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Human papillomavirus (HPV) vaccine uptake among a community-recruited sample of gay, bisexual, and other men who have sex with men in the three largest cities in Canada from 2017 to 2019

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ABSTRACT

Introduction: In 2015/2016, Canada's largest provinces implemented publicly-funded human papillomavirus (HPV) vaccination programs for gay, bisexual, and other men who have sex with men (GBM) ≤ 26 years old. We sought to describe HPV vaccine uptake among GBM and determine barriers and facilitators to vaccine initiation with a focus on healthcare access and utilization.
Methods: Engage is a cohort study among GBM aged 16 + years in three Canadian cities recruited from 2017 to 2019 via respondent driven sampling (RDS). Men completed a comprehensive questionnaire at baseline. By publicly-funded vaccine eligibility (≤26 years old = eligible for vaccination, ≥27 years old = ineligible), we described HPV vaccine uptake (initiation = 1 + dose, completion = 3 doses) and explored factors associated with vaccine initiation using Poisson regression. All analyses were weighted with the RDS-II Volz-Heckathorn estimator.
Results: Across the three cities, 26–35% and 14–21% of men ≤ 26 years and 7–26% and 2–9% of men ≥ 27 years initiated and completed HPV vaccination, respectively. Vaccine initiation was significantly associated with STI/HIV testing or visiting a HIV care specialist in the past six months (≤26: prevalence ratio[PR] = 2.15, 95% confidence interval[CI] 1.06–4.36; ≥27: PR = 2.73, 95%CI 1.14–6.51) and past hepatitis A or B vaccination (≤26: PR = 2.88, 95%CI 1.64–5.05; ≥27: PR = 2.03, 95%CI 1.07–3.86). Among men ≥ 27 years old, vaccine initiation was also positively associated with accessing PrEP, living in Vancouver or Toronto, but negatively associated with identifying as Latin American and increasing age. Vaccine initiation was twice as likely among men ≥ 27 years with private insurance versus no insurance.
Conclusions: Sixty-five to 74% of men eligible for publicly-funded vaccine across the three cities remained unvaccinated against HPV by 2019. High vaccine cost may partly explain even lower uptake among

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men ≥ 27 years old. Men seeking sexual health care were more likely to initiate vaccination; bundling vaccination with these services may help improve HPV vaccine uptake.
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1. Introduction

Gay, bisexual, and other men who have sex with men (GBM) are recommended to get the human papillomavirus (HPV) vaccine because they are at higher risk for HPV and HPV-related disease compared with men who have sex with women [1–6]. The most concerning HPV genotypes are those that can cause cancers. Vaccination protects against the HPV types responsible for anal cancer with 75% efficacy among men [7].

In Canada, as of 2018, all provinces and territories have gender-neutral school-based HPV vaccination programs. Some provinces have also implemented targeted HPV vaccination programs for GBM; in most regions, eligible GBM must be ≤ 26 years old [8–10]. Despite this, data suggests that older men are still at high risk for HPV and may still receive protection against HPV types to which they have not yet been exposed [11]. The National Advisory Committee on Immunization (NACI) in Canada recommends men 9–26 years old get vaccinated against HPV [2]. Due to the higher risk of HPV among GBM, NACI recommends all GBM get vaccinated regardless of age [2] and the vaccine has now been authorized for use up to age 45 years among men in Canada [12].

Identifying barriers and facilitators to vaccination is important to improve vaccine uptake. To obtain HPV vaccine, adult men must first attend health care, which not all men may have easy access to. Among young GBM in the United States (US), convenience was stated as one of the most important factors influencing vaccination. In that study, men stated they would likely wait until their next routine health visit to get vaccinated against HPV to avoid having to visit their provider twice [13]. A pilot assessment of England's HPV vaccination program found that 85% of men reported accessing other services at the time of vaccination, and only 11% attended the clinic just to get vaccinated [14]. Access to and utilization of different healthcare services may be particularly crucial for GBM, and a greater understanding of their association with vaccination may help determine where vaccine services should be offered, and where further outreach is required.

Other factors may also influence HPV vaccination. Young men getting vaccinated under GBM publicly-funded programs must disclose same-sex activity to healthcare providers, which may be a barrier for some [15]. Men ≥ 27 years old must pay for the vaccine, whether through private insurance or out-of-pocket, and thus cost may be a deterrent. Cost of the HPV vaccine has been reported as a barrier to vaccination, internationally [16,17].

Among GBM living in the three largest cities in Canada including Vancouver, British Columbia (BC); Toronto, Ontario; and Montreal, Quebec, we sought to 1) quantify and describe HPV vaccine uptake, 2) explore the association between HPV vaccine initiation and healthcare access, healthcare utilization, and other potential barriers and facilitators, and 3) determine if factors associated with vaccine initiation differed between men eligible for publicly-funded vaccine (≤26 years old) versus men ineligible (≥27 years old) but still recommended to get vaccinated.

2. Methods

2.1. Setting

In Canada, healthcare systems are implemented at the provincial or territorial level and cover the cost of essential medical and hospital services, including vaccines; thus, vaccination programs may differ interprovincially. BC, Ontario, and Quebec have GBM-targeted HPV vaccination programs, which were implemented in September 2015, September 2016, and January 2016, respectively [8–10]. GBM must be ≤ 26 years old to be eligible. Ineligible men must pay up to $560 for all doses of the vaccine or seek coverage through private insurance [16]. To be fully vaccinated against HPV in Canada, NACI recommends males ≥ 15 years old get three doses of the vaccine [2] and all provinces and territories, with exceptions in Quebec, follow these recommendations. Starting in 2016, Quebec requires only two doses of the vaccine for those ≤ 18 years old, and as of 2018, the regimen is one dose of bivalent and one dose of nonavalent vaccine for this age group [10]. As of 2018, all other Canadian GBM vaccination programs, including Quebec for men ≥ 18 years old, use the nonavalent vaccine. Prior to 2018, programs used the quadrivalent vaccine. Men can receive the vaccine at their local public health unit in BC or Ontario or in the *Centre local de services communautaires* (CLSC) in Quebec. In all three provinces, men can also get vaccinated by their primary care physician or other healthcare provider such as at a sexual health or walk-in clinic. In BC and Quebec, some pharmacies offer the vaccine under the publicly-funded program. Regardless of vaccination venue, healthcare providers must determine if men meet publicly-funded program eligibility requirements and it is up to the provider to determine how they will establish this.

2.2. Recruitment

We analysed baseline data from the Engage Study, an ongoing community-recruited sexual health cohort study among GBM in Vancouver, Toronto, and Montreal. From 2017 to 2019, each city recruited its own sample of participants using respondent-driven sampling (RDS), a robust form of chain-referral sampling used to recruit hard-to-reach populations [18]. Study investigators consulted with the GBM community to inform the selection of a diverse group of study "seeds" (initial participants) and to validate study procedures. Eligible men were ≥ 16 years of age, had sex with another man in the past six months, were able to read English or French, and provided written informed consent. Each seed was given six coupons to distribute to members of their social network. Recruitment was tracked using unique codes on each coupon. Identifying participant information was collected allowing for monitoring of potential repeat enrolment. Participants received $50 and an additional $15 for each eligible GBM they recruited. Network size was measured using the question: "How many men who have sex with men aged 16 years or older, including trans men, do you know who live or work in the [City] area (whether they identify as gay or otherwise)? This includes gay/bi guys you see or speak to regularly; e.g., close friends, boyfriends, spouses, regular sex partners, roommates, relatives, people you regularly hang out with, etc." The study received ethical approval from Ryerson University, University of Toronto, St. Michael's Hospital, University of Windsor, University of British Columbia, Providence Health Care, University of Victoria, Simon Fraser University, and McGill University Health Centre.

2.3. Questionnaire

Participants self-completed a detailed questionnaire using computer-assisted self-interview (CASI). Men were asked whether

they were aware of the HPV vaccine ("Before today, had you ever heard of the HPV vaccine?"); men who were unaware or unsure were not asked additional questions on HPV vaccination. Participants were asked if they knew that the HPV vaccine is recommended for boys and men, if a healthcare provider ever discussed the HPV vaccine with them, and if they were ever vaccinated. Vaccinated men were asked whether they received the vaccine free of charge (did not spend any money out-of-pocket nor claim any fees from an insurance provider), age at first dose, number of doses received (one, two, three, or don't know/remember), and where they received their most recent dose of the HPV vaccine (options: medical clinic not specializing in sexual health, sexual health clinic, hospital outpatient clinic, hospital emergency room, walk-in clinic, other [asked to specify], don't know/remember or prefer not to answer).

2.4. Outcome of interest

The primary outcome was HPV vaccine initiation (at least one dose) and it was operationalized as a dichotomous variable. For our analyses, we classified men as unvaccinated if they responded either no or unsure to having been vaccinated or if unaware of the HPV vaccine; we reasoned that few men would forget having received vaccination given its relative novelty among men and substantial price for men $\geq$ 27 years old. When compared to electronic medical records, self-report vaccination status for HPV among adults has a 89–96% sensitivity, 76–80% specificity, and 73–84% accuracy [19–22].

2.5. Variables of interest

Measures on healthcare access and utilization included categorical variables on the type of provider(s) men were currently visiting (primary care provider, sexual health care provider [has a separate provider for sexual healthcare or has HIV care specialist], both, or none); men's last sexually transmitted infection (STI) test, HIV test, or HIV specialist care visit; frequency of visits to their primary care provider in a year; and past hepatitis A or B vaccination. Among men $\geq$ 27 years old, we also considered insurance coverage. There were two questions about accessing pre-exposure prophylaxis (PrEP) for HIV: "In the past six months, have you tried to go on PrEP for HIV?" and among those that had ever taken PrEP, "When did you last take PrEP?". Nearly all men (unweighted = 98%) that were currently on PrEP also indicated they had tried to go on PrEP in the past six months. Similar associations were seen with vaccine initiation among men currently on PrEP and men who had tried to go on PrEP but were not currently on it (data not shown). Therefore, these two groups were combined for analysis and considered to have been 'accessing PrEP'.

Other variables of interest that we also considered as potential confounders of the relationship between vaccine initiation and healthcare access and utilization included ethnicity/race, education, age, gender, and disclosure of same-sex romantic relationships ("I prefer to keep my same-sex romantic relationships rather private"). The latter question was asked using a Likert scale for response options (strongly disagree to strongly agree). An ordinal relationship for this variable was observed in the model among men $\geq$ 27 years old whereas a more binary relationship was observed among younger men. Thus, disclosure of same-sex romantic relationships was operationalized differently according to whether men were aged $\leq$ 26 or $\geq$ 27 years old.

2.6. Statistical analysis

Since RDS is a network-based recruitment strategy, individuals with large social networks may have a higher probability of being recruited into the study. It is standard practice to account for this using RDS-II Volz-Heckathorn weights [23]. These weights are inversely proportional to a participant's self-reported network size [23]. To avoid extreme outlier values in network size, the upper limit was set to 150, based on research on maximum possible network sizes [24]. Weights were applied to all proportions, unless otherwise specified, and multivariable models. Unweighted proportions are provided in Supplementary Materials, Table 2 and Table 3, for comparison. Seeds were included in all analyses.

We described characteristics of the sample by age group ($\leq$26 years old = eligible for publicly-funded vaccine and $\geq$ 27 years old = ineligible) overall (unweighted), and by city (weighted). We estimated proportions that initiated vaccination, completed their HPV vaccination series (three doses; none of the men $\leq$ 18 years old in Montreal reported receiving two doses), and the proportion of completers among initiators. Using the Pearson's chi-squared test, we explored whether vaccine uptake proportions significantly differed by city. Among all men, we described men's knowledge of the vaccine and whether a doctor ever discussed the vaccine with them. Among vaccinated men, we described findings on payment for the vaccine, age at first dose, location of most recent dose, and number of doses received.

2.6.1. Univariable and multivariable analysis

We identified factors associated with vaccine initiation in a pooled analysis of all three cities combined. We used Poisson regression with a robust error variance to estimate unadjusted and adjusted prevalence ratios (PR) with 95% confidence intervals (CI) [25]. We included city as a fixed effect. We used a complete case strategy because data were missing for <2% in multivariable models. Clustering between recruiters and recruits has been shown to have little impact on regression analyses using RDS data [26]. To explore this in our data, we used generalized estimating equations with an exchangeable correlation matrix to calculate the intraclass correlation coefficient (ICC) for clustering at the recruiter and seed level. Models had low ICCs and similar estimates compared to when clustering was not accounted for, and thus clustering at these levels was not considered in the final models. We also explored whether enrolment date altered results, since the longer HPV vaccination programs had been in place, the more opportunity men would have had to get vaccinated.

Analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, North Carolina, USA). All p-values were two-sided and statistical significance was determined using a p-value of < 0.05.

2.6.2. Sample size considerations

We calculated the minimum effect size needed to detect an association between an independent variable and the dichotomous outcome of HPV vaccine initiation using Poisson regression and: 80% power, 50% vaccinated among those 'unexposed', 0.005 alpha error probability accounting for the Bonferroni adjustment since multiple hypotheses were being tested, a low-moderate correlation (correction factor of 0.2) with other covariates in the model, and the recruited sample size ($\leq$26 years old = 550, $\geq$27 years old = 1899). We accounted for RDS recruitment using a design effect equal to two [27], which indicates that double the sample size is needed to detect the same association as simple random sampling. G*Power 3.1 was used for calculations [28]. The observed sample size allowed for detection of prevalence ratios of 1.83 and 1.40 for an independent variable with a binomial and normal distribution, respectively, among men $\leq$ 26 years old, and for detection of prevalence ratios of 1.41 and 1.20 among men $\geq$ 27 years old.

3. Results

The final recruited sample was 2449 men (Vancouver = 753, Toronto = 517, and Montreal = 1179), including 240 seeds (Supplementary Materials, Table 1). Across the three cities, men were between 16 and 80 years old. Among men ≤ 26 years old, 70–80% of men identified as gay, 50–71% were white, 61–71% had some or completed post-secondary education, few were living with HIV and 22–28% did not have a primary or sexual health care provider (Table 1). Among men ≥ 27 years old, 71–79% identified as gay, 57–71% were white, 44–60% had some or completed post-secondary education, 16–27% were living with HIV, 12–22% did not have a healthcare provider, and 33–41% did not have any insurance for medications or non-publicly-funded vaccines (Table 1).

3.1. HPV vaccine knowledge and provider recommendation

3.1.1. ≤26 years old

In Vancouver, Toronto, and Montreal, respectively, 73%, 73%, and 81% of men were aware of the HPV vaccine, and among these men, 73%, 65%, and 78% were aware that the vaccine was recommended for boys and men. The proportion that indicated that a healthcare professional had ever discussed the HPV vaccine with them was 82%, 88%, and 90% of vaccinated men but only 10%, 18%, and 13% of unvaccinated men.

3.1.2. ≥27 years old

Among older men, 62%, 75%, and 55% were aware of the HPV vaccine in Vancouver, Toronto, and Montreal, respectively, and among these men, 76%, 77%, and 60% were aware that the vaccine was recommended for boys and men. The proportion that indicated that a healthcare professional had ever discussed the HPV vaccine with them was 98%, 77%, and 96% among vaccinated men compared with only 10%, 13%, and 11% of unvaccinated men.

3.2. Vaccine initiation and completion

3.2.1. ≤26 years old

In Vancouver, Toronto, and Montreal, respectively, vaccine initiation was 26% (95%CI 16.8–34.7%), 33% (95% CI 19.4–45.6), and 35% (95%CI 25.9–43.8%) (p = 0.395) (Fig. 1). Among all younger men, vaccine completion was 14% (95%CI 7.7–20.3%) in Vancouver, 21% (95%CI 10.0–32.7%) in Toronto, and 15% (95%CI 9.2–21.0%) in Montreal (p = 0.421) (Fig. 1). Among men who had initiated vaccination, 54% (95%CI 39.0–69.7%) in Vancouver, 66% (95%CI 46.9–84.4%) in Toronto, and 43% (95%CI 28.5–58.0%) in Montreal (p = 0.140) completed vaccination, respectively. There was no significant difference in uptake across the three cities.

Most young men (82–85%) reported receiving the vaccine free of charge. The median age at which men received their first dose was 21 years old in Montreal (IQR 19–23) and 22 years old in Vancouver (IQR 20–23) and Toronto (IQR 19–24). The most popular venue for receiving the most recent dose of the vaccine was a sexual health clinic (Vancouver = 49%, Toronto = 40%, Montreal = 30%). Other common venues included a medical clinic not specializing in sexual health (Vancouver = 13%, Toronto = 15%, Montreal = 22%), a community health centre or CLSC (Vancouver = 3%, Toronto = 10%, Montreal = 18%), and a doctor's office (Vancouver = 6%, Toronto = 11%, Montreal = 3%). The most popular response when men specified other venues was a college or university student health centre.

3.2.2. ≥27 years old

Among older men, there was a significant difference in vaccine initiation across cities where 18% (95%CI 12.6–23.2%), 26% (95% CI 16.3–35.7%), and 7% (95%CI 3.5–9.5%) (p < 0.0001) initiated HPV vaccination in Vancouver, Toronto, and Montreal, respectively (Fig. 1). A minority of men had initiated vaccination when aged ≤ 26 years old when they could have received the vaccine for free (unweighted proportion = 13%). Among men living with HIV, 19% (95%CI 7.3–30.6%) in Vancouver, 21% (95%CI 6.3–36.4) in Toronto, and 7% (95%CI 0.0–16.2%) in Montreal (p = 0.242) had initiated HPV vaccination.

Among all older men, vaccine completion differed significantly by city where 9% (95%CI 5.6–13.1%) in Vancouver, 17% (95%CI 7.9–26.0%) in Toronto, and 2% (95%CI 0.1–2.5%) in Montreal (p < 0.0001) completed vaccination (Fig. 1). Among men who initiated vaccination, 52% (95%CI 36.7–68.1%) in Vancouver, 65% (95%CI 47.7–82.8%) in Toronto, and 33% (95%CI 13.5–52.9%) in Montreal (p = 0.053) completed vaccination, respectively.

Among older vaccinated men, the median age at first dose was 28 years old for Vancouver (IQR 26–44) and Montreal (IQR 26–43), and 32 years old (IQR 27–41) for Toronto. In Vancouver and Montreal, the most popular venue for receiving the most recent dose of the vaccine was a sexual health clinic (35% and 49%, respectively) compared with 22% in Toronto. The most popular venue in Toronto was the doctor's office (33%), but this was less commonly reported in Vancouver (23%) and Montreal (4%). Other common venues where older men were vaccinated included medical clinics not specializing in sexual health (Vancouver = 15%, Toronto = 13%, Montreal = 4%) and a community health centre or CLSC (Vancouver = 9%, Toronto = 2%, Montreal = 30%). The most popular response when men specified other venues was a pharmacy.

3.3. Barriers and facilitators of HPV vaccine initiation

3.3.1. ≤26 years old

In all models, men more likely to have initiated HPV vaccination were those who had a STI/HIV test or visited their HIV specialist in the past 0–6 months compared with > 12 months ago/no tests or visits (weighted PR = 2.15, 95%CI 1.06–4.36) and men previously vaccinated for hepatitis A or B (weighted PR = 2.88, 95%CI 1.64–5.05) (Table 2). In both unweighted unadjusted and adjusted models, we found that men who were accessing PrEP were significantly more likely to initiate HPV vaccination compared with those who were not accessing PrEP or were unaware of PrEP, though findings were no longer statistically significant in the weighted model. There was no significant association between HPV vaccine initiation and age or city in any models (Table 2).

3.3.2. ≥27 years old

In all models, men more likely to initiate HPV vaccination were those who: had a STI/HIV test or visited their HIV specialist in the past 0–6 months compared to > 12 months ago/no tests or visits (weighted PR = 2.73, 95%CI 1.14–6.51), were accessing PrEP compared to not accessing PrEP or being unaware of PrEP (weighted PR = 1.66, 95%CI 1.02–2.70), and were previously vaccinated for hepatitis A or B (weighted PR = 2.03, 95%CI 1.07–3.86) (Table 3). Men living in Vancouver (weighted PR = 1.87, 95%CI 1.12–3.13) or Toronto (weighted PR = 2.81, 95%CI 1.69–4.67) compared to Montreal were more likely to initiate HPV vaccination. The likelihood of initiating vaccination was lower among Latin American men compared to white men (weighted PR = 0.37, 95%CI 0.17–0.83) and decreased with age in all models (weighted PR = 0.88, 95%CI 0.80–0.96) (Table 3). In both unweighted unadjusted and adjusted models, men who had a STI/HIV test or visited their HIV specialist 6–12 months ago, men with private insurance, and men living with HIV were more likely to initiate vaccination (Table 3); however, associations lost statistical-significance in the RDS-weighted adjusted model.

Table 1
Unweighted overall proportions and means and city-specific weighted proportions and means for baseline characteristics of Engage participants (n = 2449), by age group.

	All cities		Vancouver		Toronto		Montreal	
	≤26 years n = 550	≥27 years n = 1899	≤26 years n = 178[a]	≥27 years n = 575[a]	≤26 years n = 123[a]	≥27 years n = 394[a]	≤26 years n = 249[a]	≥27 years n = 930[a]
	%[a]	%[a]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]
Mean age at enrolment (SD)	23.4 (2.1)	40.7 (12.0)	23.2 (1.9)	40.3 (12.3)	23.4 (2.4)	40.1 (13.0)	23.1 (2.2)	42.3 (13.1)
Ethnicity/race								
White	66.2	72.8	49.7 (36.1, 63.3)	57.4 (49.2, 65.7)	60.3 (45.5, 75.0)	59.5 (48.4, 70.5)	70.8 (61.8, 79.9)	70.6 (64.6, 76.6)
East-Southeast Asian	10.2	6.3	23.2 (10.4, 36.0)	15.7 (10.4, 21.0)	8.0 (1.6, 14.4)	11.4 (2.4, 20.4)	3.8 (0.6, 7.1)	1.5 (0.2, 2.7)
Latin American	6.9	8.4	8.3 (2.7, 14.0)	13.9 (7.2, 20.7)	8.3 (1.0, 15.5)	8.5 (4.0, 13.0)	6.5 (2.3, 10.7)	11.1 (7.1, 15.1)
African/Caribbean/ Black	2.2	3.2	0.7 (0.0, 1.7)	2.3 (0.0, 5.1)	6.4 (0.0, 15.6)	6.9 (2.4, 11.3)	3.8 (0.0, 8.1)	3.0 (1.5, 4.6)
Indigenous	1.4	1.5	1.9 (0.0, 4.5)	4.9 (0.0, 10.3)	1.9 (0.0, 5.7)	2.3 (0.0, 6.7)	4.0 (0.0, 10.0)	0.3 (0.0, 0.8)
South Asian	4.0	1.7	11.4 (3.0, 19.9)	1.9 (0.0, 3.9)	4.2 (0.0, 9.5)	3.6 (1.5, 5.7)	1.4 (0.2, 2.6)	2.3 (0.0, 4.6)
West Asian/North African	4.0	2.7	0.2 (0.0, 0.6)	0.5 (0.0, 1.2)	1.8 (0.1, 3.6)	4.4 (0.0, 9.4)	5.8 (1.2, 10.3)	7.5 (3.1, 11.8)
Other	0.7	1.3	0.2 (0.0, 0.5)	0.9 (0.0, 1.9)	1.2 (0.0, 3.6)	1.1 (0.0, 2.2)	0.4 (0.0, 1.1)	2.2 (0.3, 4.2)
Mixed	4.4	2.2	4.4 (0.0, 10.9)	2.4 (0.4, 4.4)	7.8 (0.4, 15.3)	2.3 (0.6, 4.0)	3.5 (0.9, 6.0)	1.4 (0.4, 2.4)
Gender								
Cisgender man	90.2	94.5	96.4 (93.2, 99.7)	92.1 (86.0, 98.2)	89.9 (79.6, 100.0)	93.0 (87.9, 98.1)	85.6 (78.5, 92.7)	89.2 (84.2, 94.3)
Trans man	2.0	1.0	1.4 (0.0, 4.0)	0.6 (0.0, 1.3)	0.2 (0.0, 0.6)	1.4 (0.3, 2.5)	4.6 (0.5, 8.8)	0.8 (0.0, 1.7)
Gender queer/Gender non-conforming	6.0	1.5	2.0 (0.2, 3.9)	1.0 (0.1, 1.9)	7.4 (0.0, 16.9)	1.8 (0.0, 3.8)	6.3 (1.6, 11.0)	1.1 (0.3, 1.8)
Other gender identities[c]	1.8	3.0	0.2 (0.0, 0.5)	6.3 (0.3, 12.4)	2.4 (0.0, 7.1)	3.8 (0.0, 8.3)	3.5 (0.0, 7.7)	8.9 (4.0, 13.9)
Sexual orientation								
Gay	75.6	83.3	80.3 (71.1, 89.5)	79.4 (71.2, 87.6)	74.9 (61.6, 88.3)	71.2 (60.4, 82.0)	70.2 (61.0, 79.4)	76.8 (71.2, 82.4)
Bisexual	7.1	6.5	13.3 (5.0, 21.7)	10.7 (4.0 17.4)	10.1 (0.1, 20.1)	15.2 (4.8, 25.6)	12.0 (4.2, 19.7)	13.0 (8.7, 17.2)
Queer	12.9	5.9	4.3 (1.6, 7.1)	3.4 (1.2, 5.7)	9.9 (4.1, 15.8)	9.0 (5.1, 12.8)	12.7 (6.3, 19.1)	2.1 (1.1, 3.1)
Other[d]	4.4	4.3	2.1 (0.0, 4.8)	6.5 (0.8, 12.2)	5.0 (0.0, 14.2)	4.6 (0.0, 9.3)	5.1 (2.2, 8.0)	8.1 (3.7, 12.5)
Education								
High school or less	24.0	23.2	22.3 (12.5, 32.0)	24.1 (16.5, 31.6)	21.9 (10.1, 33.6)	23.3 (11.5, 35.1)	29.1 (19.5, 38.6)	37.7 (31.2, 44.2)
Post- secondary	66.7	56.3	69.4 (58.1, 80.7)	59.9 (52.0, 67.8)	70.6 (57.7, 83.4)	57.3 (45.8, 68.8)	61.2 (51.5, 70.8)	44.6 (38.3, 50.6)
Graduate/ professional degree	9.1	20.4	7.0 (1.2, 12.9)	16.0 (11.5, 20.6)	7.6 (1.9, 13.3)	19.4 (12.7, 26.1)	9.8 (5.1, 14.4)	17.8 (13.4, 22.2)
Personal annual income (CAD)								
<$20,000	53.4	31.0	52.8 (39.1, 66.4)	38.6 (30.5, 46.8)	50.6 (34.9, 66.4)	40.0 (28.3, 51.7)	65.6 (56.9, 74.4)	47.9 (41.5, 54.2)
$20,000-$39,999	31.1	26.8	32.3 (18.8, 45.8)	23.7 (16.6, 30.8)	41.4 (24.8, 58.0)	32.8 (21.1, 44.5)	25.6 (17.6, 33.7)	27.4 (21.7, 33.1)
$≥40,000	15.5	42.2	15.0 (6.7, 23.2)	37.7 (30.2, 45.2)	7.9 (2.5, 13.4)	27.2 (19.7, 34.8)	8.7 (4.4, 13.1)	24.7 (20.2, 29.3)
Insurance for medication/ non-publicly funded vaccines								
No insurance	33.1	28.2	38.3 (25.0, 51.7)	36.5 (28.0, 45.0)	37.3 (22.7, 51.9)	41.1 (30.0, 52.3)	29.1 (19.4, 38.9)	33.0 (27.3, 38.8)
Government insurance	17.1	23.2	12.7 (3.9, 21.5)	20.2 (13.2, 27.2)	11.1 (3.0, 19.2)	29.4 (16.6, 42.3)	21.6 (13.6, 29.7)	34.3 (27.6, 41.1)
Private insurance[e]	31.3	37.4	24.5 (15.2, 33.9)	31.9 (25.2, 38.6)	28.6 (12.1, 45.0)	21.2 (14.7, 27.7)	35.2 (26.5, 44.0)	27.8 (23.0, 32.6)
Both government and private	18.5	11.2	24.4 (10.7, 33.1)	11.4 (7.8, 15.0)	23.1 (10.7, 35.4)	8.2 (4.8, 11.7)	14.0 (8.0, 19.9)	4.8 (3.0, 6.6)
Past hepatitis A or B vaccination								
No or don't know	29.5	24.6	38.0 (25.5, 50.5)	28.1 (20.4, 35.7)	26.7 (14.6, 38.7)	26.2 (17.9, 34.5)	38.8 (29.2, 48.4)	37.3 (30.9, 43.8)
Yes	70.5	75.4	62.0 (49.5, 74.5)	71.9 (64.3, 79.6)	73.3 (61.3, 85.4)	73.8 (65.5, 82.1)	61.2 (51.6, 70.8)	62.7 (56.2, 69.1)
Prefer to keep same-sex romantic relationships private								
Disagree	56.9	50.6	46.8 (33.3, 60.4)	40.8 (33.3, 48.2)	43.6 (28.5, 58.8)	46.4 (35.0, 57.9)	49.1 (39.4, 58.7)	34.1 (28.4, 39.8)
Agree/prefer not to answer	42.9	49.0	53.2 (39.6, 66.7)	59.2 (51.8, 66.7)	56.4 (41.2, 71.5)	53.2 (41.7, 64.6)	50.7 (41.1, 60.4)	63.3 (57.2, 69.3)
Type of provider currently visiting								
Only primary provider	26.0	28.5	15.9 (8.2, 23.7)	25.0 (17.1, 32.9)	34.2 (17.7, 50.6)	33.9 (22.7, 45.1)	25.5 (17.1, 34.0)	28.0 (22.4, 33.7)
Only sexual health provider	24.7	14.6	19.5 (10.1, 28.9)	14.9 (10.2, 19.7)	16.0 (7.8, 24.2)	7.6 (4.2, 11.0)	25.3 (17.2, 33.5)	15.1 (10.5, 19.7)
Both types of providers	33.1	46.2	36.1 (22.7, 49.5)	48.2 (40.1, 56.3)	27.6 (14.7, 40.5)	45.8 (34.2, 57.3)	25.0 (17.3, 32.7)	34.5 (28.8, 40.2)
No provider	16.2	10.7	28.5 (14.9, 42.1)	11.9 (6.2, 17.6)	22.2 (8.8, 35.7)	12.7 (5.7, 19.8)	24.1 (14.8, 33.4)	22.4 (16.6, 28.1)
Frequency of visits to primary care provider in a year								
Four or more	18.2	31.7	16.2 (3.9, 28.6)	38.9 (31.0, 46.8)	25.2 (12.6, 37.8)	38.3 (26.8, 49.8)	12.0 (4.8, 19.1)	23.9 (18.4, 29.3)
Two or three	20.7	26.1	21.0 (11.3, 30.8)	20.0 (14.6, 25.4)	16.1 (6.7, 25.4)	28.1 (16.8, 39.4)	18.7 (11.8, 25.6)	20.5 (16.1, 25.0)
Once	12.0	11.3	8.2 (2.6, 13.9)	10.9 (3.5, 18.3)	6.9 (1.3, 12.4)	6.7 (3.8, 9.7)	10.5 (6.2, 14.8)	10.1 (7.5, 12.6)
Only every 2–3 years or don't know	7.8	5.3	6.5 (2.1, 11.0)	2.5 (1.2, 3.7)	13.6 (0.0, 30.7)	6.5 (1.3, 11.6)	8.8 (3.4, 14.3)	5.9 (3.1, 8.6)
No primary provider	40.9	25.3	48.0 (34.3, 61.7)	26.8 (20.0, 33.7)	38.2 (23.6, 52.9)	20.4 (12.6, 28.2)	49.4 (39.7, 59.1)	37.5 (31.2, 43.8)

Table 1 (*continued*)

	All cities		Vancouver		Toronto		Montreal	
	≤26 years n = 550	≥27 years n = 1899	≤26 years n = 178[a]	≥27 years n = 575[a]	≤26 years n = 123[a]	≥27 years n = 394[a]	≤26 years n = 249[a]	≥27 years n = 930[a]
	%[a]	%[a]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]	% (95% CI)[b]
Last STI/HIV test or HIV specialist visit								
0–6 months ago	62.0	67.8	49.9 (36.2, 63.5)	70.5 (62.6, 78.3)	60.8 (44.1, 77.4)	60.7 (49.1, 72.3)	57.2 (47.7, 66.8)	56.1 (49.7, 62.4)
6–12 months ago	15.4	15.1	16.3 (7.1, 25.5)	11.2 (6.7, 15.6)	14.2 (3.6, 24.8)	15.0 (8.1, 22.0)	16.2 (9.0, 23.3)	19.3 (14.0, 24.7)
>12 months ago	14.0	15.1	14.4 (5.8, 23.0)	17.2 (9.7, 24.6)	19.2 (2.1, 36.3)	16.2 (7.1, 25.3)	14.7 (7.6, 21.8)	20.0 (15.4, 24.6)
No testing or visits	8.2	1.1	19.5 (9.6, 29.3)	1.1 (0.1, 2.0)	5.8 (0.0, 11.7)	3.6 (0.0, 7.2)	11.5 (5.7, 17.2)	1.3 (0.0, 2.5)
HIV status								
Living with HIV	3.1	21.4	1.0 (0.0, 2.5)	26.9 (19.2, 34.6)	4.4 (0.9, 7.9)	25.0 (13.2, 36.8)	0.7 (0.02, 1.3)	16.2 (12.5, 20.0)
Not living with HIV	80.0	71.6	65.6 (53.2, 78.0)	61.3 (52.9, 69.7)	77.8 (61.1, 94.5)	59.6 (47.3, 71.9)	80.4 (73.5, 87.3)	71.7 (66.1, 77.3)
Unknown[f]	16.9	7.0	33.4 (21.1, 45.7)	11.8 (5.4, 18.2)	17.8 (0.7, 34.9)	15.4 (5.5, 25.3)	19.0 (12.1, 25.8)	12.1 (7.2, 17.0)
Accessing PrEP[g]								
No	70.3	62.0	65.8 (52.1, 79.6)	56.7 (47.5, 65.9)	59.8 (44.0, 75.6)	70.5 (60.8, 80.2)	73.4 (64.0, 82.8)	55.1 (47.7, 62.4)
Yes	19.9	24.6	18.4 (6.0, 30.8)	23.7 (17.1, 30.3)	20.2 (8.7, 31.6)	14.4 (9.4, 19.4)	12.1 (5.1, 19.2)	11.4 (7.7, 15.1)
Never heard of PrEP	9.8	13.4	15.7 (5.8, 25.7)	19.6 (10.6, 28.7)	20.0 (6.4, 33.7)	15.1 (6.4, 23.8)	14.4 (6.6, 22.2)	33.5 (25.9, 41.2)

SD = standard deviation. CAD = Canadian currency. STI = sexually transmitted infection. PrEP = pre-exposure prophylaxis for HIV. Proportions may not add to 100% due to missing data; missing data not >2% for any unweighted variable. dIncludes straight, questioning, asexual, pansexual, two-spirit, and other.

[a] Unweighted proportions and means.

[b] Proportions and means weighted using the RDS-II Volz-Heckathorn estimator[23].

[c] Includes two-spirit and other.

[d] Includes employee-sponsored benefit plan, plan sponsored through an association such as union/trade/student organization, and other private plans purchased from an insurance company.

[e] Includes don't remember HIV test result, prefer not to answer, did not receive test result, was never tested, or unsure if tested for HIV.

[f] Restricted to HIV-negative men or unknown status (≤26 years old = 533; ≥27 years old = 1493). Men considered to have been accessing PrEP are those that tried to get on PrEP in the past six months or those currently on PrEP.

3.4. Additional analyses

Enrolment date neither modified nor confounded associations, and thus was removed from the final models for increased precision. We could not thoroughly explore gender identity in statistical models due to low variability; 94% of all men identified as a cisgender man. Nonetheless, the crude, unweighted proportion of men vaccinated across all three cities was similar between cisgender and trans men (≤26 years old: 44% of cisgender men, 50% of trans-men; ≥27 years old: 17% of cisgender men, 18% of trans-men).

4. Discussion

We estimated HPV vaccine uptake among GBM in the largest Canadian cities in 2017–2019 following implementation of GBM-targeted HPV vaccination programs in 2015–2016. Among men ≤ 26 years old and eligible for publicly-funded programs, city-specific findings ranged from 26 to 35% for initiation of HPV vaccination, 43–66% for series completion among initiators, and 14–21% for series completion among the total population of younger men. As expected, uptake was considerably lower among older men ineligible for programs. Among older men, 7–26% initiated, 33–65% of initiators completed the series, and 2–17% of the total population of older men completed the series. Recent utilization of sexual healthcare services and past hepatitis A or B vaccination were significantly associated with vaccine initiation for both age groups.

Internationally, few jurisdictions have implemented publicly-funded HPV vaccination programs for GBM [29–31]. Two other community-recruited Canadian studies explored vaccine initiation after implementation of GBM-targeted vaccination programs [32,33]. In a convenience sample of GBM ≤ 26 years old in Ontario, vaccine initiation was 26% in 2017–2018, and among GBM ≤ 26-years-old recruited using RDS in Vancouver, vaccine initiation increased from 9% in 2012 prior to program implementation to 28% by 2019 [32,33]. Outside Canada, the HPV vaccine is offered free for GBM ≥ 45 years old in the United Kingdom at sexual health and HIV clinics since 2017–2018. Vaccine initiation ranged between 33 and 54% among men ≤ 25 years old in clinic samples in England and Scotland in the first year of the program [29,30]. After implementing a time-limited HPV vaccination program for GBM ≤ 26 years old in Victoria, Australia, from 2017 to 2018, vaccine initiation in Melbourne sexual health clinics was 43% [31]. These clinic-based estimates are higher than what we observed in our community-recruited study, such that differences could be attributed in part to sampling strategies. Altogether, in the settings that have implemented targeted vaccination programs, vaccine uptake is occurring and is likely to increase the longer these programs are in place. Nevertheless, uptake is likely to be less than what can be achieved using universal, routine vaccination programs, as has been seen for other vaccines [34]. After implementation of universal school-based HPV vaccination programs in Canada in 2016/2017, by 2018/2019, vaccine completion in Vancouver, Toronto, and Montreal, was already between 62 and 69% among boys [35–37].

Our finding that fewer older men had been vaccinated is consistent with other studies. In a clinical cohort of men living with HIV in Ontario (mean age = 51 years old), vaccine initiation was 7% as of 2016–2017 [38], considerably lower than the 21% of men ≥ 27 years old and living with HIV that initiated vaccination among Engage participants in Toronto, the largest city in Canada. In a convenience sample of GBM in Ontario, vaccine initiation was 14% among men ≥ 27 years old in 2017–2018, though it was higher for men residing in Toronto compared to elsewhere in

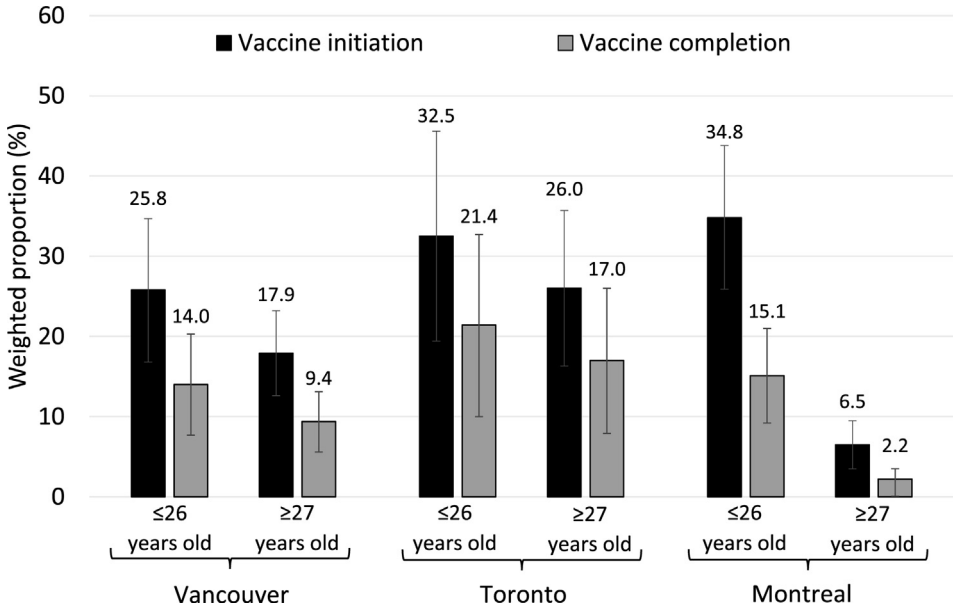

Fig. 1. RDS-II weighted proportion of men who initiated (1 + dose) and completed (3 doses) HPV vaccination, by city and age group.

Ontario [32]. In addition to regional differences, lower vaccine initiation in these studies could also be attributed to differences in age because the mean age of men ≥ 27 years old in our study was only 40 years old; this is substantiated by our finding that vaccine initiation decreased with increasing age among Engage participants. Despite guidelines recommending vaccination among older GBM given their continued risk for HPV and HPV-associated diseases, physicians experienced in HIV/STI care remain reluctant to recommend the HPV vaccine since most men would have already been exposed to HPV, the limited evidence on vaccine effectiveness in this age group, and the high cost of the vaccine [39].

We are not certain as to why significant differences were seen in vaccine uptake among older men across the three cities but hypothesize that there may be greater variability in vaccine promotion and messaging from physicians, public health workers, and the provincial government for older versus younger GBM. In Montreal, where only 7% of men ≥ 27 years old had initiated vaccination, only 55% were aware of the HPV vaccine. In comparison, in Toronto, where 26% of men had initiated vaccination, 75% were aware of the vaccine.

Quantitative and qualitative findings among older men living with HIV in Ontario, who are ineligible for publicly-funded programs, found that one of the largest deterrents of HPV vaccine uptake was cost [16,38]. Similarly, in our study, nearly twice as many men ≥ 27 years old with private insurance were vaccinated compared to men with no insurance coverage for non-publicly-funded vaccines. In the US, where publicly-funded programs for HPV vaccination do not exist yet vaccination is recommended for young GBM, lack of insurance coverage was also highlighted as a barrier to vaccination among young GBM [15,40]. These differences are not specific to the HPV vaccine. In Canada, significantly lower vaccine coverage was seen for essential childhood vaccines, such as the rotavirus vaccine, when vaccines were privately purchased [41]. We also found men ≥ 27 years old and identifying as Latin American were less likely to initiate vaccination compared to white men, which may be attributed to differences in socioeconomic status, less comfort disclosing sexual preferences to healthcare providers, and lack of knowledge around HPV [42–44]. These disparities in insurance coverage and ethnoracial identities reveal social inequities in HPV vaccine initiation within the population of older men that cannot receive publicly-funded vaccine.

GBM who engaged in healthcare services, and particularly sexual healthcare services, were more likely to initiate HPV vaccination. This association has also been seen in the US [40]. Regardless of age, recent STI/HIV testing or HIV care visits were one of the strongest predictors of vaccination. Among men ≥ 27 years old, men accessing PrEP were 66% more likely to initiate vaccination compared to men who had not. We hypothesize that the mechanism of engagement in sexual healthcare leading to vaccination may differ by age. For young men eligible for publicly-funded vaccine, vaccinations may occur during visits for other sexual health care services due to convenience and opportunity, as was recognized in England's HPV vaccination program pilot assessment [14]. For older men, more risk assessment, discussions around sexual health, and decision-making alongside providers may be involved.

The role of healthcare professionals in initiating vaccination was evident given the high number of vaccinated men who had a healthcare provider discuss the HPV vaccine with them. In the English and Australian program pilot assessments, vaccine initiation among young men increased to 51% and 73%, respectively, when a physician offered to vaccinate them against HPV [31,45]. We also observed a robust association between past receipt of vaccines, notably hepatitis A or B, and HPV vaccination. This was despite potential inaccurate self-reporting of hepatitis A or B vaccination, which has a lower sensitivity (63–73%) and specificity (67–84%) [19]. Our results are in keeping with past findings among young GBM in the US [46]. In general, people who receive one vaccine are more likely to receive another [47,48].

We observed heterogeneity in the venues where men received HPV vaccine. The most popular venue among men ≤ 26 years old, and men ≥ 27 years old in Vancouver and Montreal, was a sexual health clinic. In Montreal, CLSCs were also common venues. Although HPV vaccination at sexual health clinics among men ≥ 27 years old was still common in Toronto, the most common venue was the doctor's office. In comparison, only 4% of older men in Montreal were vaccinated at a doctor's office, which may be attributed to differences in vaccine delivery across cities; few visit a primary care provider to receive vaccinations in the province of Quebec. These geographical variations suggest that interventions may need to be tailored accordingly in settings such as Canada where healthcare delivery varies across provincial and territorial jurisdictions.

Table 2
Factors associated with HPV vaccine initiation among men aged ≤ 26 years old from the Engage Study (n = 550).

	Unweighted percent vaccinated	Unweighted unadjusted prevalence ratio (95%CI)	Unweighted adjusted prevalence ratio (95%CI)	Weighted adjusted prevalence ratio[a] (95% CI)
Type of provider currently visiting				
Both sexual health and primary care provider	53.3	Reference	Reference	Reference
Only primary provider	42.7	0.80 (0.63, 1.01)	0.87 (0.70, 1.09)	1.04 (0.69, 1.58)
Only sexual health provider	44.8	0.84 (0.67, 1.06)	0.90 (0.63, 1.28)	1.36 (0.69, 2.69)
No provider	23.6	**0.44 (0.30, 0.66)**	0.74 (0.47, 1.17)	0.65 (0.28, 1.52)
Last STI/HIV test or HIV specialist visit				
0–6 months ago	55.7	**3.09 (2.09, 4.56)**	**2.15 (1.44, 3.21)**	**2.15 (1.06, 4.36)**
6–12 months ago	32.9	**1.83 (1.12, 2.97)**	1.45 (0.90, 2.32)	1.59 (0.69, 3.59)
>12 months ago or no test/visit	18.0	Reference	Reference	Reference
Frequency of visits to primary care provider in year				
4 or more times a year	55.0	Reference	Reference	Reference
2–3 times a year	25.6	0.83 (0.63, 1.08)	0.85 (0.66, 1.10)	1.18 (0.66, 2.13)
Once a year	51.5	0.94 (0.70, 1.26)	0.96 (0.70, 1.31)	1.18 (0.57, 2.44)
Once every 2–3 years/don't know/ no provider	36.9	**0.67 (0.53, 0.85)**	0.90 (0.63, 1.30)	0.90 (0.38, 2.12)
HIV status and HIV PrEP access				
Living with HIV	47.1	1.26 (0.75, 2.11)	0.94 (0.58, 1.53)	1.01 (0.45, 2.29)
HIV-negative/unknown[b], accessing PrEP[c]	67.9	**1.81 (1.52, 2.17)**	**1.28 (1.05, 1.55)**	1.46 (0.99, 2.15)
HIV-negative/unknown[b], not accessing HIV PrEP[c]	37.5	Reference	Reference	Reference
Past hepatitis A or B vaccination				
No or don't know	16.7	Reference	Reference	Reference
Yes	54.9	**3.30 (2.31, 4.70)**	**2.66 (1.87, 3.78)**	**2.88 (1.64, 5.05)**
Prefer to keep same-sex romantic relationships private				
Agree/prefer not to answer	37.3	**0.77 (0.63, 0.95)**	0.88 (0.73, 1.06)	0.80 (0.57, 1.13)
Disagree	48.2	Reference	Reference	Reference
Age at enrolment				
Every one-year increase	–	1.03 (0.99, 1.08)	1.01 (0.97, 1.07)	0.98 (0.90, 1.06)
City				
Montreal	44.2	Reference	Reference	Reference
Toronto	40.6	0.92 (0.71, 1.19)	0.82 (0.64, 1.05)	0.87 (0.57, 1.31)
Vancouver	44.9	1.02 (0.82, 1.26)	0.92 (0.76, 1.12)	0.71 (0.47, 1.09)
Ethnicity/race				
White	46.4	Reference	Reference	Reference
East-Southeast Asian	46.4	1.00 (0.74, 1.35)	1.03 (0.79, 1.36)	1.21 (0.72, 2.02)
Latin American	23.7	**0.51 (0.29, 0.91)**	0.72 (0.41, 1.27)	1.04 (0.58, 1.87)
Mixed	50.0	0.94 (0.73, 1.21)	1.15 (0.79, 1.69)	0.99 (0.53, 1.86)
Other[d]	35.3	0.76 (0.54, 1.07)	**0.72 (0.53, 0.96)**	0.78 (0.48, 1.28)
Education				
High school or less	35.1	Reference	Reference	Reference
Post-secondary	45.9	**1.31 (1.01, 1.70)**	1.14 (0.91, 1.44)	1.05 (0.70, 1.57)
Graduate or professional degree	52.0	**1.49 (1.05, 2.13)**	1.21 (0.86, 1.70)	1.22 (0.70, 2.15)

STI = sexually transmitted infection. PrEP = pre-exposure prophylaxis for HIV.
[a] Weighted model adjusted by RDS-II Volz-Heckathorn weights[23].
[b] Unknown includes don't remember HIV test result, prefer not to answer, did not receive test result, was never tested or unsure if tested for HIV.
[c] Men considered to have been accessing PrEP are those that tried to get on PrEP in the past six months or those currently on PrEP. Men not accessing PrEP are those that did not try to go on PrEP, are not currently on PrEP, or men who have never heard of PrEP.
[d] Includes Indigenous, West Asian/North African, African/Caribbean/Black, South Asian, or other ethnicity/race.

Bundling HPV vaccination with other sexual healthcare services may be a solution to help increase vaccine uptake in all three cities, and internationally. In Rhode Island, US, bundling HPV vaccination with rapid HIV testing was found to be feasible, effective in increasing HPV vaccine uptake and HIV testing, and acceptable among young GBM [49]. The concept of bundling has also been recommended by young GBM, as was seen in focus group discussions in Boston, US [50]. Among older men ineligible for publicly-funded programs, conversations with healthcare professionals around HPV risk, cost, and potential insurance coverage options for the vaccine must also be incorporated.

There are limitations to our study. Although accuracy, sensitivity, and specificity of self-reported HPV vaccination is high among adult populations, misclassification may still exist. The analysis was cross-sectional and thus temporality for time variant variables cannot be confirmed. These were hypothesis-generating models and not all confounding may have been accounted for; results should be interpreted accordingly. Volunteer participants in a sexual health study may be more health conscious; thus, we may have over-estimated vaccine uptake compared with the overall population of GBM. Moreover, our sample of GBM recruited through social networks may be more open about their sexual preferences compared to a general sample of GBM. Our use of RDS-weighted estimates would mitigate this selection bias but may not have eliminated it. RDS weights are dependent on accurate measurement of participants' network size [23]; inaccuracies may bias results.

Nevertheless, this study has many strengths. It is the first community-recruited sample of men from the three Canadian cities with the largest GBM populations. It is one of the few studies internationally to explore HPV vaccine uptake and associated fac-

Table 3
Factors associated with HPV vaccine initiation among men aged ≥ 27 years old from the Engage Study (n = 1899).

	Unweighted percent vaccinated	Unweighted unadjusted prevalence ratio (95%CI)	Unweighted adjusted prevalence ratio(95%CI)	Weighted adjusted prevalence ratio[a] (95% CI)
Type of provider currently visiting				
Both sexual health and primary care provider	19.9	Reference	Reference	Reference
Only primary provider	16.2	0.81 (0.64, 1.03)	0.87 (0.69, 1.10)	0.61 (0.37, 1.00)
Only sexual health provider	17.3	0.87 (0.65, 1.16)	0.92 (0.54, 1.59)	0.72 (0.27, 1.91)
No provider	5.9	**0.30 (0.17, 0.52)**	0.56 (0.28, 1.09)	0.70 (0.24, 2.00)
Last STI/HIV test or HIV specialist visit				
0–6 months ago	21.1	**5.42 (3.08, 9.54)**	**2.55 (1.43, 4.54)**	**2.73 (1.14, 6.51)**
6–12 months ago	13.2	**3.40 (1.81, 6.37)**	**2.28 (1.25, 4.16)**	0.90 (0.37, 2.16)
>12 months ago or no test/visit	3.9	Reference	Reference	Reference
Frequency of visits to primary care provider in year				
4 or more times a year	21.4	Reference	Reference	Reference
2–3 times a year	18.6	0.87 (0.68, 1.10)	0.96 (0.77, 1.20)	0.72 (0.44, 1.17)
Once a year	12.1	**0.57 (0.38, 0.84)**	0.90 (0.62, 1.31)	0.60 (0.30, 1.17)
Once every 2–3 years/don't know/ no provider	12.9	**0.60 (0.47, 0.78)**	0.98 (0.57, 1.66)	0.97 (0.32, 2.95)
HIV status and HIV PrEP access				
Living with HIV	15.8	**1.41 (1.07, 1.86)**	**1.44 (1.03, 2.02)**	0.93 (0.40, 2.12)
HIV-negative/unknown[b], accessing PrEP[c]	36.1	**3.23 (2.61, 3.99)**	**1.83 (1.44, 2.31)**	**1.66 (1.02, 2.70)**
HIV-negative/unknown[b], not accessing PrEP[c]	11.2	Reference	Reference	Reference
Past hepatitis A or B vaccination				
No or don't know	6.4	Reference	Reference	Reference
Yes	20.5	**3.19 (2.23, 4.58)**	**1.97 (1.38, 2.81)**	**2.03 (1.07, 3.86)**
Prefer to keep same-sex romantic relationships private				
Increasing agreement	–	**0.83 (0.78, 0.88)**	0.94 (0.88, 1.00)	0.97 (0.86, 1.10)
Age at enrolment				
Every five-year increase	–	**0.79 (0.75, 0.84)**	**0.81 (0.76, 0.87)**	**0.88 (0.80, 0.96)**
City				
Montreal	7.1	Reference	Reference	Reference
Toronto	29.2	**4.11 (3.11, 5.44)**	**2.67 (2.01, 3.54)**	**2.81 (1.69, 4.67)**
Vancouver	24.7	**3.48 (2.65, 4.57)**	**2.32 (1.77, 3.04)**	**1.87 (1.12, 3.13)**
Ethnicity/race				
White	17.6	Reference	Reference	Reference
East- Southeast Asian	27.5	**1.57 (1.15, 2.14)**	1.04 (0.78, 1.38)	0.77 (0.50, 1.27)
Latin American	8.2	**0.47 (0.27, 0.79)**	**0.45 (0.26, 0.78)**	**0.37 (0.17, 0.83)**
Mixed	24.4	1.39 (0.80, 2.41)	1.14 (0.75, 1.74)	0.87 (0.41, 1.90)
Other[d]	12.2	0.70 (0.47, 1.03)	**0.67 (0.46, 0.97)**	0.75 (0.36, 1.54)
Education				
High school or less	8.2	Reference	Reference	Reference
Post-secondary	18.9	**2.31 (1.65, 3.24)**	1.23 (0.89, 1.69)	1.20 (0.65, 2.23)
Graduate or professional degree	21.9	**2.69 (1.87, 3.88)**	1.34 (0.95, 1.89)	1.22 (0.66, 2.26)
Insurance for medication/non-publicly funded vaccines				
No insurance for meds	12.1	Reference	Reference	Reference
Government insurance	10.7	0.88 (0.62, 1.25)	1.02 (0.72, 1.43)	0.79 (0.39, 1.62)
Private insurance[e]	22.7	**1.87 (1.43, 2.43)**	**1.49 (1.16, 1.91)**	1.50 (0.96, 2.35)
Both government and private	23.5	**1.93 (1.39, 2.69)**	1.17 (0.85, 1.59)	1.12 (0.64, 1.96)

STI = sexually transmitted infection. PrEP = pre-exposure prophylaxis for HIV.
[a] Weighted model adjusted by RDS-II Volz-Heckathorn weights[23].
[b] Unknown includes don't remember HIV test result, prefer not to answer, did not receive test result, was never tested or unsure if tested for HIV.
[c] Men considered to have been accessing PrEP are those that tried to get on PrEP in the past six months or those currently on PrEP. Men not accessing PrEP are those that did not try to go on PrEP in the past six months, are not currently on PrEP, or men who have never heard of PrEP.
[d] Includes Indigenous, West Asian/North African, African/Caribbean/Black, South Asian, or other ethnicity/race.
[e] Includes employee-sponsored benefit plan, plan sponsored through an association such as union/trade/student organization, and other private plans purchased from an insurance company.

tors after the implementation of GBM-targeted publicly-funded HPV vaccination programs and explore associations amongst those eligible for programs as well as ineligible.

Despite our observed gains in vaccine uptake in three Canadian cities shortly after targeted HPV vaccination programs were implemented, 65–74% of men eligible for publicly-funded vaccine and 74–93% of those ineligible remained unvaccinated against HPV by 2019, respectively. Newly-implemented gender-neutral school-based programs in Canada should improve HPV vaccine uptake for birth cohorts attending elementary school now and in the future. However, many adult men from birth cohorts that missed that opportunity can still receive the vaccine within these GBM-targeted programs. Non-stigmatizing patient-provider conversations around HPV and HPV vaccination including exploring cost coverage options among older men and bundling vaccination with other sexual healthcare services are potential methods to help improve HPV vaccine uptake in this population.

All authors attest they meet the ICMJE criteria for authorship.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: CS has research grants paid to the organization (INSPQ

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Appendix A. Supplementary material

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References

[1] Nyitray AG et al. Age-specific prevalence of and risk factors for anal HPV among MSW and MSM: the HIM study. J Infect Dis 2011;203(1):49–57. https://doi.org/10.1093/infdis/jiq021.
[2] National Advisory Committee on Immunization (NACI), "Canadian Immunization Guide: Part 4 - Active Vaccines - Human Papillomavirus Vaccine," Government of Canada, Ottawa, ON, 2016. [Online]. Available: https://www.canada.ca/en/public-health/services/publications/healthy-living/canadian-immunization-guide-part-4-active-vaccines/page-9-human-papillomavirus-vaccine.html.
[3] CDC. Recommendations on the use of quadrivalent HPV vaccine in males — ACIP, 2011. MMWR, vol. 60, no. 50, pp. 1705–1708.
[4] JCVI. JCVI statement on HPV vaccination of MSM, JCVI, UK, Nov. 2015. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/477954/JCVI_HPV.pdf.
[5] Sauvageau C, Dufour-Turbis C. HPV vaccination for MSM: Synthesis of the evidence and recommendations from the Québec Immunization Committee. Hum Vaccines Immunother 2015;12(6):1560–5. https://doi.org/10.1080/21645515.2015.1112474.
[6] Meites E. Human papillomavirus vaccination for adults: Updated recommendations of the Advisory Committee on Immunization Practices. MMWR Morb Mortal Wkly Rep 2019;68. https://doi.org/10.15585/mmwr.mm6832a3.
[7] Goldstone SE et al. Quadrivalent HPV vaccine efficacy against disease related to vaccine and non-vaccine HPV types in males. Vaccine 2013;31(37):3849–55. https://doi.org/10.1016/j.vaccine.2013.06.057.
[8] ImmunizeBC, "HPV (Human Papillomavirus). Evidence-based immunization information and tools for B.C. residents. Quest HPV Study," Mar. 21, 2011. https://immunizebc.ca/hpv (accessed Jan. 03, 2020).
[9] Government of Ontario M of H and L-TC, Vaccines and Immunization. http://www.health.gov.on.ca/en/pro/programs/immunization/ (accessed Jan. 15, 2020).
[10] Santé et Services Sociaux Québec, VPH: vaccin contre les virus du papillome humain. https://www.msss.gouv.qc.ca/professionnels/vaccination/piq-vaccins/vph-vaccin-contre-les-virus-du-papillome-humain/ (accessed Jan. 03, 2020).
[11] Poynten IM et al. Vaccine-preventable anal human papillomavirus in Australian gay and bisexual men. Papillomavirus Res 2017;3:80–4. https://doi.org/10.1016/j.pvr.2017.02.003.
[12] Merck Canada Inc, Product monograph: Gardasil® [Quadrivalent Human Papillomavirus (Types 6, 11, 16, 18) Recombinant Vaccine]. 2020, [Online]. Available: https://www.merck.ca/static/pdf/GARDASIL_9-PM_E.pdf.
[13] Wheldon CW, Daley EM, Buhi ER, Baldwin JA, Nyitray AG, Giuliano AR. HPV vaccine decision-making among young men who have sex with men. Health Educ J 2017;76(1):52–65. https://doi.org/10.1177/0017896916647988.
[14] Edelstein M, et al., Implementation and evaluation of the human papillomavirus (HPV) vaccination pilot for men who have sex with men (MSM), England, April 2016 to March 2017. Euro Surveill., vol. 24, no. 8, 2019, doi: 10.2807/1560-7917.ES.2019.24.8.1800055.
[15] Loretan C, Chamberlain AT, Sanchez T, Zlotorzynska M, Jones J. Trends and characteristics associated with human papillomavirus vaccination uptake among men who have sex with men in the United States, 2014–2017. Sex Transm Dis 2019;46(7):465–73. https://doi.org/10.1097/OLQ.0000000000001008.
[16] Grace D, et al. HIV-positive gay men's knowledge and perceptions of Human Papillomavirus (HPV) and HPV vaccination: A qualitative study. PLoS ONE, vol. 13, no. 11, 2018, doi: 10.1371/journal.pone.0207953.
[17] Newman PA, Logie CH, Doukas N, Asakura K. HPV vaccine acceptability among men: a systematic review and meta-analysis. Sex Transm Infect, p. sextrans-2012-050980, 2013, doi: 10.1136/sextrans-2012-050980.
[18] Heckathorn DD. Respondent-driven sampling: A new approach to the study of hidden populations. Soc Probl 1997;44(2):174–99. https://doi.org/10.2307/3096941.
[19] Rolnick SJ et al. Self-report compared to electronic medical record across eight adult vaccines: do results vary by demographic factors?. Vaccine 2013;31(37):3928–35. https://doi.org/10.1016/j.vaccine.2013.06.041.
[20] Niccolai LM, McBride V, Julian PR. Sources of information for assessing human papillomavirus vaccination history among young women. Vaccine 2014;32(25):2945–7. https://doi.org/10.1016/j.vaccine.2014.03.059.
[21] Thomas R, Higgins L, Ding L, Widdice LE, Chandler E, Kahn JA. Factors associated with HPV vaccine initiation, vaccine completion, and accuracy of self-reported vaccination status among 13- to 26-year-old men. Am J Mens Health 2018;12(4):819–27. https://doi.org/10.1177/1557988316645155.
[22] Oliveira CR et al. Feasibility and accuracy of a computer-assisted self-interviewing instrument to ascertain prior immunization with human papillomavirus vaccine by self-report: Cross-sectional analysis. JMIR Med Inform 2020;8(1):. https://doi.org/10.2196/16487e16487.
[23] Volz EM, Heckathorn DD. Probability based estimation theory for respondent driven sampling. J Off Stat 2008;24(1):79–97.
[24] Dunbar R. How Many Friends Does One Person Need?: Dunbar's Number and Other Evolutionary Quirks. Faber & Faber; 2010.
[25] Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol 2004;159(7):702–6. https://doi.org/10.1093/aje/kwh090.
[26] Avery L, Rotondi N, McKnight C, Firestone M, Smylie J, Rotondi M. Unweighted regression models perform better than weighted regression techniques for respondent-driven sampling data: results from a simulation study. BMC Med Res Methodol 2019;19(1):202. https://doi.org/10.1186/s12874-019-0842-5.
[27] Salganik MJ. Variance estimation, design effects, and sample size calculations for respondent-driven sampling. J Urban Health Nov. 2006;83(1):98. https://doi.org/10.1007/s11524-006-9106-x.
[28] Faul F, Erdfelder E, Lang A-G, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39(2):175–91. https://doi.org/10.3758/BF03193146.
[29] Checchi M, Coukan F, Mesher D, Soldan K. Human papillomavirus (HPV) vaccination uptake in gay, bisexual and other men who have sex with men (MSM): National programme 2018 annual report. England, United Kingdom: Public Health England; 2020.
[30] Pollock K, Wallance L, Wrigglesworth S, McMaster D, Steedman N. HPV vaccine uptake in men who have sex with men in Scotland. Vaccine 2019;37(37):5513–4. https://doi.org/10.1016/j.vaccine.2018.11.081.

[31] McGrath L, Fairley CK, Cleere EF, Bradshaw CS, Chen MY, Chow EPF. Human papillomavirus vaccine uptake among young gay and bisexual men who have sex with men with a time-limited targeted vaccination programme through sexual health clinics in Melbourne in 2017. Sex Transm Infect 2019;95(3):181–6. https://doi.org/10.1136/sextrans-2018-053619.
[32] Yeung A, Brennan D, Grewal R, Bekele T, Kesler M, Burchell A. P550 high awareness but low uptake of HPV vaccine among GBMSM in Ontario, Canada: results from the #iCruise Study. Sex Transm Infect, vol. 95, no. Suppl 1, pp. A248–A248, 2019, doi: 10.1136/sextrans-2019-sti.625.
[33] Khatra J, et al. Longitudinal uptake of the human papillomavirus vaccine among gay, bisexual, and other men who have sex with men in British Columbia, Canada 2012-2019. Presented at the Community-Based Research Centre Summit 2020, Nov. 04, 2020.
[34] Shepard CW, Simard EP, Finelli L, Fiore AE, Bell BP. Hepatitis B virus infection: Epidemiology and vaccination. Epidemiol Rev 2006;28(1):112–25. https://doi.org/10.1093/epirev/mxj009.
[35] BC Centre for Disease Control, "Immunization Uptake in Grade 6 Students," BC Centre for Disease Control, Vancouver, Canada, Nov. 2019. [Online]. Available: http://www.bccdc.ca/resource-gallery/Documents/Statistics%20and%20Research/Statistics%20and%20Reports/Immunization/Coverage/Grade%206%20Coverage%20Results.pdf.
[36] Institut national de santé publique du Québec, "Bulletin québécois de vigie, de surveillance et d'intervention en protection de la santé publique," Institut national de santé publique du Québec, Quebec City, Canada, Sep. 2019. [Online]. Available: https://publications.msss.gouv.qc.ca/msss/fichiers/flashvigie/FlashVigie_vol14_no7.pdf.
[37] Public Health Ontario, "Immunization Coverage Report for School Pupils in Ontario: 2018–19 School Year," Public Health Ontario, Toronto, Canada, Aug. 2020. [Online]. Available: https://www.publichealthontario.ca/-/media/documents/i/2020/immunization-coverage-2018-19.pdf?la=en.
[38] Grewal R, et al. Low human papillomavirus (HPV) vaccine uptake among men living with HIV: findings from a clinical cohort. Prev Med, vol. 143, no. 106329, 2020, doi: 10.1016/j.ypmed.2020.106329.
[39] Grace D et al. Economic barriers, evidentiary gaps, and ethical conundrums: a qualitative study of physicians' challenges recommending HPV vaccination to older gay, bisexual, and other men who have sex with men. Int J Equity Health 2019;18. https://doi.org/10.1186/s12939-019-1067-2.
[40] McClung N, Burnett J, Wejnert C, Markowitz LE, Meites E, NHBS Study Group. Human papillomavirus vaccination coverage among men who have sex with men-National HIV Behavioral Surveillance, United States, 2017. Vaccine, vol. 38, no. 47, pp. 7417–7421, 2020, doi: 10.1016/j.vaccine.2020.08.040.
[41] Wilson SE et al. Rotavirus vaccine coverage and factors associated with uptake using linked data: Ontario, Canada. PLoS ONE 2018;13(2):. https://doi.org/10.1371/journal.pone.0192809e0192809.
[42] Ruben MA, Fullerton M. Proportion of patients who disclose their sexual orientation to healthcare providers and its relationship to patient outcomes: A meta-analysis and review. Patient Educ Couns 2018;101(9):1549–60. https://doi.org/10.1016/j.pec.2018.05.001.
[43] Gillis J et al. Low human papillomavirus (HPV) knowledge related to low risk perception among men living with HIV: Implications for HPV-associated disease prevention. Prev Med 2020;141:. https://doi.org/10.1016/j.ypmed.2020.106274106274.
[44] Quach S et al. Influenza vaccination coverage across ethnic groups in Canada. CMAJ Can Med Assoc J 2012;184(15):1673–81. https://doi.org/10.1503/cmaj.111628.
[45] Checchi M et al. HPV vaccination of gay, bisexual and other men who have sex with men in sexual health and HIV clinics in England: vaccination uptake and attendances during the pilot phase. Sex Transm Infect 2019;95(8):608–13. https://doi.org/10.1136/sextrans-2018-053923.
[46] Gorbach PM et al. Human papillomavirus vaccination among young men who have sex with men and transgender women in 2 US cities, 2012–2014. Sex Transm Dis 2017;44(7):436–41. https://doi.org/10.1097/OLQ.0000000000000626.
[47] Kessels SJM, Marshall HS, Watson M, Braunack-Mayer AJ, Reuzel R, Tooher RL. Factors associated with HPV vaccine uptake in teenage girls: a systematic review. Vaccine 2012;30(24):3546–56. https://doi.org/10.1016/j.vaccine.2012.03.063.
[48] McEwen M, Farren E. Actions and beliefs related to hepatitis B and influenza immunization among registered nurses in Texas. Public Health Nurs 2005;22(3):230–9. https://doi.org/10.1111/j.0737-1209.2005.220306.x.
[49] van den Berg JJ, Larson HE, Zimet GD, Lally MA. Bundling human papillomavirus vaccination and rapid human immunodeficiency virus testing for young gay and bisexual men. LGBT Health 2014;1(3):233–7. https://doi.org/10.1089/lgbt.2014.0028.
[50] Fontenot HB, Fantasia HC, Vetters R, Zimet GD. Increasing HPV vaccination and eliminating barriers: Recommendations from young men who have sex with men. Vaccine 2016;34(50):6209–16. https://doi.org/10.1016/j.vaccine.2016.10.075.