The impact of publicly funded immunization programs on human papillomavirus vaccination in boys and girls: An observational study

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Summary

Background Reaching and maintaining high global human papillomavirus (HPV) vaccine uptake has been challenging. The impact of publicly funded HPV immunization programs and the interplay of sociodemographic, psychosocial and policy factors in maximizing vaccination is poorly understood. This observational study examined the impact of introducing publicly funded school-based HPV vaccination programs for boys directly on uptake in boys and indirectly on uptake in girls, while concurrently examining other important sociodemographic and psychosocial factors.

Methods Data were collected from a national, longitudinal sample of Canadian parents of children aged 9–16 years during August-September 2016 (T1) and June-July 2017 (T2). Participants completed an online questionnaire measuring sociodemographic characteristics, vaccine knowledge and attitudes, health care provider recommendation, and HPV vaccine uptake. Analyses were conducted separately for parents of boys and girls using logistic regression analyses at T1 and T2. Jurisdictions with HPV vaccine funding for boys at both time-points were compared to those with funding at neither time-points and those that introduced funding between time-points.

Findings The sample included parents of boys (n = 716) and girls (n = 843). In multivariable analyses, jurisdictions with funding for boys at both time-points had higher odds of vaccination (adjusted odds ratio, T1 = 10.18, T2 = 11.42; 95% confidence interval, T1 = 3.08–33.58, T2 = 5.61–23.23) than jurisdictions without funding at both time-points; however, funded jurisdictions did not have higher odds of vaccination compared to jurisdictions that newly introduced funding for boys. Vaccination was associated with consistent determinants in boys and girls including child's age, health care provider recommendation, perceived vaccine harms, and perceived vaccine affordability.

Interpretation This gender-sensitive analysis highlights the interplay of sociodemographic, psychosocial, and policy factors that can improve HPV vaccination. Publicly funded school-based programs are an impactful strategy to increase vaccine uptake.

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Keywords: Immunization; Gender; Human papillomavirus; Health policy; Vaccine funding

Introduction

Routine childhood immunization programs are amongst the most lifesaving and cost-effective public health interventions available.[1,2] Vaccinations can

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Research in Context

Evidence before this study

It is known that HPV vaccine uptake is higher if parents of eligible children have more positive attitudes about the vaccine and their health care provider recommends it. However, there is limited evidence on the role of publicly funded HPV vaccination programs on increasing vaccine uptake. In Canada, healthcare is the responsibility of each province and territory, and this has led to substantial variation in the introduction of publicly funded HPV vaccination programs for boys. This variation allowed us to estimate and compare the impact of introducing publicly funded HPV vaccination programs for boys directly on vaccine uptake in boys and indirectly on vaccine uptake in girls.

Added value of this study

This study reports on a longitudinal, natural experiment in Canada where the implementation of publicly funded HPV vaccination programs unfolded differently across the 10 Canadian provinces. We surveyed parents at two times points separated by 9-months and were able to divide the provinces into three groups based on program funding initiation: 1) provinces that provided publicly funded HPV vaccination to boys at both timepoints, 2) provinces that did not provide publicly funded HPV vaccination to boys at either timepoints, and 3) provinces where there was no publicly funded HPV vaccination for boys at Time 1, but it was introduced by Time 2. We found that publicly funded school-based vaccination programs for boys was associated with greater uptake in boys at both timepoints and in the three different funding groups, but the expected indirect effect of vaccine funding was not observed in girls. Moreover, we found that important determinants of vaccination in both boys and girls included older child's age, health care provider recommendation, perceived vaccination harms, and perceived vaccine affordability.

Implications of all the available evidence

This study demonstrated the specific impact of vaccine funding for increasing uptake, and supported enhancing other determinants of vaccination such as health care provider's recommendation and positive vaccine attitudes. In addition, this study revealed the importance of gender-neutral HPV immunization programs, without which structural inequities in vaccination become more pronounced. In future research, the complex interplay of sociodemographic, psychosocial, and policy decisions should be concurrently examined to develop evidence to improve the accessibility and effectiveness of immunization programs.

mitigate oropharyngeal and genital cancers with potentially high morbidity and mortality caused by human papillomavirus (HPV).[3–6] Reductions in the uptake of immunization due to delayed, missed, or incomplete vaccination can lead to increases in vaccine preventable diseases.[7–10] Achieving timely and high vaccination uptake is therefore crucial to the success of immunization programs, and a priority for health systems.[11] Attaining global HPV vaccine uptake has been challenging.[12] In Canada, HPV vaccine uptake is not reaching targets, is significantly lower than other routine child or adolescent vaccines, and is lower than rates in other comparable programs (e.g., Australia or the United Kingdom).[13,14] Understanding the social determinants and modifiable factors that impact HPV vaccine uptake is critical.

There are several known sociodemographic and psychosocial factors associated with HPV vaccine uptake including health care provider recommendation, knowledge, and specific attitudes (such as perceived benefits and harms of HPV vaccination).[15–18] There is relatively less data examining which policy factors contribute to sustaining high-uptake rates. Emerging evidence suggests the success and cost-effectiveness of implementing school-based vaccination,[19–23] routine child preventive check-up appointments,[18] reminders and recalls,[24–28] and educational interventions.[29–35] There is insufficient evidence examining the effectiveness of other policy strategies such as HPV vaccine government mandates,[36,37] or publicly funded HPV vaccination programs on increasing vaccine uptake. [38]

Publicly funded vaccination is thought to increase vaccine uptake directly by expanding access to vaccination and indirectly by signalling government endorsement. Indeed, parents often report cost as a barrier to providing their child with the HPV vaccine, and unaffordability is consistently cited as a service delivery challenge to vaccine uptake.[38,39] A systematic review and meta-analysis that examined multiple factors associated with HPV vaccine uptake reported that health insurance-covered HPV vaccination (r = 0.16) and lower out-of-pocket cost (r = -0.15) had significant effects on vaccine uptake.[18] However, the authors found only a handful of studies that examined these findings and reported heterogeneity between studies. Few publicly funded immunization programs have examined multiple important determinants of HPV vaccination concurrently.

Vaccine funding is thought to directly impact behaviour in the targeted group, and indirectly impact behaviour beyond the targeted group. HPV was first discovered to be an aetiological agent for cervical cancer in females, and the vaccine's development, licensure, immunization programs, marketing and funded programs therefore initially focused on girls.[15] This so-called "feminization of HPV" is believed to have a deleterious impact on HPV vaccine uptake in both boys and girls.[40] When HPV vaccination is funded for boys, it may also indirectly impact parents of girls to agree to vaccinate their daughters. Indirect effects on girls might

occur due to perceived government endorsement and greater legitimacy, decreased confusion, or changing cultural values towards vaccination.

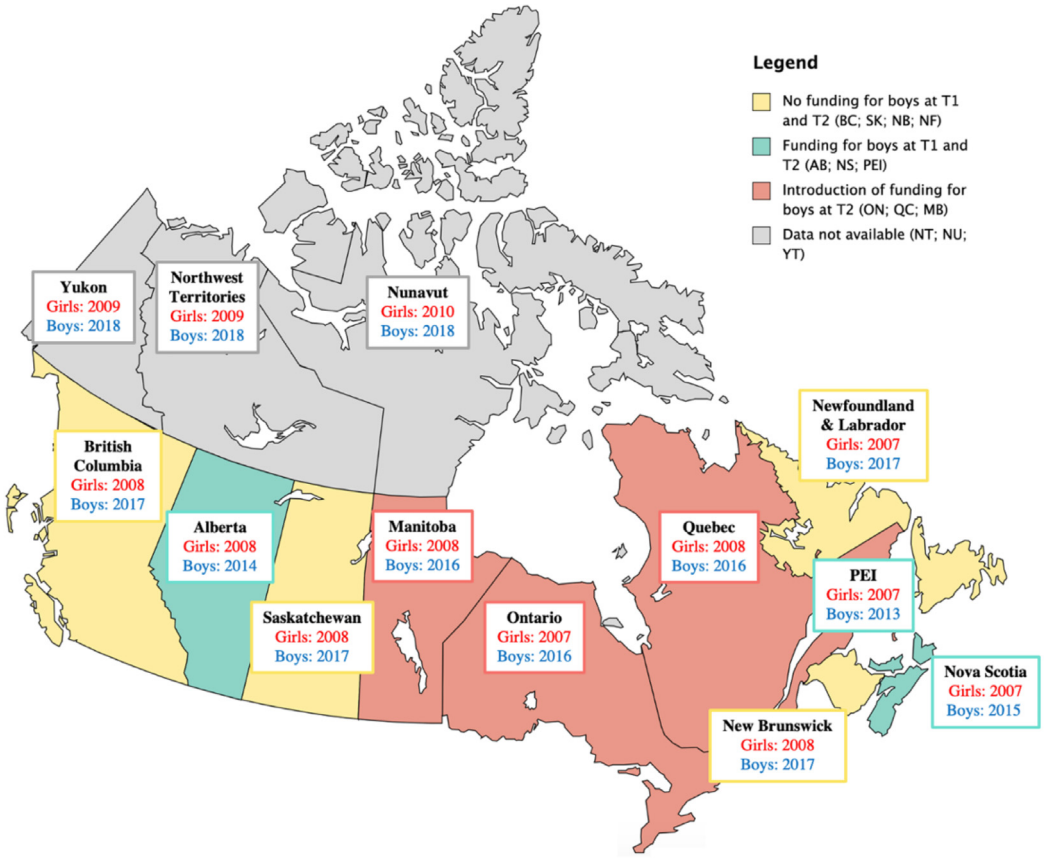
In the context of Canada where the implementation of publicly funded HPV vaccination programs for boys unfolded differently across the 10 provinces from 2013 to 2018 (see Fig. 1), the purpose of this study was to estimate the association between sociodemographic, psychosocial, HPV vaccine related factors, and different funding policies, with vaccine uptake separately in boys and girls.

Methods

Data and study design

This study used a longitudinal design to collect self-reported online survey data from a national sample of Canadian parents and/or guardians (hereafter referred to as parents). Data presented in this study were part of a larger two-wave protocol collected from August to September 2016 (i.e. Time 1, T1) and June to July 2017 (i.e. Time 2, T2). Participants were recruited using Canada's largest market research and polling firm, Leger-*The Research Intelligence Group*, which uses proprietary software informed by Canada's census data in order to generate a nationally representative panel of Canadians.[41] The sample was constructed to be nationally and regionally representative, and to provide representative data by gender and provincial distribution of children aged 9–16. The online survey was offered in English and French. To recruit participants, Leger sent email invitations and survey links to panellists; a maximum of three reminder emails were sent. Participants were paid a modest cash amount in accordance with standard panel member compensation of Leger. A detailed explanation of the survey methodology has been described previously.[42]

This study received Research Ethics Board approval from the Research Review Office, Integrated Health and Social Services University Network for West-Central Montreal (CODIM-FLP-16–219).[42] All participants



Note. This figure identifies the year that publicly funded school-based HPV vaccine programs were initiated for boys and girls by Canadian jurisdiction.

Fig. 1. Initiation of publicly funded school-based HPV vaccination programs across Canada.

provided informed consent and all data collected was anonymized.

HPV vaccine funding context in Canada

In Canada, healthcare is the responsibility of each province and territory. As a result, there is substantial variation in policy, delivery, and administration of the HPV vaccine across the 13 different programs.[43] Jurisdictions vary in the date their programs began, the target of vaccination programs (including child's gender and age), the vaccine being administered, and its dosing schedule.[42]

From 2007 to 2010, all Canadian provinces and territories implemented publicly funded, school-based vaccination programs for girls, albeit at different ages and with different dosing schedules and catch-up programs (Fig. 1).[42,44] From 2013–2018, Canadian provinces and territories extended their programs to all boys in Canada.[42,45] Canada's HPV vaccine programs are now all gender neutral, albeit at different ages.[42] HPV vaccination is voluntary and consent is required from the child or the child's parent, depending on the child's age and the provincial guidelines for consenting to vaccination.

In this study, all jurisdictions had a publicly funded HPV vaccination program for girls at both timepoints (August to September 2016, T1, and June to July 2017, T2). We divided jurisdictions into three groups based on the funding of their programs for boys (Fig. 1): 1) provinces that provided publicly funded HPV vaccination to boys at both timepoints (i.e., the "always funded program"; including Alberta, AB; Nova Scotia, NS; and, Prince Edward Island, PEI), 2) provinces that did not provide publicly funded HPV vaccination to boys at neither timepoints (i.e., the "never funded program"; including British Columbia, BC; New Brunswick, NB; Newfoundland, NF; and, Saskatchewan, SK;), and, 3) provinces where there was no publicly funded HPV vaccination for boys at T1, but a funded programs was introduced by T2 (i.e., the "newly funded program"; including Manitoba, MB; Ontario, ON; and, Quebec, QC).

Participants

This study included Canadian parents who responded to the survey in reference to their 9–16-year-old son (hereafter parents of boys) and parents who responded to the survey in reference to their 9–16-year-old son daughter (hereafter parents of girls); the target ages of HPV vaccination programs.[13,14] Eligibility criteria included internet access and residence in Canada. We asked parents to respond to the survey regarding their child with the most recent birthday at T1. At T2, we asked parents who completed the survey at T1 to respond to the survey regarding the same child.

Measures

Sociodemographic factors. Participants reported baseline sociodemographic characteristics including gender, age, education, number of children, marital status, employment status, city size, race, income, child's age, and child's gender.

Psychosocial factors. Psychosocial factors included vaccine knowledge and attitudes. *HPV and HPV* vaccine knowledge was measured by two validated scales.[46,47] The HPV General Knowledge (GK) Scale is a 23-item measure (α_{Boys} = .93; α_{Girls} = .91), and the HPV Vaccine Knowledge (VK) Scale is an 11 items measure (α_{Boys} = .88; α_{Girls} = .82). To each item, respondents answered 'true', 'false', or 'don't know', for which a total score was calculated based on correct answers, with higher scores indicating greater knowledge on both scales.

Vaccine attitudes were assessed using the validated HPV vaccination Attitudes and Beliefs Scale (HABS) that uses a 7-point Likert-type rating scale ranging from 1 (strongly disagree) to 7 (strongly agree).[48] Sub-scale constructs evaluated in this study included those from the Health Belief Model,[17,49,50] including perceived susceptibility of child to HPV and its consequences (3 items, α_{Boys} = .93; α_{Girls} = .93), perceived severity of HPV and its consequence (3 items, α_{Boys} = .86; α_{Girls} = .81), perceived benefits of the HPV vaccine (10 items, α_{Boys} =.95; α_{Girls} =.94), perceived harms of the HPV vaccine (6 items, α_{Boys} = .93; α_{Girls} = .92), self-efficacy to receive the HPV vaccines (4 items, α_{Boys} = .87; α_{Girls} = .89), perceived inaccessibility of the HPV vaccine (4 items, α_{Boys} = .78; α_{Girls} = .74), perceived unaffordability of the HPV vaccine (3 items, α_{Boys} = .85; α_{Girls} = .83), and social influence in favour of vaccination (8 items, α_{Boys} = .89; α_{Girls} = .90). All scales are subscales of the HABS except self-efficacy, which was included given that self-efficacy is an important construct in making behavioural decisions according to the Health Belief Model.[49] All Cronbach alpha scores of subscales used in this study were calculated at T1.

Health care provider (HCP) recommendation. HCP recommendation was assessed by asking parents, 'did a health care provider (e.g. a doctor, paediatrician, or nurse) recommend that [child's name] receive the HPV vaccine within the last 12 months?'. Parents who received this question would have answered affirmatively that they had seen a HCP within the last 12 months and discussed their child receiving the HPV vaccine with a HCP in the last 12 months.

Self-reported HPV vaccination (outcome variable). Parents were asked if their child received the HPV vaccine. Responses of "yes" or "no" were calculated; parents

who responded "I don't know" to this question (i.e., 63 parents of girls and 100 parents of boys) were excluded from the bivariate and multivariable analyses. Parents who reported their child to be vaccinated at T1 and not at T2 were excluded due to inaccurate report (i.e., 19 parents of girls and 13 parents of boys).

Statistical analyses

Inattentive or unmotivated responders were detected and removed using two bogus items and statistical psychometric synonyms (i.e., participants who respond inconsistently across similar items in the questionnaire).[51–53] Participants who did not complete the study at both timepoints were removed from analyses.

The characteristics of the parents of boys and girls were described. Tests of proportions and *t*-test analyses were conducted to examine differences between parents of boys and girls at T1. For significant ($p < .05$) differences in proportions and means we calculated the effect size (i.e., Cohen's *d* and Cohen's *h*). As sample sizes were large, even minor differences can be statistically significant. We considered a difference of 10% to be relevant for proprotions and a difference of 5 years in age.

We used chi-square analyses to examine the association between HPV vaccine funding and vaccination uptake separately for parents of boys and parents of girls at T1 and T2. To estimate the effect of the explanatory variables (sociodemographic, psychosocial, HCP recommendation, and vaccination program) on the outcome (self-reported HPV vaccination), we used binary bivariate and multivariable logistic regression anayses separately for parents of boys and parents of girls at T1 and T2 (see Tables 2,3). For the psychosocial predictors in the T2 analyses, we used the change score from T1. A 95% significant confidence interval in the binary bivariate logistic regression analyses at T1 or T2 was used to select the variables for the final (parsimonious) binary multivariable logistic regression model.

All statistical analyses were conducted using the R software v. 4.0.5.[54]

Role of funding source

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Results

Participant characteristics

A total of 4606 parents completed the survey at T1, and 2359 at T2. Overall, 1004 participants (21.7%) were removed from the sample as these participants were detected to be inattentive or unmotivated respondents based on data cleaning either at T1 ($n = 827$) or at T2 ($n = 461$).[42] An additional 1846 (51%) of the remaining participants were removed because they did not complete the study at both time-points. Additionally, only 3 participants from the territories of Canada were recruited; these participants were removed from the analysis due to lack of statistical power.

Characteristics of the baseline sample are presented in Table 1 ($N = 1559$). The sample consisted of 716 parents of boys and 843 parents of girls. The majority of parents were women (67% and 70%), White (83% and 85%), married or common law (82% and 83%), employed (79% and 81%), Canadian born (82% and 87%), and had some college/university education (86% and 82%). At both timepoints, most parents of boys (T1 = 92%, T2 = 85%) and parents of girls (T1 = 84%, T2 = 79%) reported that they had not received a HCP recommendation. None of the characteristics of the parents of boys and girls differed substantially.

Impact of publicly funded HPV vaccination programs

Receipt of HPV vaccination in boys significantly differed between jurisdictions that received funding at neither timepoints (T1 = 5%, T2 = 14%), jurisdictions that only received funding by T2 (T1 = 6%, T2 = 23%), and jurisdictions that received funding at both timepoints (T1 = 36%, T2 = 57%), $X^2(2, N = 716)_{T1} = 85.34$, $p < .001$, $X^2(2, N = 716)_{T2} = 62.81$, $p < .001$ (Fig. 2, Supplementary Material 1).

Receipt of HPV vaccination in girls did not differ between jurisdictions that received funding for boys at neither timepoints (T1 = 48%, T2 = 62%), jurisdictions that only received funding by T2 (T1 = 49%, T2 = 65%), and jurisdictions that received funding at both timepoints (T1 = 44%, T2 = 61%), $X^2(2, N = 843)_{T1} = 1.56$, $p = .458$, $X^2(2, N = 843)_{T2} = 0.83$, $p = .659$.

Analysis of factors associated with vaccination separetely in parents of boys and girls at T1 and T2

Bivariate analyses. In bivariate analyses at T1, older child's age ($OR_{Boys} = 1.17$; $OR_{Girls} = 1.61$) was associated with higher odds of HPV vaccination (Table 2). HCP vaccine recommendation was associated with increased odds of HPV vaccine uptake ($OR_{Boys} = 9.83$; $OR_{Girls} = 2.08$). In both parents of boys and girls, HPV vaccine uptake was associated with higher HPV vaccine knowledge, perceived susceptibility, perceived vaccine benefits, increased self-efficacy, and social influence. Conversely, the odds of HPV vaccine uptake were lower in parents who perceived the HPV vaccine to be unaffordable, inaccessible, and in those who were concerned about vaccine-related harms.

	Parents of Boys (*n* = 716) *n* (%)	Parents of Girls (*n* = 843) *n* (%)
Parent gender		
Women	478 (66.8)	589 (69.9)
Men	238 (33.2)	254 (30.1)
Race		
White	597 (83.4)	716 (84.9)
Non-White	119 (16.6)	127 (15.1)
Marital status		
Single/separated	129 (18.0)	147 (17.4)
Married/common law	587 (82.0)	696 (82.6)
Employment status		
Not employed	153 (21.4)	159 (18.9)
Employed	563 (78.6)	684 (81.1)
Canadian born		
Yes	**589 (82.3)**	**735 (87.2)**
No	127 (17.7)	108 (12.8)
City size		
< 100K	316 (44.1)	412 (48.9)
≥ 100 K	400 (55.9)	431 (51.1)
Parent education		
Elementary/high school	104 (14.5)	152 (18.0)
College/university •	612 (85.5)	691 (82.0)
Family annual income (CAD)		
≥ 100K	271 (37.8)	323 (38.3)
< 100K	367 (51.3)	441 (52.3)
Prefer not to answer	78 (10.9)	79 (9.4)
Number of children		
One child	166 (23.2)	198 (23.5)
Two children	322 (44.9)	408 (48.4)
Three or more children	228 (31.9)	237 (28.1)
HCP recommendation		
Yes (T1, T2)	**61 (8.5)**, **108 (15.1)**	**134 (15.9)**, **175 (20.8)**
No (T1, T2)	655 (91.5), 608 (84.9)	709 (84.1), 668 (79.2)
Provincial funding		
No funding for boys at T1 and T2 (BC; NB; NF; SK; Group = 1)	**145 (20.3)**	**124 (14.7)**
Funding for boys at T1 and T2 (AB; NS; PEI; Group = 2)	101 (14.1)	131 (15.5)
Introduction of funding for boys by T2 (MB; ON; QC; Group = 3)	470 (65.6)	588 (69.8)
	M (SD)	*M (SD)*
Parent age	44.2 (6.9)	43.7 (6.8)
Child age	12.6 (2.3)	12.5 (2.3)

***Table 1*: Baseline participant characteristics.**

Note. Bold denotes significant difference (proportions or means) between parents of boys and girls. All effect sizes were small (Cohen's *h* or Cohen's *d* range 0.14 to 0.23). • Includes trade, technical or vocational diplomas, or CEGEP (a publicly funded post-secondary education pre-university, collegiate technical college exclusive to the province of Quebec's education system).

Abbreviations. HCP = Health Care Provider; BC = British Columbia; SK = Saskatchewan; NB = New Brunswick; NF = Newfoundland and Labrador; AB — Alberta; NS = Nova Scotia; PEI = Prince Edward Island; ON = Ontario; QC = Quebec; MB = Manitoba; T1 = Time 1; T2 = Time 2.

Boys in provinces that had publicly funded HPV vaccine programs at both timepoints or in provinces that initiated funded programs by T2 had higher odds of vaccination at T2 (OR = 7.96; OR = 1.80, respectively) compared to provinces without publicly funded HPV vaccination programs. Publicly funded HPV vaccine program for boys was not associated with HPV vaccine uptake in girls.

Fig. 2. Proportion of HPV vaccinated boys and girls across three different funding groups.

Multivariable analyses. In multivariable analyses, older child's age was associated with increased odds of HPV vaccination at T1 (AOR_{Boys} = 1.20; AOR_{Girls} = 1.74), and at T2 in girls (AOR_{Girls} = 1.44). HCP recommendation on HPV vaccine uptake was significant at T1 (AOR_{Boys} = 8.42; AOR_{Girls} = 2.34) and T2 (AOR_{Boys} = 8.38; AOR_{Girls} = 1.55). At T1, lower odds of vaccination were associated with concerns about perceived harms (AOR_{Boys} = 0.53;

Predictor	Parents of Boys (*n* = 716)		Parents of Girls (*n* = 843)	
	OR (95% CI) Time 1	Time 2	OR (95% CI) Time 1	Time 2
Sociodemographic factors				
Parents' gender (men vs. women)	0.81 (0.48 1.38)	0.83 (0.58; 1.18)	0.92 (0.69; 1.24)	1.02 (0.75; 1.39)
Parents' age (continuous, 1-year increase)	1.03 (1.00; 1.07)	1.00 (0.98; 1.03)	**1.04 (1.02; 1.06)**	1.03 (1.00; 1.05)
Parents' education (trade/university vs. elementary/high school	0.94 (0.47; 1.84)	1.09 (0.67; 1.76)	**0.69 (0.48; 0.98)**	0.87 (0.60; 1.26)
Number of children (three or more children)	Reference		Reference	
One child	0.82 (0.41; 1.65)	0.86 (0.54; 1.38)	0.95 (0.65; 1.38)	0.93 (0.63; 1.39)
Two children	1.09 (0.62; 1.89)	1.26 (0.86; 1.84)	0.76 (0.55; 1.05)	0.83 (0.59; 1.16)
Marital status (single/separated vs. married/common law)	1.34 (0.74; 2.43)	1.00 (0.65; 1.54)	1.22 (0.85; 1.74)	1.01 (0.69; 1.46)
Employment status (not employed vs. employed)	1.48 (0.85; 2.56)	1.07 (0.72; 1.60)	0.98 (0.69; 1.38)	0.83 (0.59; 1.19)
Not Canadian born vs. Canadian born	0.64 (0.31; 1.32)	0.84 (0.53; 1.31)	0.70 (0.47; 1.06)	0.73 (0.49; 1.11)
City size (≥ 100 K vs. <100 K)	0.72 (0.44; 1.18)	0.80 (0.57; 1.12)	0.94 (0.72; 1.24)	0.85 (0.64; 1.12)
Race (White vs. non-White)	0.73 (0.40; 1.34)	0.79 (0.52; 1.22)	1.47 (1.00; 2.16)	**1.54 (1.05; 2.25)**
Income (CAD) < 100K	Reference		Reference	
≥ 100K	1.35 (0.80; 2.29)	**1.46 (1.02; 2.08)**	1.32 (0.99; 1.76)	1.30 (0.96; 1.76)
Prefer not to answer	1.78 (0.85; 3.72)	**1.84 (1.09; 3.12)**	1.12 (0.69; 1.80)	1.02 (0.63; 1.68)
Age of the child (continuous, 1-year increase)	**1.17(1.05; 1.31)**	1.05 (0.97; 1.13)	**1.61 (1.49; 1.73)**	**1.39 (1.30; 1.48)**
Psychosocial factors§				
HPV general knowledge	1.04 (0.99; 1.08)	1.00 (0.97; 1.04)	1.01 (0.98; 1.03)	1.01 (0.97; 1.04)
HPV vaccine knowledge	**1.18 (1.07; 1.29)**	1.03 (0.96; 1.11)	**1.17 (1.10; 1.24)**	0.98 (0.92; 1.04)
Susceptibility*	**2.03 (1.62; 2.54)**	1.10 (0.95; 1.28)	**1.91 (1.68; 2.17)**	1.02 (0.90; 1.16)
Severity	1.29 (1.00; 1.67)	0.93 (0.79; 1.10)	**1.38 (1.20; 1.58)**	0.93 (0.81; 1.07)
Benefits	**1.81 (1.41; 2.33)**	**1.26 (1.04; 1.53)**	**1.88 (1.63; 2.16)**	0.95 (0.80; 1.13)
Unaffordability	**0.41 (0.34; 0.50)**	**0.75 (0.68; 0.83)**	**0.60 (0.54; 0.67)**	**0.82 (0.75; 0.91)**
Inaccessibility	**0.42 (0.32; 0.54)**	**0.68 (0.58; 0.79)**	**0.53 (0.46; 0.61)**	0.88 (0.78; 1.00)
Harms	**0.46 (0.40; 0.57)**	**0.68 (0.57; 0.82)**	**0.47 (0.42; 0.53)**	0.91 (0.79; 1.05)
Self-efficacy	**1.55 (1.14; 2.09)**	**1.30 (1.08; 1.55)**	**1.33 (1.14; 1.56)**	**1.26 (1.08; 1.49)**
Social influence*	**4.81 (3.50; 6.61)**	**1.70 (1.41; 2.05)**	**3.68 (3.06; 4.44)**	1.07 (0.91; 1.25)
HCP recommendation				
HCP recommendation (Yes vs. No)	**9.83 (5.46; 17.73)**	**5.62 (3.65; 8.65)**	**2.08 (1.42; 3.05)**	**1.54 (1.07; 2.22)**
Provincial funding				
No funding for boys at T1 and T2 (BC; NB; NF; SK; Group = 1)	Reference		Reference	
Funding for boys at T1 and T2 (AB; NS; PEI; Group = 2)	**10.92 (4.61; 25.85)**	**7.96 (4.34; 14.63)**	0.85 (0.52; 1.39)	0.96 (0.58; 1.59)
Introduction of funding for boys by T2 (MB; ON; QC; Group = 3)	1.30 (0.56; 3.02)	**1.80 (1.08; 3.00)**	1.08 (0.73; 1.59)	1.12 (0.75; 1.68)

***Table 2*: Bivariate logistic regression model for HPV vaccination in parents of boys and parents of girls at T1 and T2.**

Note. Bold indicates significant CI. § Denotes use of change scores for psychosocial factors at T2 (i.e., score at T2- score at T1). * Denotes variables with strong mediation effect that were removed from multivariable analyses.
Abbreviations. OR = odds ratio; CI = confidence interval; HCP = Health Care Provider; BC = British Columbia; SK = Saskatchewan; NB = New Brunswick; NF = Newfoundland and Labrador; AB – Alberta; NS = Nova Scotia; PEI = Prince Edward Island; ON = Ontario; QC = Quebec; MB = Manitoba; T1 = Time 1; T2 = Time 2.

Predictor	Time 1 AOR	95% CI	Time 2 AOR	95% CI
Sociodemographic factors				
Income (CAD) < 100K	Reference		Reference	
≥ 100K	0.62	0.30; 1.30	1.21	0.79; 1.86
Prefer not to answer	1.63	0.61; 4.38	1.58	0.85; 2.95
Age of the child (continuous, 1-year increase)	**1.20**	**1.03; 1.41**	1.09	1.00; 1.19
Psychosocial Factors				
HPV vaccine knowledge	0.99	0.87; 1.13	1.05	0.96; 1.15
Benefits	1.02	0.67; 1.55	1.17	0.91; 1.50
Unaffordability	**0.45**	**0.34; 0.58**	**0.73**	**0.64; 0.83**
Inaccessibility	0.83	0.59; 1.19	**0.75**	**0.63; 0.90**
Harms	**0.53**	**0.38; 0.73**	0.85	0.68; 1.07
Self-efficacy	0.82	0.53; 1.26	**1.26**	**1.01; 1.56**
HCP recommendation				
HCP recommendation (Yes vs. No)	**8.42**	**3.58; 19.77**	**8.38**	**5.04; 13.93**
Provincial funding				
No funding for boys at T1 and T2 (BC; NB; NF; SK; Group = 1)	Reference		Reference	
Funding for boys at T1 and T2 (AB; NS; PEI; Group = 2)	**10.18**	**3.08; 33.58**	**11.42**	**5.62; 23.23**
Introduction of funding for boys by T2 (MB; ON; QC; Group = 3)	2.54	0.81; 7.98	1.35	0.74; 2.46

***Table 3*: Multivariable logistic regression model of HPV vaccination in parents of boys at T1 and T2 (*n* = 716).**
Note. Bold indicates significant CI. This table includes the estimates using multivariable binary logistic regression model. Predictors that were significant in bivariate analyses at T1 or T2 were included in the model. The estimates for psychosocial predictors at T2 are presented for one unit increase in the change score (i.e., score at T2-score at T1).
Abbreviations. AOR = adjusted odds ratio; CI = confidence interval; HCP = Health Care Provider; BC = British Columbia; SK = Saskatchewan; NB = New Brunswick; NF = Newfoundland and Labrador; AB — Alberta; NS = Nova Scotia; PEI = Prince Edward Island; ON = Ontario; QC = Quebec; MB = Manitoba; T1 = Time 1; T2 = Time 2.

AOR_{Girls} = 0.48) or perceived unaffordability (AOR_{Boys} = 0.45; AOR_{Girls} = 0.63). At T2, higher odds of vaccination were associated with an increase in self-efficacy (AOR_{Boys} = 1.26; AOR_{Girls} = 1.31), and lower odds of vaccination were associated with an increase in perceived unaffordability (AOR_{Boys} = 0.73; AOR_{Girls} = 0.79).

Compared to jurisdictions that did not receive publicly funded HPV vaccination for boys, HPV vaccine funding was associated with uptake in boys in provinces with funding at both timepoints (AOR_{T1} = 10.18; AOR_{T2} = 11.42), but not in provinces that introduced HPV vaccine funding by T2.

Discussion

We found that publicly funded school-based vaccination programs for boys was associated with greater uptake in boys at both timepoints and in the three different funding groups, but the indirect effect of vaccine funding was not observed in girls. In multivariable analyses that concurrently examined important sociodemographic and psychosocial determinants separately in parents of boys and parents of girls at T1 and T2, only jurisdictions that received funding for boys at both timepoints had greater odds of vaccination compared to jurisdictions that received funding at neither timepoints. In contrast, jurisdictions that introduced HPV vaccine funding for boys by T2 did not have significantly greater odds of uptake than those that received funding at neither timepoints. These findings provide further empircal support that program funding is an important factor in vaccination and suggest that a longer time interval—longer than the 9-month study period—is necessary for funding to demonstrate an impact on vaccine uptake.

Observational studies have emphasized the importance of funding HPV vaccination programs,[55–58] as well as health insurance-covered HPV vaccination and lower out-of-pocket costs.[18] Additional research is necessary to further understand the mechanisms of association between publicly funded vaccination and uptake. It is possible that government funding is associated with greater vaccine uptake by expanding access to vaccination, indirectly signalling governmental endorsement, accompanying media coverage, or through complementary educational campaigns with parents and health care providers. Notably, HPV vaccine funding was not found to have an additional, indirect impact beyond the targeted group.

This study also highlighted other important sociodemographic and psychosocial determinants of HPV vaccine uptake in boys and girls. We found that when all variables were concurrently considered in multivariable analyses, important determinants of vaccination of both boys and girls included older child's age, health care

Predictor	Time 1 AOR	95% CI	Time 2 AOR	95% CI
Sociodemographic factors				
Parents' age (continuous, 1-year increase)	0.99	0.96; 1.01	0.99	0.97; 1.02
Parents' education (trade/university vs. elementary/high school	0.80	0.49; 1.32	0.93	0.61; 1.40
Race (White vs. non-White)	0.75	0.44; 1.29	1.54	1.00; 2.36
Age of child (continuous, 1-year increase)	**1.74**	**1.58; 1.92**	**1.44**	**1.34; 1.55**
Psychosocial factors				
HPV vaccine knowledge	1.04	0.96; 1.13	1.01	0.94; 1.08
Severity	1.17	0.95; 1.44	0.90	0.77; 1.05
Benefits	1.10	0.87; 1.39	0.87	0.71; 1.07
Unaffordability	**0.63**	**0.54; 0.74**	**0.79**	**0.70; 0.89**
Inaccessibility	0.93	0.74; 1.17	0.97	0.83; 1.14
Harms	**0.48**	**0.40; 0.57**	0.88	0.75; 1.04
Self-efficacy	0.80	0.64; 1.01	**1.31**	**1.09; 1.57**
HCP recommendation				
HCP recommendation (Yes vs. No)	**2.34**	**1.42; 3.84**	**1.55**	**1.04; 2.29**

***Table 4*: Multivariable logistic regression model of HPV vaccination in parents of girls at T1 and T2 (*n* = 843).**
Note. Bold indicates significant CI. This table includes the estimates using multivariable binary logistic regression model. Predictors that were significant in bivariate analyses at T1 or T2 were included in the model. The estimates for psychosocial predictors at T2 are presented for one unit increase in the change score (i.e., score at T2-score at T1).
Abbreviations. AOR = adjusted odds ratio; CI = confidence interval; HCP = Health Care Provider; BC = British Columbia; SK = Saskatchewan; NB = New Brunswick; NF = Newfoundland and Labrador; AB – Alberta; NS = Nova Scotia; PEI = Prince Edward Island; ON = Ontario; QC = Quebec; MB = Manitoba; T1 = Time 1; T2 = Time 2.

provider recommendation, perceived vaccine harms, and perceived vaccine affordability. Previous research has identified these variables as important, though not in the context of also examining vaccine funding.[15–18] Accordingly, this study has highlighted that parents' confidence in vaccines and vaccination remain importantly associated with delayed and missed HPV childhood vaccination. Improving vaccine confidence and achieving high vaccination coverage is crucial in order for countries to receive the full benefit of immunization.[59]

To the best of our knowledge, this is the first study that has conducted an analysis of the impact of publicly funded HPV immunization programs across Canada. There is a feasibility challenge in studying funding in large-scale, controlled studies as many immunization programs are longstanding and new programs are often implemented nation-wide. The staggered implementation of HPV vaccine funding for boys in Canada presented this research opportunity. Our study is unique in examining vaccine funding alongside a comprehensive set of sociodemographic and psychosocial variables known to be important for HPV vaccine uptake. Another study strength was our gender-sensitive analysis of HPV vaccine uptake for boys and girls that highlighted similar and distinct factors.

Our study is not without limitations. The study's outcome variable (HPV vaccination) was reported by parents and not verified using vaccination surveillance data as there is no national surveillance of HPV vaccination. Parents' recollection can contain inaccuracies and recall bias, particularly in school-based vaccination programs, and this has been found to disproportionately impact certain segments of the population.[60–62] Nevertheless, studies have found parents' self-report of their adolescent HPV vaccination status to be reasonably accurate. For example, self-reported data from a national Statistics Canada survey of Canadian parents of 12–13-year-old girls was similar to the proportion and distribution of uptake as reported by provincial programs.[14] In addition, US studies specifically examining the accuracy of parents reports of adolescent HPV vaccination in large national surveys have found reasonable agreement of parents' recall for HPV vaccine uptake with vaccination status (e.g., kappa = 0.785).[62,63]

This study's analysis was conducted at the provincial level and considered city size; however, there may be other important regional differences within provinces that should be accounted for in future analyses. Furthermore, although the sample is generally representative of the Canadian population, this study's sample was wealthier, more educated, and White as compared to the 2016 Census.[64] While our study aimed to be representative by gender and provincial distribution of children aged 9–16, we recommend future studies to also incorporate other sociodemographic criteria to achieve a more representative sample. In addition, this study was also not able to recruit many participants living in Canada's three territories due to constraints of the marketing panel used, and therefore this study only focuses on Canada's ten provinces. Greater evaluation of the import of vaccine funding in Canada's territories as well

as other jurisdictions (such as low- and middle-income countries) is needed. Lastly, this study is limited in its ability to generalize to other vaccines used in school-based vaccination programs and regions with other healthcare delivery systems.

Overall, this study demonstrated the specific importance of publicly funded school-based programs for uptake in the target population, and supported the importance of other known determinants of vaccination such as health care provider's recommendation, child's age, perceived vaccine affordability, and perceived vaccine harms. Further comparative research on educational, behavioural, social, and policy strategies to increase child vaccination is critical. Lastly, this study also highlights the complex interplay of sociodemographic, psychosocial and policy decisions, which continue to challenge immunization programs in reaching targets. In future research these factors need to be concurrently examined.

Contributors

All authors made substantial contributions to the study conception and design. GKS and OT completed data analysis and verified the underlying data. GKS and OT wrote the first draft of the manuscript. All authors contributed to data interpretation, and the critical review of the manuscript for important intellectual content. All authors had full access to the full data in the study and accept responsibility to submit for publication. All authors read and approved the final manuscript version.

Data sharing

Data collected for this study may be available from the corresponding authors on reasonable request.

Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations Table 4.

Declaration of interests

GKS reports consulting fees from the World Health Organization outside the submitted work and is supported by a Canadian Institutes of Health Research 2019 Fellowship Award (CIHR MFE 171271) outside the submitted work. OT is supported by the Canadian Institutes of Health Research (CIHR)-Frederick Banting and Charles Best Doctoral award (Award No. FBD-170837) outside the submitted work, and is a Research Associate (part-time) at the Lady Davis Institute for Medical Research (Montreal, Canada). BK declares no conflict of interest. GGM is a Research Assistant at the Lady Davis Institute for Medical Research (Montreal, Canada) and receives funding from the Canadian Insitutes of Health Research (CIHR Project Grant No. 420029) associated with a project outside the submitted work. ZR reports payment for presentation to the Consortium for Infectious Disease Control outside the submitted work, and unpaid leadership involvement in a non-governmental organization (Vice-President, HPV Global Action) outside the submitted work.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2021.100128.

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