Household income ($0–$39,999, $40–$59,999, $60–$79,999, ≥ $80k) - Marital status - Parent's place of birth	- Total non-vaccination - Non-vaccination for measles - Incomplete vaccination for pertussis (< 4 doses by age 2)	No vaccine history (2.7%) predicted by: - High school diploma, trade certificate, or less (OR 1.99, 95% CI 1.02–3.91, $p = 0.044$) - Living in: – Quebec (OR 2.43, 95% CI 1.15–5.15, $p = 0.015$) – Prairies (OR 5.18, 95% CI 2.83–9.47, $p < 0.0001$) – BC (OR 3.18, 95% CI 1.36–7.45, $p = 0.012$) Reasons cited for no vaccines: - Vaccine safety concern (56.4%) - Philosophical or religious reasons (32.8%) No measles vaccine (10.3%, includes children with no vaccine history) predicted by: - Living in: – Prairies (OR 2.66, 95% CI 1.69–4.20, $p = 0.000$) – BC (OR 2.06, 95% CI 1.20–3.54, $p = 0.040$) – Territories (OR 2.49, 95% CI 1.55–3.99, $p = 0.001$) - High school diploma, trade certificate, or less (OR 1.86, 95% CI 1.26–2.76, $p = 0.000$) - Household income < $40K (OR 1.84, 95% CI 1.26–2.68, $p = 0.002$); $40k–$59k (OR 1.70, 95% CI 1.06–2.72, $p = 0.027$) - Single-parent household (OR 1.63, 95% CI 1.01–2.61, $p = 0.043$) Incomplete pertussis vaccination (23.6%; 4.7% with no pertussis vaccine) predicted by: - Living in: - Prairies (OR 1.55, 95% CI 1.22–1.96, $p < 0.001$) - BC (OR 1.56, 95% CI 1.15–2.12, $p = 0.005$)

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					- Territories (OR 1.99, 95% CI 1.57–2.53, $p < 0.001$) - Child born outside Canada (OR 3.01, 95% CI 1.73–5.58, $p < 0.001$) - High school diploma, trade certificate, or less (OR 1.92, 95% CI 1.41–2.62, $p < 0.001$) - Annual income < $40k (OR 1.58, 95% CI 1.13–2.22, $p < 0.001$) or $40k–$59K (OR 1.47, 95% CI 1.04–2.07, $p = 0.001$)
Greenberg et al. 2017 Vaccine Hesitancy: In search of the Risk Communication Comfort Zone Canada (national)	$N = 1000$ Parents of children 5 years old or younger	Online survey Response rate = 89%	- Perceptions about vaccines and vaccine-preventable disease - Views on public vaccine debate - Information-seeking needs and practices - Opinion on risk communication strategies	MMR vaccination history (vaccinated or intentionally unvaccinated)	92% stated they had vaccinated their children; 6% had not vaccinated their children for MMR: - 2.1% children too young - 3.9% chose not to vaccinate due to fears about serious reactions (25%) and skepticism about vaccine effectiveness (11%) - 82–90% had good scientific knowledge of vaccines - 14% agreed that vaccines can cause autism and 14% were uncertain - 25% thought serious adverse reactions were likely - 44% thought vaccinating should be a personal choice - Most trusted health info sources are physicians, public health officials and academics (90% vaccinators, 55% non-vaccinators) - Distrust in drug companies higher among non-vaccinators (80%) than vaccinators (51%) Respondents opted for risk messages that emphasized vaccine safety, risk of vaccine-preventable disease, and effects of childhood disease. Vaccine-hesitant parents opted for risk communication that

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					emphasized choice, compassion, and honesty
Kiely et al. 2018 Impact of vaccine delays at the 2, 4, 6 and 12-month visits on incomplete vaccination status by 24 months of age in Quebec, Canada Quebec	Parents of 1- or 2-year-old children from 6 cohorts: - 2006 $N = 844$ - 2008 $N = 1282$ - 2010 $N = 1233$ - 2012 $N = 1459$ - 2014 $N = 1384$ - 2016 $N = 1295$	Mailed survey (vaccine status verified by medical records) Response rates: - 2006 = 70% - 2008 = 64% - 2010 = 62% - 2012 = 73% - 2014 = 69% - 2016 = 65%	Child: - Vaccine history - Omitted vaccines - Chronic disease - Daycare - Gestational age at birth - Birth order - Main vaccine provider Respondent: - Sex - Marital status Maternal: - Age at birth - Language - Birth country - Education level (<secondary, secondary, college, university) - Birth attendant	- Immunization status at 24 months of age for all recommended vaccines in Quebec (complete or incomplete) - Immunization delay (>30 days) at 2, 4, 6, 12, and 24 months - Immunization status attributable to delay	Vaccination status at 24 months (mo.): - In 2016, 50% complete with no delay (17% in 2006) - 46.4% of children with delay at 2 mo. were incomplete at 24 mo. - 11.1% of children with no delay at 2 mo. were incomplete at 24 mo. - 72.5% of incomplete vaccination at 24 mo. attributed to new delays at 2 mo. (16.1%), 4 mo. (10.6%), 6 mo. (14%), and 12 mo. (31.8%) Vaccination delay at 2 mo. predicted by: - Not receiving all recommended vaccines at appt (RR 4.28, 95% CI 3.18–5.77) - Not attending daycare (RR 1.48, 95% CI 1.20–1.84) - Not first child (RR 1.68, 95% CI 1.36–2.09) - Single parent (RR 1.48, 95% CI 1.07–2.05) - Higher level of maternal education protective against delay (RR 0.90, 95% CI 0.81–0.99) Vaccination delay at 6 mo. predicted by: - Not first child (RR 1.47, 95% CI 1.28–1.68) - Vaccine provided by medical clinic/hospital protective (RR 0.79, 95% CI 0.68–0.92) Vaccination delay at 12 mo. predicted by: - Not receiving all recommended vaccines at appt (RR 1.47, 95% CI (1.26–1.71) - Vaccine provided by medical clinic or hospital (RR 1.22, 95% CI 1.08–1.39)

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					- Premature at birth (RR 1.26, 95% CI 1.04–1.53)
Kuwaik et al. 2014 Immunization uptake in younger siblings of children with autism spectrum disorder Toronto, Hamilton, and Halifax	$N = 261$ ($n = 98$ children with autism spectrum disorder (ASD), $n = 98$ younger sibling ≤ 1 year, $n = 65$ community controls)	Prospective study on early development of ASD and childhood immunization records up to 3 years old	- Immunization status of older sibling (full, partial, or none)	- Younger sibling immunization status (full, partial, or none) - ASD or speech delay diagnosis in younger sibling	- 60.2% of younger siblings had at least 1 immunization delayed (48%) or declined (12.2%) - 76% of younger siblings with delayed immunizations had older sibling fully immunized on time - No MMR vaccine in 18% and no DPT vaccine in 13.3% of younger siblings by 3 years old - MMR delayed in younger siblings more often (43% immunized vs. 90% older siblings, Fisher's exact test = 80.82, $p < 0.001$) - 9.2% of controls had delayed immunizations, but were all fully immunized by 3 years - No relationship between immunization status and younger sibling diagnosis (MMR $p = 0.22$)
MacDonald et al. 2014 Parental concern about vaccine safety in Canadian children partially immunized at age 2: a multivariable model including system level factors Edmonton, Alberta	$N = 331$ Parents of completely immunized children $N = 113$ Parents of incompletely immunized children	Mailed survey	Parent/guardian: - Age - Place of birth - Marital status - Education level (<secondary, secondary, some post-secondary, post-secondary, college or trade certificate/diploma, undergrad degree, ≥ graduate degree) - Aboriginal status - Household income (<$40k, $40k–$59,999, $60k–$79,999, $80k–$99,999, $100k–$119,999, ≥ $140k) - Knowledge, attitudes, and beliefs - Children (< 18 years) in home (≥ 3)	Immunization status: - Complete (all recommended vaccines for AB) - Incomplete (missing 1 or more doses but not refusing all vaccines)	Incomplete immunization predicted by: - Residential move in last 2 years (OR 3.908, 95% CI 2.075–7.358) - "Too many needles at once" strong association with partial immunization (OR 7.734, 95% CI 2.598–23.025) - Immunizations a "big hassle" strong association (OR 14.470, 95% CI 2.206–34.922) but no specific items correlated (distance, wait time) - Concerns about vaccine safety (OR 2.829, 95% CI 1.151–6.957) - Lack of belief in disease susceptibility/severity (OR 4.629, 95% CI 2.017–10.625) Factors protective against incomplete immunization:

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
			- Social support available - Health issue in home - Move in previous 2 years - Child attending daycare		- Child attending daycare and primary caregiver working outside the home (OR 0.310, 95% CI 0.14–0.671) - Regular family doctor (OR 0.219, 95% CI 0.057–0.846)
Martens et al. 2014 The Effect of Neighborhood Socioeconomic Status on Education and Health Outcomes for Children living in Social Housing Winnipeg, Manitoba	$N = 13,238$ Children aged 0–9 living in social housing $N = 174,017$ Children aged 0–9 not living in social housing	Administrative data from population-based repository at Manitoba Centre of Health Policy for 2006–2007 and 2008–2009	Neighbourhood income quintiles (Q1 = ≤ $34,642, Q2 = $34,643–$48,525, Q3 = $48,526–$64,444, Q4 = $64,445–$77,264, Q5 = ≥ $77,265)	- Immunization status at 2 years - School readiness - Adolescent pregnancy - Grade 9 completion - High school completion	Children (≤ 2 years) in social housing are more likely to be incompletely immunized regardless of neighbourhood, but rate difference increases with increase in neighbourhood wealth 2-year-old children completely immunized: - 52.5% living in social housing - 67.8% all other children (60.2% in lowest income quintile, 72.3% in highest)
O'Donnell et al. 2017 Determinants of under-immunization and cumulative time spent under-immunized in a Quebec cohort Quebec	$N = 246$ Children 2–3 years presenting to emergency departments (EDs) with gastroenteritis from 2012 to 2014 Children whose parents refused all vaccines excluded from sample	Medical record analysis and telephone interview	Child: - Sex - Healthy - Prematurity - Ever breastfed - Daycare Parent/caregiver: - Age - Education level (< 12 years, college, university, graduate) - Household income (< $55k, $55k–$64,999, $65k–$75k, > $75k) - Marital status - Primary caregiver (mother/father) - Children (< 18 years) in home - Urgent care health service (family doctor, walk-in clinic, ED)	- Immunization status at 24 months (complete or incomplete for all recommended vaccines) - Delay of ≥ 6 mo. for 1 or more vaccines	- 73% UTD at 24 months old, 26% incomplete - 60% experienced delay for at least 1 vaccine (DTaP-VPI-Hib most likely to be incomplete) Completely immunized at 24 mo. predicted by: - First immunizations on time (OR 5.85, 95% CI 2.80–12.22, $p < 0.0001$) - Maternal education of high school or less (OR 2.01, 95% CI 1.39–2.90, $p < 0.0001$) Incompletely immunized at 24 mo. predicted by: - 3 or more siblings (OR 0.50, 95% CI 0.28–0.86, $p < 0.05$) - 18-mo. immunizations not given concurrently (etiological fraction 0.35; OR 3.61, 95% CI 2.47–4.39, $p < 0.0001$) - Delay > 6 mo. predicted by mother younger than 39 years at child's

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					birth (< 27 years OR 2.77, 95% CI 2.13–3.30; 26–39 years OR 2.13, 95% CI 1.73–2.61, $p < 0.0001$) Delay > 6 mo. at 24 months: - Predicted by ≥ 2 siblings (OR 2.99, 95% CI 1.45–6.22) - Protected against by: - Income < 75k: < $55k; OR 0.80, 95% CI 0.67–0.97 $55–< $65k; OR 0.42, 95% CI 0.22–0.78 $65k–$75k; OR 0.68, 95% CI 0.47–0.98 - Family doctor for urgent care (OR 0.63, 95% CI 0.44–0.91)
Perinet et al. 2018 Delayed measles vaccination of toddlers in Canada: Associated sociodemographic factors and parental knowledge, attitudes and beliefs Canada (national)	$N = 3604$ Parents of 2-year-old children	2013 Childhood National Immunization Coverage Survey (CNICS) data analysis Response rate = 63.5% Immunization history confirmed by health care record for 33.1% of respondents	- Sex of child - Province - Parent education (secondary or less, post-secondary, university graduate) - Household income ($0–$39k, $40k–$59,999, $60k–$79,999, $80k–$99,999, ≥ $100k) - Marital status - Knowledge, attitudes, and beliefs about vaccines	Measles vaccine (due at 12 months old) received: - Without delay (within 1 month of eligibility) - Delayed 1–6 months - Delayed 7–18 months - Not vaccinated	12 months old: 69% of children received their measles vaccine without delay 18% received measles vaccine with delay of 1–3 months 16 months old: 10.7% unvaccinated 19 months old: 7.1% unvaccinated 30 months: 4.11% unvaccinated Delay of 1–6 months predicted by: - Born outside of Canada (OR 2.33, 95% CI 1.13–4.80) - Living in: – BC (OR 1.68, 95% CI 1.24–2.26) – AB (OR 1.65, 95% CI 1.20–2.27) – SK (OR 1.61, 95% CI 1.16–2.23) – MB (OR 2.53, 95% CI 1.86–3.3) – Territories (OR 2.14, 95% CI 1.67–2.75) - Parental belief vaccines are safe protective against delay (OR 0.48, 95% CI 0.26–0.87) - Male child protective against delay (OR 0.78, 95% CI 0.61–0.99) Delay of 7–18 months predicted by: - Living in: – QC (OR 3.02, 95% CI 1.32–6.95) - SK (OR 4.13, 95% CI 1.63–10.46) - MB (OR 3.37, 95% CI 1.22–9.36)

Table 1 (continued)

Authors, year, title, location	Sample	Methods	Measures		Results
			Independent	Dependent	
					- Territories (OR 4.67, 95% CI 2.12–10.28) - Single parent (OR 3.17, 95% CI 1.37–7.35) - Child born outside Canada (OR 7.83, 95% CI 2.72–22.54) - Using alternative health care to replace vaccines (OR 3.6, 95% CI 1.77–7.33) - Having enough information protective against delay (OR 0.42, 95% CI 0.22–0.81) - Parental belief vaccines are safe protective against delay (OR 0.29, 95% CI 0.09–0.91) - SK (OR 4.13, 95% CI 1.63–10.46) - MB (OR 3.37, 95% CI 1.22–9.36) - Territories (OR 4.67, 95% CI 2.12–10.28) - Single parent (OR 3.17, 95% CI 1.37–7.35) - Child born outside Canada (OR 7.83, 95% CI 2.72–22.54) - Using alternative health care to replace vaccines (OR 3.6, 95% CI 1.77–7.33) - Having enough information protective against delay (OR 0.42, 95% CI 0.22–0.81) - Parental belief vaccines are safe protective against delay (OR 0.29, 95% CI 0.09–0.91)

7 years old (Dubé et al. 2016c). In addition, measles vaccines were absent in 7–10.3% of 2-year-olds (Carpiano et al. 2019; Gilbert et al. 2017) and 4.1% of 30-month-olds across Canada (Perinet et al. 2018), 13.7% in 2-year-olds in Nova Scotia (Dummer et al. 2012), and 18% of 3-year-olds who had an older sibling with ASD (Kuwaik et al. 2014). Gilbert et al. (2017) also found 4.7% of 2-year-olds had no pertussis vaccines.

Five studies reported incomplete vaccination status in children (Bell et al. 2015; Carpiano et al. 2019; Dummer et al. 2012; Gilbert et al. 2017; Kuwaik et al. 2014). One study found that 21.9% had incomplete vaccination status at 2 years old (Bell et al. 2015) and another found that 60.2% of parents of children under 3 years old who had a sibling with ASD had delayed (48%) or declined (12.2%) at least one vaccine, usually MMR (Kuwaik et al. 2014). One study found that 0.4% of 2-year-olds had incomplete MMR vaccines and 28.5% had incomplete pertussis-containing vaccines (Dummer et al. 2012). Additionally, one study examined selective vaccination status and reported that 21.9% of children had received all of the recommended doses for certain vaccines but not others, usually omitting varicella and MMR vaccines (Bell et al. 2015).

Only one study asked parents to indicate whether they had ever hesitated to vaccinate their children (Dubé et al. 2016c). In this study, 40.2% reported vaccine hesitancy and 59.2% did not. Of the vaccine-hesitant parents, 58.2% eventually accepted all vaccines and 2% refused all vaccines; 39% accepted some vaccines, usually refusing influenza, varicella, and rotavirus vaccines (Dubé et al. 2016c). In contrast, 95.3% of children whose parents were not hesitant were fully vaccinated (Dubé et al. 2016c).

Gender

Four studies examined whether the child's sex was associated with vaccination status (Dummer et al. 2012; Gilbert et al. 2017; O'Donnell et al. 2017; Perinet et al. 2018). Only one study found that male babies were less likely to have delayed measles vaccinations than females, though the authors considered it to be of little population significance (Perinet et al. 2018). No associations were found in the other three studies (Dummer et al. 2012; Gilbert et al. 2017; O'Donnell et al. 2017).

Maternal age

Mother's age at birth was examined in five studies (Bell et al. 2015; Dubé et al. 2016c; Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017). Two cohort studies examined associations between vaccine status and mother's age at time of birth; no association was found in one study (Kiely et al. 2018) while the other study found that the likelihood of incomplete vaccination decreased with increased maternal age (Bell et al. 2015). The difference in findings may be attributed to the greater proportion of those vaccinated in the Bell et al. 2015 study compared with the Kiely et al. 2018 study (71.1% vs. 50%). Maternal age of older than 39 years predicted fewer immunization delays in children under 24 months old; however, this difference was only observed within the first 24 months (O'Donnell et al. 2017). One study found no difference in maternal age between children completely and incompletely vaccinated (MacDonald et al. 2014). Mothers aged 45 years and older were 4× more likely to report incomplete vaccination based on a small survey subset (17.8%) of children aged between 1 and 17 years old (Dubé et al. 2016c).

Marital status

Marital status was examined in six studies (Bell et al. 2015; Gilbert et al. 2017; Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017; Perinet et al. 2018). Single-parent families predicted incomplete vaccination (OR 1.58) (Bell et al. 2015) and no measles vaccines (OR 1.63) (Gilbert et al. 2017). They were also one (Kiely et al. 2018) to three times (Perinet et al. 2018) more likely to have delayed vaccinations. Two studies found no correlation between marital status and vaccination (MacDonald et al. 2014; O'Donnell et al. 2017).

Household income

Eight studies examined the association between annual household income and vaccine history (Bell et al. 2015; Carpiano et al. 2019; Dummer et al. 2012; Gilbert et al. 2017; MacDonald et al. 2014; Martens et al. 2014; O'Donnell et al. 2017; Perinet et al. 2018). In one national study, no measles vaccine was predicted by household income of < $40,000 (OR 1.84) and between $40,000 and $59,000 (OR 1.70), and incomplete pertussis series was predicted by income of < $40,000 (OR 1.58) and an income between $40,000 and $59,000 (OR 1.47) (Gilbert et al. 2017). One study showed that 52.5% of 2-year-old children living in social housing were completely vaccinated compared with 67.8% who were living elsewhere (Martens et al. 2014). In this study, approximately 60% of children of low-income families (< $34,642) and 72.3% of highest income families (≥ $77,265) were completely vaccinated (Martens et al. 2014). Carpiano et al. (2019) found that not receiving MMR vaccines was predicted by side effect concerns in middle-high-income households across Canada (ORs 1.70–2.25) ($60,000 to $119,999) and perceived unimportance in low-middle-income households ($40,000 to $79,999). One survey study found that incomes less than $55,000 annually and between $55,000–< $65,000 and $65,000–$75,000 were all protective against delayed vaccinations (O'Donnell et al. 2017).

No association was found between income and vaccination history in four studies (Bell et al. 2015; Dummer et al. 2012; MacDonald et al. 2014; Perinet et al. 2018).

Education

The association between parental education and vaccine history was examined in seven studies (Carpiano et al. 2019; Dummer et al. 2012; Gilbert et al. 2017; Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017; Perinet et al. 2018). Lower parental education (undefined) predicted complete vaccination status at 24 months (OR 2.0) in a provincial cohort study (Dummer et al. 2012) while another study reported that maternal education (high school or less) was associated with a 2× greater odds of having complete vaccination in a small Quebec sample, though this study excluded children whose parents had refused all vaccines (O'Donnell et al. 2017). However, a national study found that having a high school diploma, trade certificate, or less (compared with university graduation) was associated with increased odds of no vaccinations (OR 1.99), no measles vaccinations (OR 1.86), and incomplete pertussis vaccinations (OR 1.92) (Gilbert et al. 2017). Having secondary education or less predicted incomplete measles vaccinations (OR 1.78) with a 75% higher odds of parental side effect concerns and a 62% higher odds of vaccine safety concerns (Carpiano et al. 2019). A repeated survey of parents with children 2 years old or younger administered six times over 10 years found that greater maternal education was protective (OR 0.90) of vaccination delays (Kiely et al. 2018). However, two other studies found no association between parental (maternal/paternal not specified) education level and vaccination history (MacDonald et al. 2014; Perinet et al. 2018).

Housing

One study found that living in social housing predicted incomplete vaccination status regardless of neighbourhood (Martens et al. 2014). Two studies assessed the number of household moves (Bell et al. 2015; MacDonald et al. 2014). One study found that one, two, and three or more household moves since a child's birth increased the odds of incomplete vaccinations by 1.10×, 1.35×, and 1.69×, respectively (Bell et al. 2015). Another found that a move in the last two years increased the odds of incomplete vaccination in 2-year-olds by 3.98× (MacDonald et al. 2014).

Province of residence

Two national studies examined the association between province of residence and vaccine uptake (Gilbert et al. 2017; Perinet et al. 2018). One study found that living in British Columbia (BC) (OR 3.18), the Prairies (Saskatchewan, Manitoba, and Alberta) (OR 5.18), and Quebec (OR 2.43) predicted not receiving any vaccines (Gilbert et al. 2017). The other study found that delayed vaccinations of 1–6 months were predicted by living in Saskatchewan, Alberta, BC, the Territories, and Manitoba (ORs 1.61–2.5), and delays of 7–18 months were predicted by living in Quebec, Saskatchewan, Manitoba, or the Territories (ORs 3.02–4.67) (Perinet et al. 2018).

Rural or urban residence

Rural and urban residence was assessed in two provincial cohort studies (Bell et al. 2015; Dummer et al. 2012). One large cohort study ($N = 43{,}965$) found that rural residence predicted incomplete (OR 1.16) and absent vaccination (OR 2.14) in Alberta (Bell et al. 2015). The second study, a smaller cohort study ($N = 8245$), found no difference in vaccination status between urban and rural residence in Nova Scotia (Dummer et al. 2012). The difference in sample size may explain the discrepant findings.

Cultural identity and religion

One study examined cultural identity and found no association between Aboriginal identity and partial or complete immunization (MacDonald et al. 2014). One study found that 32.8% of parents cited religious or philosophical reasons (not specified) for not vaccinating their children by two years of age (Gilbert et al. 2017).

Family size and birth order

Five studies examined the association between family size and/or birth order and vaccination history (Bell et al. 2015; Dubé et al. 2016c; Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017). Children from families with ≥ 3 children under 18 years were 3× more likely to be incompletely vaccinated (Bell et al. 2015) and 5× more likely to have no vaccinations (O'Donnell et al. 2017). Children from a household of ≥ 5 members were 6× more likely to have incomplete vaccinations (Dubé et al. 2016c), while one study found no significant association between family size and vaccine history (MacDonald et al. 2014). Vaccination delays were predicted by children who were not first-born (RR 1.47) (Kiely et al. 2018) and when an older sibling had ASD ($\chi^2 = 80.82$, $p < 0.001$) (Kuwaik et al. 2014).

Country of birth

Two studies found that being born outside of Canada significantly increased the likelihood of incomplete pertussis (OR 3.01) (Gilbert et al. 2017) and delayed measles vaccinations of 1–6 months (OR 2.33) and 7–18 months (OR 7.83) (Perinet

et al. 2018). However, a parent born outside of Canada was not associated with vaccine status of children (Gilbert et al. 2017; MacDonald et al. 2014) or vaccine delays (Kiely et al. 2018; Perinet et al. 2018).

Daycare attendance

Three studies examined the association between daycare attendance and vaccination history (Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017). In one study, attending daycare before 2 years old predicted complete vaccination in Edmonton (MacDonald et al. 2014) while another found no association between daycare attendance and vaccination status at 2 years old in Quebec (O'Donnell et al. 2017). In another study, not attending daycare predicted delays in vaccination at 2 months old but not for later vaccinations (Kiely et al. 2018).

Breastfeeding

One study found no association between children who had been breastfed and vaccination status at 2 years old (O'Donnell et al. 2017).

Parent knowledge and beliefs about vaccination

Parents who believed they had adequate knowledge regarding vaccines were less likely to delay vaccinations by 7–18 months (OR 0.42) (Perinet et al. 2018). Parents who were not hesitant to vaccinate their children believed vaccines were effective in protecting their children and the community from disease (Dubé et al. 2016c). However, one study found that even though 92% of parents vaccinated their children, 14% agreed vaccines can cause autism, another 14% were unsure if they could cause autism, and 25% thought serious side effects were likely (Greenberg et al. 2017).

Parental safety concerns and fear of side effects were cited as reasons for not vaccinating by 56.4% of parents whose children had no vaccine history (Gilbert et al. 2017). Additionally, safety concerns and fear of side effects increased the odds of partial vaccinations by 2.8× (MacDonald et al. 2014) and parents who were very concerned were 125–130% more likely to omit MMR than parents who were less concerned (Carpiano et al. 2019). Parental perception that vaccines are safe was protective against vaccination delays of 1–6 months (OR 0.48) and 7–18 months (OR 0.29) (Perinet et al. 2018). Greenberg et al. (2017) found that 25% of parents who chose not to vaccinate did so due to fears of serious side effects.

Parents believing their children were not likely to contract VPDs were 4× more likely to partially vaccinate (MacDonald et al. 2014). Skepticism about vaccine effectiveness was cited by 11% of parents who chose not to vaccinate their children (Greenberg et al. 2017) believing that vaccines could weaken their child's immune system, resulting in greater vulnerability to disease than if they were not vaccinated (Dubé et al. 2016c). Believing MMR vaccinations were not important was also related to non-vaccination status (OR 1.19) (Carpiano et al. 2019).

Choosing alternative medicine

Two studies examined the association between use of alternative and complementary medicine and vaccine status (Bell et al. 2015; Perinet et al. 2018). One study found that children whose parents used alternative or complementary medicine as a replacement for vaccines were 3× more likely to have a delay of 7–18 months for the first measles vaccine (Perinet et al. 2018). Choosing a midwife-assisted delivery at home was significantly associated with incomplete (OR 4.66), selective (OR 6.77), and non-vaccination (OR 51.7) and was considered to be a proxy for alternative medicine in a large cohort study in Alberta (Bell et al. 2015). However, there was no association between birth attendant (physician or midwife/other professional) and vaccinations in another study (Kiely et al. 2018).

Trust

Two studies examined the impact of trust on vaccine acceptance (Dubé et al. 2016c; Greenberg et al. 2017). Parents who vaccinated their children were more likely to trust public health authorities, physicians, and academics than those who did not; distrust of pharmaceutical companies was higher among non-vaccinating parents (80%) than among parents who vaccinated (51%) (Greenberg et al. 2017). Another study found that parents who trusted information about vaccines were significantly less likely to be vaccine hesitant and were more likely to accept vaccines even if they were initially hesitant (Dubé et al. 2016c).

Vaccine administration

Three studies found a positive association between vaccine hesitancy and the number of needles recommended (Dubé et al. 2016c; MacDonald et al. 2014; O'Donnell et al. 2017). Too many needles at once was cited as a reason for vaccine hesitancy (Dubé et al. 2016c) resulting in a 7× increased likelihood of partial immunizations (MacDonald et al. 2014). One study found that not receiving all the recommended vaccinations at 18 months accounted for 35% of vaccination delays at 24 months, although the study did not specify whether this was a parent, child, or provider decision (O'Donnell et al. 2017).

Ease of accessing services

Parent perception that getting immunizations was a hassle resulted in a 14.47× increased risk of incomplete immunization (MacDonald et al. 2014). One study found that the likelihood of complete vaccinations was almost double in communities where family doctors and public health nurses both provided vaccines (OR 2.1) and communities where public health nurses primarily provided vaccines (OR 1.8) compared with communities where physicians were the primary providers (Dummer et al. 2012). Another study found that there were fewer delays in vaccination at 12 months of age when public health clinics provided vaccines (RR 1.22) compared with medical clinics or hospitals, but the opposite was true at 2, 4, and 6 months (RR 0.79) (Kiely et al. 2018). Two studies found that access to family doctors for regular (OR 0.219) (MacDonald et al. 2014) and urgent (OR 0.63) (O'Donnell et al. 2017) care was protective against delayed vaccinations, although they did not indicate whether the family doctor was administering vaccines.

Discussion

The findings show that vaccine uptake in 2-year-old children ranged from 92% to 97% (Gilbert et al. 2017; Greenberg et al. 2017); however, complete vaccinations ranged from 50% to 70% (Bell et al. 2015; Kiely et al. 2018; Martens et al. 2014). This means that while more than 90% of Canadian children have received at least one vaccine, only 50–70% have received all of the recommended vaccines. Alternatively, parental refusal of all vaccines was between 2% and 5.1% (Bell et al. 2015; Dubé et al. 2016c; Gilbert et al. 2017; Greenberg et al. 2017). The rates of vaccine uptake and refusal are similar to the findings of the CNICS, where 90% of 2-year-old children had received at least one measles vaccine; 76% had received all recommended doses of diphtheria, tetanus, and pertussis vaccine; and 2.3% of 2-year-old children had not received any vaccines (Public Health Agency of Canada 2020a).

The findings show that trust is an important factor in vaccine uptake. Parents who accepted vaccines were more trusting of doctors and public health professionals (Dubé et al. 2016c; Greenberg et al. 2017). Several qualitative studies have found that there is a relationship between trust and vaccine hesitancy (Attwell et al. 2017; Dubé et al. 2013; Larson et al. 2018; MacDonald 2015; Smith et al. 2017). According to Larson et al. (2018), trust is determined by historical experiences (especially for religious and ethnic minorities), as well as family, friends, alternative medicine, religious leaders, or celebrities. While studies were consistent in their findings that trust is an important consideration in vaccine uptake, none of the studies reported on the strength of the associations. Future studies should further examine the association between trust and vaccine uptake to determine whether there indeed is an association. This may have important implications for how vaccines are delivered, as well as how messages and advertisements are created to support vaccine uptake.

Our review found that choosing alternative medicine predicted incomplete vaccination by 3–6× (Bell et al. 2015; Perinet et al. 2018) while two studies found that having access to a family doctor protected against vaccination delays (MacDonald et al. 2014; O'Donnell et al. 2017). Additionally, approximately one third (33%) of parents who do not vaccinate their children cite religious or philosophical reasons (Gilbert et al. 2017), which may further contribute to the low vaccination rates in some rural communities (Bell et al. 2015). Even though there are only a few studies in this review examining these factors, these findings are consistent with studies showing that vaccine hesitancy is related to alternative medicine practices (Dubé et al. 2016b ; Dubé et al. 2013; Frawley et al. 2018; McNeil et al. 2019) and religious beliefs in Canada (Dubé et al. 2018; Kulig et al. 2002) and elsewhere in the world (Kershaw et al. 2014; Rainey et al. 2011; SAGE Working Group 2014; Spaan et al. 2017).

Parents were less likely to delay vaccines when they believed vaccines would prevent disease (Dubé et al. 2016c) and when they had an appropriate level of knowledge believing in their safety (Perinet et al. 2018). However, concerns over vaccine safety appear to be strongly related to incomplete or delayed vaccination (Carpiano et al. 2019; Gilbert et al. 2017; MacDonald et al. 2014). More than 50% of parents who refused vaccines were concerned about vaccine safety (Gilbert et al. 2017) and 28% of parents who accepted vaccines thought vaccines could cause autism, with another 25% believing vaccines cause serious side effects (Greenberg et al. 2017). Additionally, parents who believed the MMR vaccine was unimportant was predictive of non-vaccination, although the strength of the association was small (OR 1.19) (Carpiano et al. 2019). These findings are consistent with other studies that show the relationship between knowledge and vaccine uptake is not uniform (Dubé et al. 2013) and the decision to vaccinate can be based on intuition and perception more so than factual knowledge (MacDonald et al. 2018). Research has suggested that knowledge is related to trust, finding that trust in information is determined by the information source (Benin et al. 2006; Larson et al. 2018). Consequently, parental knowledge about vaccines may be informed by the level of trust in the provider of the information.

The findings also show that socio-economic factors are not consistently associated with vaccine uptake. Parental education of a high school diploma, trade certificate, or less was moderately (OR range from 1.78 to 1.99) associated with incomplete vaccinations in two national studies (Carpiano et al. 2019; Gilbert et al. 2017). Meanwhile, greater maternal education was protective against vaccination delays in another study but the association was small (OR 0.90) (Kiely et al.

2018). Two other studies found that less education was associated with a twofold increase in vaccine uptake (Dummer et al. 2012; O'Donnell et al. 2017) while two other studies found no association (Perinet et al. 2018; MacDonald et al. 2014). Similarly, households with incomes less than $40,000 were between 1.47 and 1.84× more likely to have fewer vaccinations (Gilbert et al. 2017) and one study found that vaccine uptake increased with neighbourhood wealth (Martens et al. 2014). Alternatively, annual incomes of less than $55,000 and up to $75,000 were protective against delayed vaccinations, although these income cut-offs are considerably higher than in other studies (O'Donnell et al. 2017). Four other studies found no association between income and vaccine uptake (Bell et al. 2015; Dummer et al. 2012; MacDonald et al. 2014; Perinet et al. 2018). While the findings are generally inconsistent regarding education and income with vaccine uptake, one study found that poorer education was associated with increased vaccine concerns and a greater perception of vaccine side effects (Carpiano et al. 2019), which suggests that a complex interplay may exist among education, vaccine concerns, and trust. Future research is needed to examine the complex interactions among these factors on vaccine uptake.

Social housing, which is also an indicator of low income, predicted incomplete vaccination regardless of neighbourhood wealth (Martens et al. 2014). In addition, 2-year-old children from single-parent households were 1.58–1.63× more likely to have incomplete vaccinations (Bell et al. 2015; Gilbert et al. 2017) and 1.48–3.17× more likely to have delayed vaccinations (Kiely et al. 2018; Perinet et al. 2018). Incomplete or delayed vaccinations were 3–6× more likely for children with multiple siblings (Bell et al. 2015; Dubé et al. 2016c; O'Donnell et al. 2017), 1.47× for non-first-born children (Kiely et al. 2018), 1.35–3.98× more likely for those who had moved 2 or more times in the past two years (Bell et al. 2015; MacDonald et al. 2014), and 3.01–7.83× more likely if they had moved to Canada in the past two years (Gilbert et al. 2017; Perinet et al. 2018). Additionally, there is also an association between having an older sibling with ASD and incomplete vaccinations (Kuwaik et al. 2014). It is impossible to fully understand the contexts in which these children live, and how these factors may overlap or compound, but it is apparent that housing and family dynamics have an impact on vaccine uptake and may also be related to other socio-demographics (e.g., income and education).

Access to health care service is consistently related to greater vaccine uptake and may compensate for some of the challenges of housing and family dynamics. Studies in this review found that regular access to physicians for regular or urgent health needs was protective against incomplete (OR 0.219) (MacDonald et al. 2014) and delayed (OR 0.63) (O'Donnell et al. 2017) vaccinations, although it was unclear who was giving the vaccines, while children of parents who felt getting vaccines was a hassle were 14.47× more likely to have incomplete vaccinations (MacDonald et al. 2014). Additionally, incomplete vaccinations, particularly in rural areas, may also be due to decreased access to health services (Bell et al. 2015). Another study found that communities with lower education and employment rates were twice as likely to receive a vaccine when administered by family physicians and public health nurses, whereas lower uptake in communities was related to physician only providing the vaccines (Dummer et al. 2012), suggesting that easy access to health care providers and vaccine services may improve vaccine uptake.

While this review identified several socio-demographic factors related to vaccinations, further research examining the association between daycare attendance, region of residence, and parental influence is needed. Daycare attendance resulted in inconsistent associations with vaccination status (Kiely et al. 2018; MacDonald et al. 2014; O'Donnell et al. 2017). Although there were only a few studies that examined the association between daycare attendance and vaccination status, future studies should assess how different provincial daycare immunization requirements impact vaccine uptake. Additionally, it also appears that vaccination uptake is lower in the Prairies, BC, Quebec, and the Territories (Gilbert et al. 2017; Perinet et al. 2018). The greater proportion of rural communities in these provinces and associated issues related to access to health care (including transportation), as well as religious underpinnings, need to be further examined in order to increase vaccination uptake. Future research should also examine whether vaccine uptake could be influenced by children's relationships with their mothers and fathers, and their grandparents. Although 52% of the CNICS respondents were male, no gender comparisons were conducted on whether differences in vaccine acceptance could be explained by gender (Perinet et al. 2018). Only one small survey study compared gender and vaccine uptake and found that being a female respondent predicted incomplete vaccinations compared with their male counterparts (Dube et al. 2016c) .

Limitations

There are some limitations to this review. First, grey literature was not searched during the article retrieval process, limiting our results only to literature published in journals. Second, only English articles were used, which may have excluded studies from Quebec or the Maritimes that were not translated from French into English. Third, qualitative articles were not included in this review, which may have resulted in missing information on specific contextual factors that influence vaccine hesitancy.

Other limitations from the findings include the inconsistency in the measures used to define vaccine uptake. For example, vaccinations were defined as the full set of recommended vaccines in some studies (Bell et al. 2015; Dubé et al. 2016c;

Dummer et al. 2012; Kuwaik et al. 2014; MacDonald et al. 2014; Martens et al. 2014; O'Donnell et al. 2017) and MMR status in others (Carpiano et al. 2019; Gilbert et al. 2017; Greenberg et al. 2017; Perinet et al. 2018), even though MMR was selectively refused more often than other vaccines (Bell et al. 2015; Dubé et al. 2016c). There was also inconsistency in the methods of collecting data to assess vaccination status in the studies reviewed. While half of the included studies used medical records, considered the most accurate source of vaccination data (Dorell et al. 2011), the remaining studies used either parental records or surveys. Parental records may have been incomplete (missing data) and surveys are subject to recall and social desirability bias. Additionally, Canadian vaccine data, including the CNICS, do not include children from First Nations communities (Public Health Agency of Canada 2020a; Wilson et al. 2016), likely because vaccination programs are administered and monitored federally for Canada's First Nations communities (Indigenous Services, Government of Canada 2019). As a result, national vaccine data may overestimate national vaccine coverage as coverage rates are slightly lower in First Nations communities (Indigenous Services, Government of Canada 2019).

Conclusion

Health care professionals who provide vaccine services should be aware of the impact of trust on vaccine uptake in Canada, in particular, understanding that knowledge alone is likely not enough to increase vaccine uptake. Vaccine programs also need to be adapted to be accessible to families who may be struggling with socio-economic challenges. Future research should examine how access to health care providers and development of trusting relationships between health care providers and parents of preschoolers would increase vaccine uptake in Canada. In addition, future research should evaluate vaccine status according to a more complete vaccine schedule to avoid missing data from selectively refused vaccines, provincial differences should be examined in more detail, and data from First Nation communities should be included to provide a complete picture of vaccine uptake in Canada.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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