Submitted: 23 March, 2023 Accepted: 09 June, 2023 Published: 30 October, 2023 DOI:10.22514/jomh.2023.097

ORIGINAL RESEARCH

JOMH Journal of Men's Health

HPV vaccination among gay, bisexual and other men who have sex with men in Canada's three largest cities: a person-centred approach

Ramandip Grewal[1], Shelley L Deeks[2,3], Trevor A Hart[2,4], Joseph Cox[5,6], Alexandra De Pokomandy[7], Troy Grennan[8,9], Gilles Lambert[6], David Moore[9,10], Mark Gaspar[2], Clemon George[11], Jennifer Gillis[12], Daniel Grace[2], Jody Jollimore[13], Nathan J Lachowsky[10,14], Rosane Nisenbaum[1,2], Gina Ogilvie[8,9], Chantal Sauvageau[15], Darrell HS Tan[1,16], Anna Yeung[1], Ann N Burchell[1,2,17,*]

[1]St. Michael's Hospital, Unity Health Toronto, Toronto, ON M5B 1T8, Canada
[2]Dalla Lana School of Public Health, University of Toronto, Toronto, ON M5T 3M7, Canada
[3]Department of Health and Wellness, Halifax, NS B3J 2R8, Canada
[4]Department of Psychology, Toronto Metropolitan University, Toronto, ON M5B 2K3, Canada
[5]Epidemiology, Biostatistics and Occupational Health, McGill University, Montréal, QC H3A 1Y7, Canada
[6]Direction régionale de santé publique, Montréal, QC H2L 2W5, Canada
[7]Department of Family Medicine, McGill University, Montréal, QC H3S 1Z1, Canada
[8]BC Centre for Disease Control, Vancouver, BC V5Z 4R4, Canada
[9]Department of Medicine, University of British Columbia, Vancouver, BC V6T 1Z3, Canada
[10]BC Centre for Excellence in HIV/AIDS, Vancouver, BC V6Z 1Y6, Canada
[11]Health, Nutrition, and Dietetics, SUNY Buffalo State University, Buffalo, NY 14222, USA
[12]Canadian Cancer Society, Vancouver, BC V5Z 4J4, Canada
[13]Community-Based Research Centre, Vancouver, BC V6Z 2H2, Canada
[14]School of Public Health and Social Policy, University of Victoria, Victoria, BC V8P 5C2, Canada
[15]Institut national de santé publique du Québec, Québec, QC G1V 5B3, Canada
[16]Department of Medicine, University of Toronto, Toronto, ON M5S 1A8, Canada
[17]Department of Family and Community Medicine, University of Toronto, Toronto, ON M5G 1V7, Canada

***Correspondence:** ann.burchell@unityhealth.to (Ann N Burchell)

Abstract

Starting in 2015, many Canadian provinces and territories introduced publicly-funded human papillomavirus (HPV) vaccination programs targeted to gay, bisexual and other men who have sex with men (GBM) 9–26 years old. Using baseline data from the Engage study, a sexual health study of GBM from three Canadian cities, we explored how social and programmatic factors intersect and affect stages of HPV vaccination (Stage 1: unaware of HPV vaccine, Stage 2: undecided/unwilling to get vaccinated, Stage 3: willing to get vaccinated, Stage 4: vaccinated with at least one dose). First, by city, we created subgroups of GBM $\leq$26 years old (N Vancouver = 178; Toronto = 123; Montreal = 249) using latent class analysis. Next, by latent class, we estimated the probability of being in the four HPV vaccination stages using the Bolck, Croon and Hagenaar method. Latent class membership was associated with HPV vaccination stage in Vancouver ($p = 0.003$) and Montreal ($p = 0.048$) but not Toronto ($p = 0.642$). In Vancouver and Montreal, membership in the "no barriers" latent class had the highest probability of vaccination (56–58%). In Vancouver, the "racialized, GBM privacy, immigration and healthcare access barriers" class had a 75% probability of being vaccine unaware. In Montreal, the "immigration and past vaccines barriers" and "socio-economic, GBM privacy and healthcare access barriers" classes had the highest probabilities of being vaccine unaware (43% and 46%) and of being undecided or unwilling to get vaccinated (40% and 25%). In conclusion, our person-centred findings suggest tailored interventions by locale may help to increase HPV vaccine uptake among GBM in Canada's three largest cities.

Keywords

Vaccination; Human papillomavirus; Gay, bisexual and other men who have sex with men; Vaccine hesitancy

1. Introduction

Gay, bisexual and other men who have sex with men (GBM) are at high risk of human papillomavirus (HPV) infection [1, 2]. Most HPV infections clear naturally but a small fraction persist and can lead to cancer [1, 2]. To prevent HPV infections, the National Advisory Committee on Immunization in Canada recommends vaccination for all males aged 9–26

years. For men ≥27 years old, vaccination is recommended for those at ongoing risk of exposure to HPV, such as GBM [3].

Starting in 2015, provinces and territories in Canada, including British Columbia (BC), Ontario and Quebec, initiated publicly-funded HPV vaccination programs for GBM aged 9–26 years old. The provinces differ in the design, delivery and promotion of their publicly-funded programs. In BC and Quebec, people living with HIV aged 9–26 years can also receive publicly-funded vaccine, but not in Ontario. In Quebec, vaccination through primary care is less common whereas it is more common in Ontario and BC. Shortly after these programs were initiated, the GetGarded campaign was launched in BC with the goal to increase awareness of HPV infection and vaccination among men [4]. Similar, large-scale campaigns were not released in the other two provinces.

Soon thereafter, we reported suboptimal vaccine uptake among GBM within each of the province's largest cities (Vancouver, BC; Toronto, Ontario; and Montreal, Quebec) [5]. For that report, we used variable-centred analysis techniques (*i.e.*, linear statistical models) to examine correlates of vaccine uptake, and found that factors such as socio-economic barriers, discomfort disclosing sexual orientation, and not accessing healthcare were associated with not having initiated vaccination [6]. Although that variable-centred approach identified which individual variables were associated with vaccine uptake, it was not able to identify subgroups of people (*i.e.*, communities of people sharing several characteristics) that have better or worse vaccine uptake. For planning of HPV vaccine promotion, identifying such subgroups using person-centred analysis approaches may better help to target HPV vaccination interventions [7].

Person-centred analyses have been used to understand patterns of sexual behaviours, sexual decision-making, substance use and risk factors for HIV to aid in sexually transmitted infection and HIV program planning for GBM [8–11]. They have also been used in vaccination research to identify subgroups to target for interventions [12–16]. To the best of our knowledge, person-centred analyses have not been used to explore HPV vaccine uptake among GBM. To address this gap, our first objective was to use a person-centred analysis to create subgroups of GBM based on barriers and facilitators of HPV vaccine uptake. Our second objective was to investigate the relationship between these subgroups and stages of vaccination, which we call the HPV vaccination cascade, to identify which subgroups are in earlier stages of vaccination.

2. Materials and methods

2.1 Population and data collection

Engage is a cohort study of GBM aged ≥16 years from Vancouver, Toronto and Montreal. Men were recruited from February 2017 and August 2019 using respondent driven sampling (RDS) [17]. RDS is a robust form of network-based chain-referral sampling used to recruit samples that may not be feasible to recruit using random sampling methods [17]. Briefly, a small group of participants (or seeds) are selected from the target population and receive coupons to recruit GBM from their social networks [17]. These new recruits are then given coupons to distribute to their own networks and so on.

Cisgender and transgender men were eligible to participate in the study if they had sex with another man in the past six months, could read English or French and provided written informed consent. Additional details on the setting and design have been published elsewhere [5, 6, 18]. Participants completed a comprehensive questionnaire, including items on HPV vaccination, using computer assisted self-interview (CASI) at their study visits.

We used a cross-sectional design to analyze baseline questionnaire data from Engage. We restricted our analysis to participants aged 16–26 years old because 26 years is the age cut-off for GBM-targeted publicly-funded HPV vaccine. Men were classified according to their stage along what we describe as the "HPV vaccination cascade" [6]. It consists of four mutually exclusive stages. Stage 1 was being unaware of the HPV vaccine. Stage 2 was being undecided or unwilling to get vaccinated. Stage 3 was being willing to get vaccinated. Stage 4 was having initiated vaccination, defined as having received at least one dose of the recommended three dose series for this age group. Clustering has been explored in this sample previously and was considered inconsequential [5]. Additionally, by restricting our sample to GBM aged 16–26 years old, recruitment chains were broken and potential for clustering was reduced.

The indicators selected (**Supplementary Table 1**) were social and programmatic barriers and facilitators informed by the World Health Organization Strategic Advisory Group of Experts on Immunization (SAGE) Working Group Determinants of Vaccine Hesitancy Matrix [19]. It is a comprehensive tool that helps identify the contextual, individual and group and vaccine/vaccination-specific influences of vaccine hesitancy. The term "racialized" is used by the Ontario Human Rights Commission to recognize that race is neither biological nor objective, but instead a social construct [20].

2.2 Statistical analysis

We described characteristics of all GBM 16–26 years old with and without RDS weights. Latent Class Analysis (LCA) was used to create subgroups of participants based on the included indicators. We fit a sequence of models up to five classes using the SAS procedure PROC LCA [21]. To select the best model, model information criteria including the Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), a-BIC (adjusted for sample size), G^2 statistic, model entropy and solution stability were assessed [22, 23]. A smaller value for the AIC, BIC, G^2, a-BIC and higher value for entropy suggested better model fit [22]. A model with at least 10% solution stability indicated that model identification was acceptable [23]. Model interpretability also informed model selection [22]. The LCA local independence assumption was assessed for each model [22, 24]. If the assumption was not met, we considered removing indicators and/or combining highly correlated indicators to account for remaining residual correlations [24]. As an initial step, we conducted a city-combined analysis; however, the models produced poor fit statistics and uninterpretable classes. As a result, and also due

to differences in HPV vaccination program design and delivery across the provinces, we conducted the analyses by city.

Latent classes were labelled according to the indicators with the highest homogeneity (*i.e.*, very high or low probability of a characteristic). Class prevalence estimates from each city's model were then weighted using the RDS-II Volz-Heckathorn weights to increase generalizability of these class sizes to the larger target populations of each city [25, 26]. Next we estimated the association between the latent classes and HPV vaccination cascade stage using the Bolck, Croon and Hagenaar method [27]. The advantage of this method is that it takes potential misclassification of class membership into account [27]. We completed a complete case analysis since few observations were missing for the outcome (4 participants in total; zero in Vancouver, one in Toronto, three in Montreal). All analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA) and R Version 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

This study included 178, 123 and 249 participants aged 16–26 years from Vancouver, Toronto and Montreal, respectively. Across the three cities, 70–80% of men identified as gay, 29–50% were racialized, 71–78% had a post-secondary education and few were living with HIV (Table 1). For all cities, models did not meet the local independence assumption when we included the sexual orientation indicator [22, 24]; therefore, we removed sexual orientation from each city's latent class model. To meet the local independence assumption in city-specific models, we also removed other variables (Vancouver: removed indicator on receipt of any sexual health information) or modified variables (Toronto: accessing healthcare and receipt of sexual health information were combined into one indicator given their high correlation).

3.1 Latent class analysis results: model selection

In Vancouver, the AIC and a-BIC were comparable for a three- (AIC: 134.3; a-BIC: 134.6) versus four-class (AIC: 136.9; a-BIC: 137.4) model; however, the entropy was higher for the four-class model (0.79 versus 0.70 for three-class), interpretability improved significantly with the addition of a distinct class, and the solution stability was above 10% (Table 2). Though addition of a fifth class increased entropy, solution stability was below 10% and an additional class did not improve interpretability. Therefore, we selected the more parsimonious four-class model (Table 3).

In Toronto, the two-class model had the lowest AIC (125. 3), a-BIC (120.1) and highest solution stability (100%) (Table 2). It also had one of the highest entropy (0.71) values. Only a five-class model had higher entropy; however, the remaining fit statistics and the interpretability of that model were suboptimal. Therefore, we selected a two-class model for Toronto (Table 3).

In Montreal, the four-class model had the lowest AIC (220.4) and a-BIC (232.6) (Table 2). It also had the highest entropy (0.69), a high solution stability (78.3%) and the model was the most interpretable. A five-class model produced poorer model fit statistics and worse interpretability. Therefore, the final model for Montreal was a four-class model (Table 3).

The classes produced in each city shared similarities but each had distinct classes with differing combinations of barriers. Each city had a "no barriers" class, which had the highest class prevalence. Radar plots with the class composition from the LCA are provided in Figs. 1,2,3. As the lines for each class move toward the outer edges of the shape, that class has a higher probability of that characteristic (*e.g.*, in Vancouver, men in the "education barriers" class have a very high probability of being white, accessing healthcare, being born in Canada and moderate probabilities of experiencing financial strain, being private about same-sex relationships, and having a past hepatitis A/B vaccination, yet a very low probability of having any post-secondary education). The unweighted class sizes can be found in **Supplementary Table 2**.

3.2 Outcome analysis results: association between latent class membership and the HPV vaccination cascade

3.2.1 Vancouver

In Vancouver, 19.1% (95% confidence interval (CI) 13.3 to 24.9%) of GBM were unaware of the vaccine, 14.0% (95% CI 9.5 to 19.1%) were undecided or unwilling to get vaccinated, 21.9% (95% CI 15.8 to 28.0%) were willing to get vaccinated, and 44.9% (95% CI 37.6 to 52.2%) had initiated vaccination. Class membership was significantly associated with stage within the HPV vaccination cascade (chi-square statistic = 24.8, degrees of freedom (DF) = 9, $p = 0.003$). GBM facing none of the explored social and programmatic barriers, labelled as the "no barriers" class, had the highest probability of having initiated HPV vaccination (56%) followed by the "racialized barriers" class (45%) (Table 4). The "racialized, GBM privacy, immigration and healthcare access barriers" class had the lowest probability of having initiated vaccination (12%). This group also had the highest probability of being unaware of the vaccine (75%). The "education barriers" class had the highest probability of being undecided or unwilling to get vaccinated (43%).

3.2.2 Toronto

In Toronto, 18.0% (95% CI 11.2 to 24.9%) were unaware of the HPV vaccine, 13.9% (95% CI 7.8 to 20.1%) were undecided or unwilling to get vaccinated, 27.1% (95% CI 19.2 to 34.9%) were willing to get vaccinated, and 41.0% (95% CI 32.3 to 49.7%) had initiated vaccination. Class membership was not significantly associated with stage within the HPV vaccination cascade (chi-square statistic =1.7, DF = 3, $p = 0.64$). The two classes had a similar probability of vaccine initiation.

TABLE 1. Unweighted and weighted proportions and means for baseline characteristics of gay, bisexual and other men who have sex with men 16–26 years old from the Engage Study, by city.

	Vancouver n = 178		Toronto n = 123		Montreal n = 249	
	Unweighted %[1]	Weighted % (95% CI)[2]	Unweighted %[1]	Weighted % (95% CI)[2]	Unweighted %[1]	Weighted % (95% CI)[2]
Mean age at enrolment (SD)	23.5 (2.1)	23.2 (1.9)	23.5 (2.2)	23.4 (2.4)	42.6 (12.5)	23.1 (2.2)
Ethnicity/race						
White	56.7	49.7 (36.1, 63.3)	61.0	60.3 (45.5, 75.0)	75.5	70.8 (61.8, 79.9)
Racialized[3]	42.7	50.2 (36.6, 63.8)	38.2	38.5 (23.9, 53.1)	23.7	28.7 (19.7, 37.7)
Other	0.6	0.2 (0.0, 0.5)	0.8	1.2 (0.0, 3.6)	0.8	0.4 (0.0, 1.1)
Sexual orientation						
Gay	78.7	80.3 (71.1, 89.5)	74.8	74.9 (61.6, 88.3)	73.9	70.2 (61.0, 79.4)
Bisexual	7.9	13.3 (5.0, 21.7)	5.7	10.1 (0.1, 20.1)	7.2	12.0 (4.2, 19.7)
Queer	10.1	4.3 (1.6, 7.1)	17.9	9.9 (4.1, 15.8)	12.5	12.7 (6.3, 19.1)
Other[4]	3.4	2.1 (0.0, 4.8)	1.6	5.0 (0.0, 14.2)	6.4	5.1 (2.2, 8.0)
Education						
High school or less	23.0	22.3 (12.5, 32.0)	20.3	21.9 (10.1, 33.6)	26.5	29.1 (19.6, 38.6)
Any post-secondary	76.4	76.4 (66.3, 86.4)	79.7	78.1 (66.4, 89.9)	73.5	70.9 (61.4, 80.4)
Country of birth						
Born in Canada	61.2	58.9 (29.3, 53.9)	60.2	58.4 (43.7, 73.1)	71.1	67.0 (58.2, 75.7)
Immigrated to Canada	38.8	41.2 (28.3, 53.9)	39.8	41.6 (26.9, 56.3)	28.9	33.0 (24.3, 41.8)
Past hepatitis A or B vaccination						
No or don’t know	30.3	38.0 (25.5, 50.5)	24.4	26.7 (14.6, 38.7)	31.3	38.8 (29.2, 48.4)
Yes	69.7	62.0 (49.5, 74.5)	75.6	73.3 (61.3, 85.4)	68.7	61.2 (51.6, 70.8)
Prefer to keep same-sex romantic relationships private						
Disagree	55.1	46.8 (33.3, 60.4)	57.7	43.6 (28.5, 58.8)	57.8	49.1 (39.4, 58.7)
Agree/prefer not to answer	44.9	53.2 (39.6, 66.7)	42.3	56.4 (41.2, 71.5)	41.8	50.7 (41.1, 60.4)
Currently accessing a healthcare provider						
No	15.7	28.5 (14.9, 42.1)	11.4	22.2 (8.8, 35.7)	18.9	24.1 (14.8, 33.4)
Yes	84.3	71.5 (57.9, 85.1)	88.6	77.8 (64.3, 91.2)	81.1	75.9 (66.7, 85.2)
Received information on sexual health in past 6 mon						
No	7.3	12.7 (4.8, 20.6)	10.6	25.2 (6.7, 43.7)	12.9	15.4 (8.6, 22.2)
Yes	92.7	87.3 (79.4, 95.2)	89.4	74.8 (56.3, 93.3)	87.1	84.6 (77.8, 91.4)
Financial Strain (FS) Index score[5]						
Not experiencing FS (Score: 5–9)	80.9	85.5 (77.2, 93.7)	74.8	81.5 (72.5, 90.4)	77.9	79.5 (71.7, 87.3)
Experiencing FS (Score: 10–15)	19.1	14.5 (6.3, 22.8)	25.2	18.5 (9.6, 27.5)	22.1	20.5 (12.7, 28.3)
HIV status						
Living with HIV	1.1	1.0 (0.0, 2.5)	7.3	4.4 (0.9, 7.9)	2.4	0.7 (0.0, 1.3)
Not living with HIV	76.4	65.6 (53.2, 78.0)	82.9	77.8 (61.1, 94.5)	81.1	80.4 (73.5, 87.3)
Unknown[6]	22.5	33.4 (21.1, 45.7)	9.8	17.8 (0.7, 34.9)	16.5	19.0 (12.1, 25.8)

TABLE 1. Continued.

	Vancouver n = 178		Toronto n = 123		Montreal n = 249	
	Unweighted %[1]	Weighted % (95% CI)[2]	Unweighted %[1]	Weighted % (95% CI)[2]	Unweighted %[1]	Weighted % (95% CI)[2]
Personal annual income (CAD)						
<20,000	46.1	52.8 (39.1, 66.4)	49.6	50.6 (34.9, 66.4)	27.4	65.6 (56.9, 74.4)
20,000–39,999	32.0	32.3 (18.8, 45.8)	35.0	41.4 (24.8, 58.0)	25.4	25.6 (17.6, 33.7)
≥40,000	21.9	15.0 (6.7, 23.2)	15.5	7.9 (2.5, 13.4)	47.2	8.7 (4.4, 13.1)
Stage of HPV vaccination cascade						
Stage 1: Unaware of vaccine	19.1	27.3 (15.8, 38.8)	17.9	27.1 (13.2, 41.0)	19.3	19.7 (11.7, 27.7)
Stage 2: Undecided/unwilling	14.0	13.3 (5.9, 20.7)	13.8	12.4 (2.3, 22.5)	13.3	16.9 (9.7, 24.1)
Stage 3: Willing	21.9	33.6 (18.3, 49.0)	26.8	27.7 (11.2, 44.2)	22.1	27.6 (18.4, 36.8)
Stage 4: Initiated	44.9	25.8 (16.8, 34.7)	40.7	32.9 (19.6, 46.1)	44.2	35.8 (26.7, 44.9)

SD: standard deviation; HIV: human immunodeficiency disorder; CAD: Canadian Dollar. Proportions may not add to 100% due to missing data; missing data not greater than 2% for any unweighted variable. CI: confidence interval.
[1]*Unweighted proportions and means.*
[2]*Proportions and means weighted using the RDS-II Volz-Heckathorn estimator [25].*
[3]*Includes East/Southeast Asian, African/Caribbean/Black, Indigenous, South Asian, West Asian/North African or mixed ethnicity/race.*
[4]*Includes straight, questioning, asexual, pansexual, two-spirit and other.*
[5]*Scale validated in general population samples measuring lack of ability to meet financial needs. Score is computed by adding response value across five questions [28].*
[6]*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.*

TABLE 2. Latent class analysis model fit statistics by city.

City & number of classes	AIC	BIC	a-BIC	G^2	Degrees of Freedom	Entropy	Solution stability
Vancouver (n = 178)							
2	135.11	182.83	135.33	105.11	112	0.57	100
3	134.26	207.44	134.6	88.26	104	0.70	84.6
4[a]	136.92	235.56	137.38	74.92	96	0.79	24.8
5	140.03	264.12	140.61	62.03	88	0.84	8.2
Toronto (n = 123)							
2[a]	125.34	167.52	120.09	95.34	112	0.71	100
3	132.42	197.10	124.38	86.42	104	0.70	75.5
4	139.60	226.77	128.75	77.60	96	0.70	18.3
5	146.13	255.80	132.49	68.13	88	0.73	3.8
Montreal (n = 249)							
2	247.25	307.05	253.16	213.25	238	0.58	79.9
3	228.82	320.28	237.86	176.82	229	0.66	68.4
4[a]	220.43	343.54	232.59	150.43	220	0.69	78.3
5	222.66	377.42	237.94	134.66	211	0.66	49.8

AIC: Akaike's Information Criterion; BIC: Bayesian Information Criterion; a-BIC: adjusted-Bayesian Information Criterion;
[a]*Final selected models.*

TABLE 3. Latent class prevalence and class probabilities among gay, bisexual and other men who have sex with men 16–26 years old in Vancouver (n = 178), Toronto (n = 123) and Montreal (n = 249), Canada.

	Vancouver				Toronto		Montreal			
Indicators	No barriers	Racialized barriers	Racialized, GBM privacy, immigration, and healthcare access barriers	Education barriers	No barriers	GBM privacy and immigration barriers	No barriers	Racialized, GBM privacy, and immigration barriers	Immigration and past vaccine barriers	Socio-economic, GBM privacy, and healthcare access barriers
	38%[1] (95% CI 24.3–50.8)	36%[1] (95% CI 22.5–49.7)	14%[1] (95% CI 5.3–23.2)	12%[1] (95% CI 3.8–20.4)	57%[1] (95% CI 42.3–72.4)	43%[1] (95% CI 27.6–57.6)	53%[1] (95% CI 42.8–62.6)	22%[1] (95% CI 13.3–30.4)	15%[1] (95% CI 8.4–22.8)	10%[1] (95% CI 1.5–18.0)
Prefer to keep same-sex romantic relationships private	0.38[3]	0.46	0.96[3]	0.29	0.22[3]	0.69	0.24[3]	0.72[3]	0.55	0.86[3]
Born in Canada	0.78[3]	0.47	0.05[3]	0.85	0.97[3]	0.13	0.90[3]	0.34[3]	0.27[3]	0.99
Past hepatitis A/B vaccination	0.87[3]	0.64	0.39	0.43	0.79[3]	0.71	0.74[3]	0.86	0.25[3]	0.58
Education										
High school or less	0.05	0.26	0.15	0.90[3]	0.19	0.22	0.25	0.01	0.42	0.79[3]
Any post-secondary/ graduate	0.95[3]	0.74	0.85	0.10	0.81[3]	0.78	0.75[3]	0.99	0.58	0.21
Experiencing financial strain	0.12[3]	0.20	0.18	0.47	0.21[3]	0.31	0.21[3]	0.18	0.00	0.79[3]
Accessing healthcare	0.93[3]	0.90	0.16[3]	0.84	0.86[2,3]	0.74[2]	0.88[3]	0.91	0.66	0.30[3]
Received information on sexual health	-	-	-	-	-	-	0.92[3]	0.98	0.64	0.64
Ethnicity/race										
White	0.99[3]	0.07	0.04	0.97	0.72[3]	0.48	0.92[3]	0.31	0.57	0.99
Racialized	0.01	0.93[3]	0.96[3]	0.03	0.28	0.52	0.08	0.69[3]	0.43	0.01

CI: confidence interval; GBM: gay, bisexual and other men who have sex with men.

[1] *class prevalence weighted using RDS-II Volz-Heckathorn weights [25].*

[2] *In Toronto, this indicator was a combination of the two indicators accessing healthcare and received information on sexual health.*

[3] *Probabilities used for labelling classes.*

3.2.3 Montreal

In Montreal, 19.5% (95% CI 14.6 to 24.5%) were unaware of the vaccine, 13.4% (95% CI 9.2 to 17.7%) were undecided or unwilling to get vaccinated, 22.4% (95% CI 17.1 to 27.6%) were willing to get vaccinated, and 44.7% (95% CI 38.5 to 50.9%) had initiated vaccination. Class membership was significantly associated with the HPV vaccination cascade (chi-square statistic = 17.0, DF =9, p = 0.048). The "no barriers" class had the highest probability of vaccine initiation (58%) followed by the "racialized, GBM privacy and immigration barriers" class (39%) (Table 4). The "socio-economic, GBM privacy and healthcare access barriers" class and the "immigration and past vaccines barriers" class had similar probabilities (43–46%) of being unaware of the vaccine. The "immigration and past vaccines barriers" class also had the highest probability of being undecided or unwilling to get vaccinated (40%), and lowest probability of willing to get vaccinated (9%) or initiating vaccination (8%).

4. Discussion

We identified subgroups of 16–26 years old GBM at various stages of HPV vaccination in Vancouver, Toronto and Montreal, the three largest cities in Canada, in 2017–2019. To the best of our knowledge, ours is the first study to use a person-centred approach [7] to identify combinations of factors influencing HPV vaccine uptake among GBM. Characteristics that represented social and programmatic barriers or facilitators to HPV vaccination clustered in defined classes in each of the cities. Class membership was statistically-significantly associated with the HPV vaccination cascade in Vancouver and Montreal but not in Toronto. The fewer combinations of social and programmatic barriers men faced, the higher their chances of having received at least one dose of the HPV vaccine.

Similarities in the patterns observed across cities included that preferring to keep same-sex romantic relationships private, being a member of a racialized group, and/or immigration to Canada clustered together. This may be influenced by a myriad of factors such as cultural values and heterosexism [29–32]. In Montreal, clustering of these characteristics produced the second largest class with a prevalence of 22%, suggesting interventions targeted to this group may have a large impact. Moreover, we also saw clustering of GBM privacy and healthcare access barriers. Sexual orientation disclosure and accessing healthcare are requirements to access publicly-funded HPV vaccine among young GBM in these cities. In Vancouver and Montreal, the classes with the highest probabilities of experiencing these barriers also had the highest probabilities of being in earlier stages of the HPV vaccination cascade. To maximize uptake of targeted programs among these subgroups, interventions are needed to improve comfort to disclose sexual orientation, while also considering cultural differences, decreasing anti-sexual and gender minority (SGM) stigma in healthcare, and helping provide access to non-stigmatizing healthcare facilities.

Subgroups of young GBM with a high probability of being unaware of the HPV vaccine had high probabilities of identifying as racialized, being an immigrant and not accessing healthcare. This suggests that interventions for these subgroups may be more effective in the local community setting versus healthcare settings. An example would be a peer-to-peer educational intervention to increase HPV awareness tailored to different cultures. The "socio-economic, GBM privacy and healthcare access barriers" class in Montreal, which had high probabilities of financial strain and lower education, and the "education barriers" class in Vancouver had higher probabilities of being undecided/unwilling to get vaccinated (25–43%) compared to other classes. Although these men can receive publicly-funded vaccine, they may face other barriers such as not having the time off work to go get the vaccine [33]. Advertising public programs and making the vaccine more accessible may help GBM to transition from being undecided/unwilling to initiate vaccination. Though subgroups across cities may benefit from a similar type of intervention, the overall composition of subgroups differed based on social and programmatic barriers, suggesting intervention components may need to be tailored by locale for optimal benefit.

It is notable that in Vancouver and Montreal, men in the classes most likely to be vaccinated (the "no barriers" class) had a near 100% probability of being white. The probability of identifying as racialized in the "racialized barriers" class in Vancouver and "racialized, GBM privacy and immigration barriers" class in Montreal was 69–93%. These classes of mostly racialized men were facing fewer other barriers; most were accessing healthcare, not experiencing financial strain and had a post-secondary or graduate education. They had the second highest probability of vaccine initiation. These results highlight the interconnectedness of social and systems-level factors and the social construct of ethnicity/race in relation to uptake of healthcare services. Studies have found that racialized individuals are disadvantaged when it comes to healthcare, including vaccine uptake, with larger social and systemic barriers playing a significant role [34–36]. Once these barriers are removed, racialized persons may have more equitable opportunity to healthcare [37]. Our person-centred approach demonstrated how ethnoracial identity interacts with other factors, compared to use of variable-centred regression models that may simply adjust for race/ethnicity.

In our past work exploring the association between these factors and the HPV vaccination cascade using a variable-centred technique, we found that compared to men who had initiated vaccination, men who had immigrated to Canada (versus born in Canada) appeared to have a lower odds of being undecided/unwilling to get vaccinated in all three cities. In contrast, using a person-centred analysis, we observed in Montreal that men who immigrated to Canada and who had low uptake of the hepatitis A or B vaccine had the highest probability of being undecided/unwilling to get vaccinated. These findings demonstrate that not being born in Canada may or may not pose a barrier, depending on other barriers men are facing and their local context. Men in this class may be immigrants who are more hesitant toward vaccines or unaware of how to access these vaccines.

This study has limitations. Vaccine initiation was based on self-report data resulting in possible misclassification of the outcome. Nonetheless, self-reported HPV vaccination among adults had an 89–96% sensitivity, 76–97% specificity

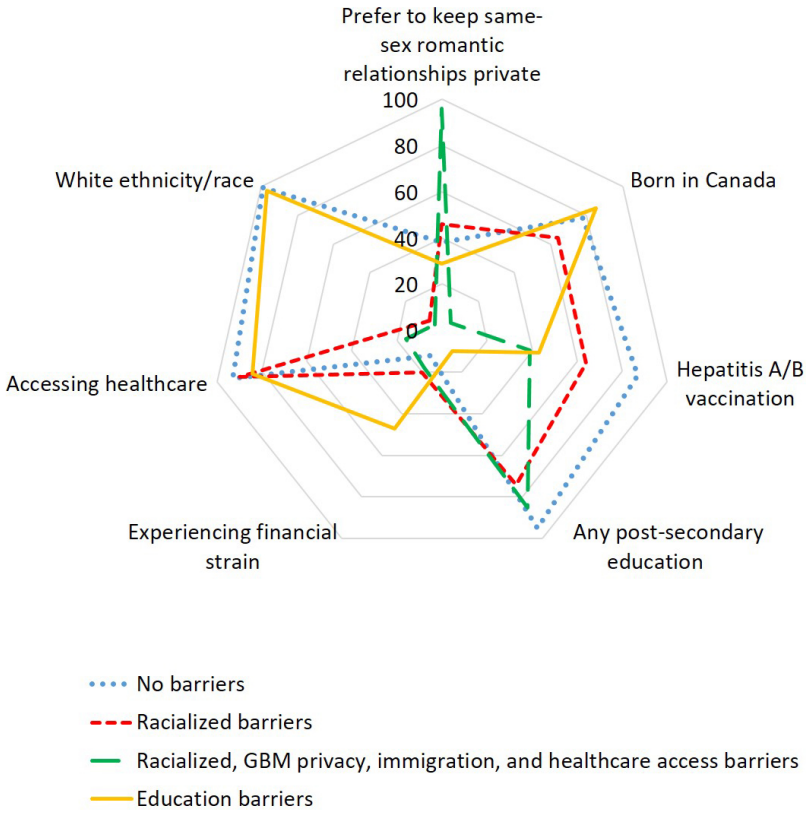

FIGURE 1. Radar plot of estimated item-response probabilities of social and programmatic barriers and facilitators among subgroups of men in Vancouver. As the lines for each class move toward the outer edges, that class has a higher probability of that characteristic.

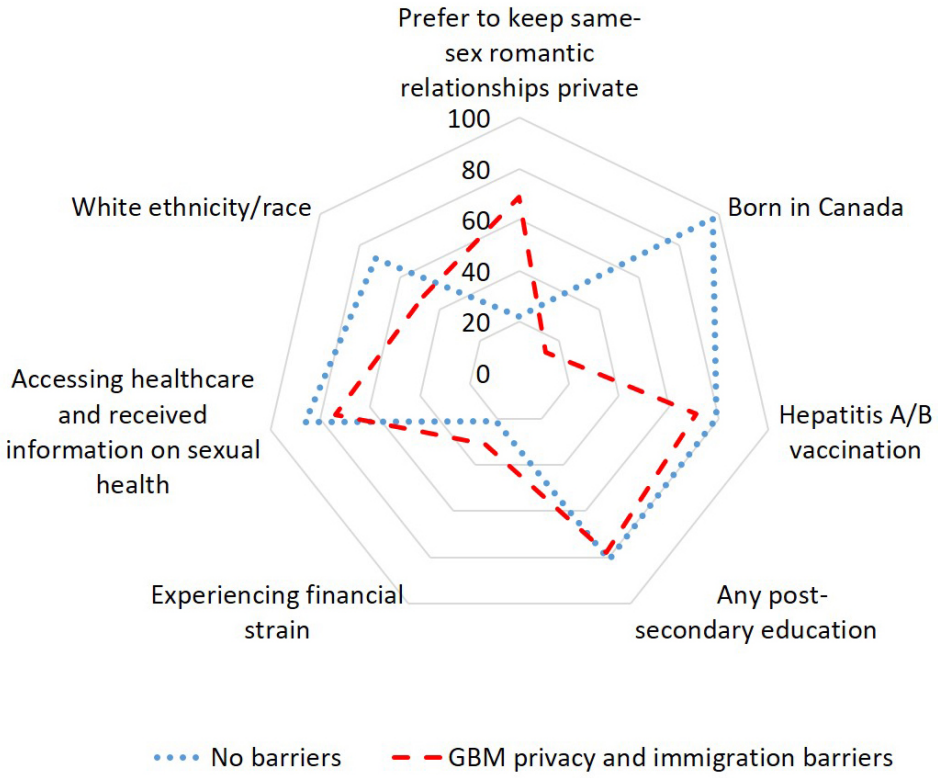

FIGURE 2. Radar plot of estimated item-response probabilities of social and programmatic barriers and facilitators among subgroups of men in Toronto. As the lines for each class move toward the outer edges, that class has a higher probability of that characteristic.

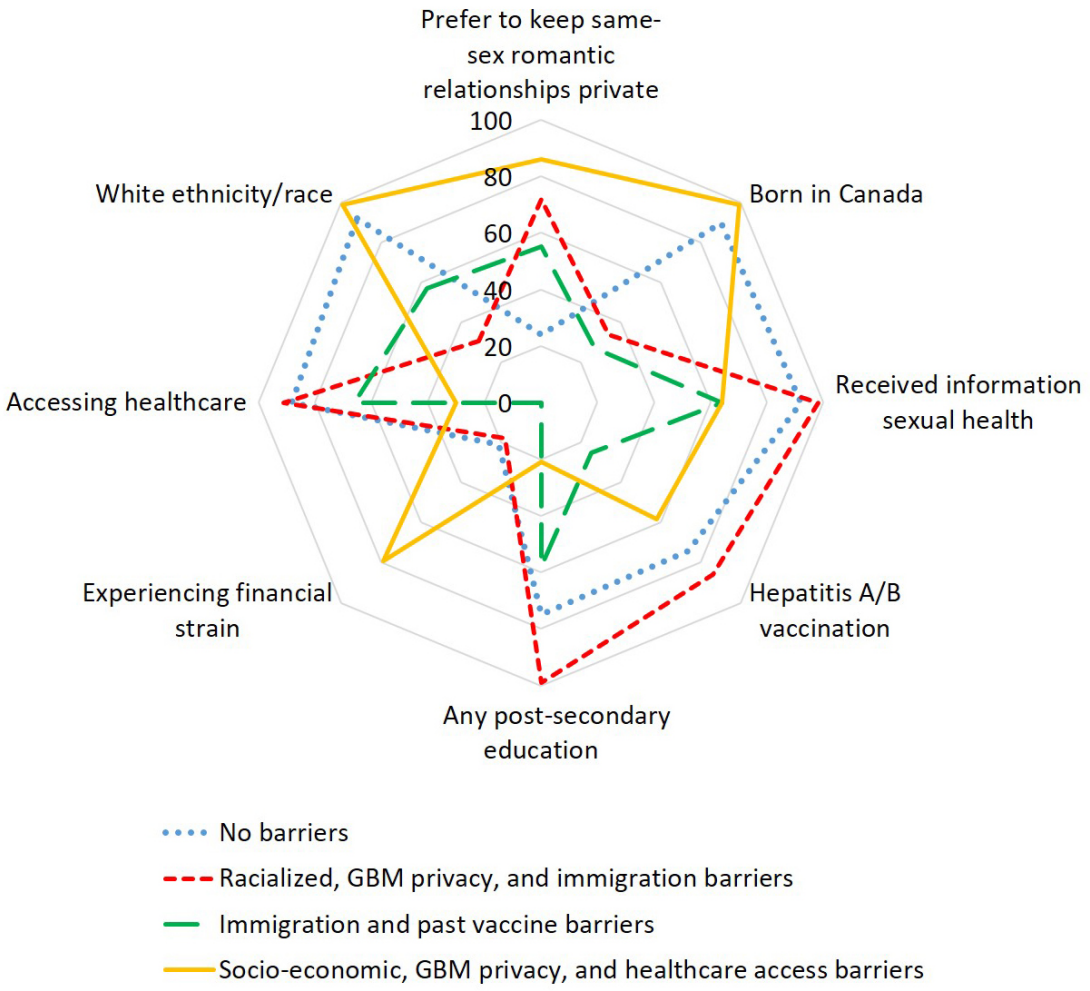

FIGURE 3. Radar plot of estimated item-response probabilities of social and programmatic barriers and facilitators among subgroups of men in Montreal. As the lines for each class move toward the outer edges, that class has a higher probability of that characteristic.

and 73–84% accuracy when compared to electronic medical records [38–41]. Since the analyses were conducted by city, we had a smaller sample size for each model. Even so, all models successfully converged and produced adequate fit statistics providing confidence in model results. There were fewer distinct classes and classes did not separate on as many indicators in Toronto, the city with the smallest sample size, nor was it associated with HPV vaccination stage. It is possible that the indicators selected for this analysis do not cluster as well in Toronto and/or may have a smaller influence on vaccine uptake. Nonetheless, the analysis in Toronto was still useful in that it was able to confirm patterns seen in the other two cities (*i.e.*, existence of no barriers group and grouping of immigration and non-disclosure barriers).

5. Conclusions

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, some adult men from birth cohorts that missed that opportunity can still receive the vaccine within these GBM-targeted programs. Additionally, due to suboptimal uptake of the HPV vaccine in school-based programs in many provinces and territories in Canada, and further reductions in coverage due to the COVID-19 pandemic, targeted publicly-funded HPV vaccination programs will continue to be necessary for years to come.

Our person-centred approach to exploring HPV vaccination among younger GBM helped identify combinations of social and programmatic barriers and facilitators associated with HPV vaccine uptake, patterns that are challenging to examine using a variable-centred approach. The findings suggest that there is no "one size fits all" solution to HPV vaccine uptake among GBM, which has also been recognized in the vaccine hesitancy literature [19]. The observed patterns can be utilized to target and tailor interventions for vaccine promotion. It is important to note that clustering of these barriers and facilitators may differ in future cohorts of men and similar analyses may need to be repeated. Moreover, we recommend ongoing qualitative research [42] to confirm and clarify reasons why men may or may not be getting vaccinated against HPV, particularly among those who are undecided/unwilling to get vaccinated.

TABLE 4. Probability of being in each stage of the HPV vaccination cascade by latent class group membership in the cities of Vancouver, Toronto and Montreal, Canada.

	Vancouver			Toronto			Montreal			
HPV Vaccination Cascade	No barriers	Racialized barriers	Racialized, GBM privacy, immigration and healthcare access barriers	Education barriers	No barriers	GBM privacy and immigration barriers	No barriers	Racialized, GBM privacy and immigration barriers	Immigration and past vaccine barriers	Socio-economic, GBM privacy, and healthcare access barriers
	38%[1] (95% CI 24.3–50.8)	36%[1] (95% CI 22.5–49.7)	14%[1] (95% CI 5.3–23.2)	12%[1] (95% CI 3.8–20.4)	57%[1] (95% CI 42.3–72.4)	43%[1] (95% CI 27.6–57.6)	53%[1] (95% CI 42.8–62.6)	22%[1] (95% CI 13.3–30.4)	15%[1] (95% CI 8.4–22.8)	10%[1] (95% CI 1.5–18.0)
Stage 1: Unaware	10%	18%	75%	17%	15%	22%	10%	22%	43%	46%
Stage 2: Undecided/ unwilling	14%	7%	8%	43%	17%	10%	8%	9%	40%	25%
Stage 3: Willing	20%	30%	5%	16%	28%	26%	24%	30%	9%	15%
Stage 4: Initiated	56%	45%	12%	24%	40%	42%	58%	39%	8%	14%

CI: confidence interval. GBM: gay, bisexual and other men who have sex with men.
[1]*class prevalence weighted using RDS-II Volz-Heckathorn weights [25].*

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

RG—conceptualization, data curation, formal analysis, writing original draft; ANB—funding acquisition, supervision; RG, ANB, SLD, TAH, RN—methodology; RG, AY—project administration; RG, SLD, TAH, JC, ADP, TG, GL, DM, MG, CG, JG, DG, JJ, NJL, RN, GO, CS, DHST, AY, ANB—writing reviewing and editing.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study received ethical approval from Toronto Metropolitan University (#2016-113), University of Toronto (#00033527), St. Michael's Hospital (#17-043), University of Windsor (#33443), University of British Columbia (H16-01226), University of Victoria (H16-01226), Simon Fraser University (H16-01226) and McGill University Health Centre (15-632-MUHC). Informed consent was obtained from all individual participants included in the study.

ACKNOWLEDGMENT

The authors would like to thank the Engage/Momentum II study participants, office staff and community engagement committee members, as well as our community partner agencies. The authors also wish to acknowledge the support of Catharine Chambers, Ashley Mah and Francois Coutlée and their contributions to the work presented here. The Engage Cohort Study is led by Principal Investigators in Toronto by Trevor A. Hart & Daniel Grace, in Montreal by Joseph Cox and Gilles Lambert; and in Vancouver by Jody Jollimore, Nathan Lachowsky and David Moore. More information about the Engage Cohort Study can be found here: https://www.engage-men.ca/.

FUNDING

Engage-HPV is funded by the Canadian Institutes for Health Research (CIHR) Canadian Immunization Research Network (CIRN, 151944) and a CIHR Foundation Grant awarded to ANB (148432). Engage/Momentum II is funded by CIHR (#TE2-138299, FDN-143342, PJT-153139), the Canadian Association for HIV/AIDS Research (CANFAR, #Engage), the Ontario HIV Treatment Network (OHTN, #1051), and the Public Health Agency of Canada (#4500370314), and Ryerson University. RG has no financial disclosures. SLD has no financial disclosures. TAH is supported by a Chair in Gay and Bisexual Men's Health from the OHTN. JC has no financial disclosures. ADP has no financial disclosures. TG is supported by a Michael Smith Health Research BC Health Professional Investigator Award (#2428). GL has no financial disclosures. DM and NJL are supported with scholar awards from the Michael Smith Foundation for Health Research (#5209, #16863). MG has no financial disclosures. CG has no financial disclosures. JG has no financial disclosures. DG is supported by a Canada Research Chair in Sexual and Gender Minority Health. RN has no financial disclosures. GO is supported by a Canada Research Chair in Global Control of HPV-Related Disease and Cancer. CS has no financial disclosures. DHST is supported by a Canada Research Chair in HIV Prevention and Sexually Transmitted Infection Research. AY has no financial disclosures. ANB is supported by a Canada Research Chair in Sexually Transmitted Infection Prevention and a Department of Family and Community Medicine Non-Clinician Research Scientist Award, University of Toronto. The study sponsor did not have any role in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication.

CONFLICT OF INTEREST

CS has research grants paid to the organization (INSPQ or CRCHU de Québec-Université Laval) for clinical trials and epidemiological studies funded by non-profit organizations: MSSS, Bill & Melinda Gates Foundation and Michael Smith Foundation). CS is an active member of the Comité sur l'immunisation du Québec and the National Advisory Committee on Immunization HPV Vaccination and Herpes Zoster Vaccination Working Group. SD is a member and Chair of the National Advisory Committee on Immunization. DHST's institution has received research grants for investigator-initiated research from Abbvie, Gilead and Viiv Healthcare; DHST's institution has also received support for industry-sponsored clinical trials from Glaxo Smith Kline. JC has research funding from ViiV Healthcare and Gilead Sciences, and reports remuneration for advisory work (ViiV Healthcare, Gilead Sciences and Merck Canada).

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jomh.org/files/article/1718879263789072384/attachment/Supplementary%20material.docx.

REFERENCES

[1] Nyitray AG, Carvalho da Silva RJ, Baggio ML, Lu B, Smith D, Abrahamsen M, *et al.* Age-specific prevalence of and risk factors for anal human papillomavirus (HPV) among men who have sex with women and men who have sex with men: the HPV in men (HIM) study. The Journal of Infectious Diseases. 2011; 203: 49–57.

[2] Marra E, Lin C, Clifford GM. Type-specific anal human papillomavirus prevalence among men, according to sexual preference and HIV status: a systematic literature review and meta-analysis. The Journal of Infectious Diseases. 2019; 219: 590–598.

[3] Government of Canada. Human papillomavirus vaccine: Canadian immunization guide. Government of Ontario: Ottawa. 2017.

[4] Health Initiative for Men. GetGarded against HPV. 2015. Available at: https://checkhimout.ca/get-garded/ (Accessed: 12 May 2023).

[5] Grewal R, Deeks SL, Hart TA, Cox J, De Pokomandy A, Grennan T, *et al.* 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. Vaccine. 2021; 39: 3756–3766.
[6] Grewal R, Deeks SL, Hart TA, Cox J, De Pokomandy A, Grennan T, *et al*. Human papillomavirus (HPV) vaccination across a cascade of knowledge, willingness, and uptake among gay, bisexual, and other men who have sex with men in Canada's three largest cities. Human Vaccines & Immunotherapeutics. 2021; 17: 5413–5425.
[7] Marsh HW, Lüdtke O, Trautwein U, Morin AJS. Classical latent profile analysis of academic self-concept dimensions: synergy of person- and variable-centered approaches to theoretical models of self-concept. Structural Equation Modeling. 2009; 16: 191–225.
[8] Carter A, Lachowsky N, Forrest JI, Cui Z, Sereda P, Kaida A, *et al*. A latent class analysis of sexual and romantic relationships among HIV-positive and HIV-negative gay and bisexual men in Vancouver. The Canadian Journal of Human Sexuality. 2017; 26: 78–96.
[9] Card KG, Armstrong HL, Carter A, Cui Z, Wang L, Zhu J, *et al*. A latent class analysis of substance use and culture among gay, bisexual and other men who have sex with men. Culture, Culture, Health & Sexuality. 2018; 20: 1424–1439.
[10] Valente PK, Bauermeister JA, Lin WY, Silva DTD, Hightow-Weidman L, Drab R, *et al*. Preferences across pre-exposure prophylaxis modalities among young men who have sex with men in the United States: a latent class analysis study. AIDS Patient Care and STDs. 2022; 36: 431–442.
[11] Traeger MW, Murphy D, Ryan KE, Asselin J, Cornelisse VJ, Wilkinson AL, *et al*. Latent class analysis of sexual behaviours and attitudes to sexually transmitted infections among gay and bisexual men using PrEP. AIDS and Behavior. 2022; 26: 1808–1820.
[12] Gilkey MB, Mohan D, Janssen EM, McRee AL, Kornides ML, Bridges JFP. Exploring variation in parental worries about HPV vaccination: a latent-class analysis. Human Vaccines & Immunotherapeutics. 2019; 15: 1745–1751.
[13] Hopfer S, Wright ME, Pellman H, Wasserman R, Fiks AG. HPV vaccine recommendation profiles among a national network of pediatric practitioners: understanding contributors to parental vaccine hesitancy and acceptance. Human Vaccines & Immunotherapeutics. 2019; 15: 1776–1783.
[14] Dudley MZ, Limaye RJ, Omer SB, O'Leary ST, Ellingson MK, Spina CI, *et al*. Latent class analysis of maternal vaccine attitudes and beliefs. Health Education & Behavior. 2020; 47: 765–781.
[15] Gravelle TB, Phillips JB, Reifler J, Scotto TJ. Estimating the size of "anti-vax" and vaccine hesitant populations in the US, UK, and Canada: comparative latent class modeling of vaccine attitudes. Human Vaccines & Immunotherapeutics. 2022; 18: 2008214.
[16] Lopez N, de la Cueva I, Taborga E, de Alba AF, Cabeza I, Raba RM, *et al.* HPV knowledge and vaccine acceptability: a survey-based study among parents of adolescents (KAPPAS study). Infectious Agents and Cancer. 2022; 17: 55.
[17] Heckathorn DD. Respondent-driven sampling: a new approach to the study of hidden populations. Social Problems. 1997; 44: 174–199.
[18] Hart TA, Moore DM, Noor SW, Lachowsky N, Grace D, Cox J, *et al*. Prevalence of HIV and sexually transmitted and blood-borne infections, and related preventive and risk behaviours, among gay, bisexual and other men who have sex with men in Montreal, Toronto and Vancouver: results from the engage study. Canadian Journal of Public Health. 2021; 112: 1020–1029.
[19] SAGE Working Group. Report of the SAGE Working Group on Vaccine Hesitancy. Geneva; date. 2014.
[20] Ontario Human Rights Commission. Policy and Guidelines on Racism and Discrimination. 2005.
[21] Lanza ST, Collins LM, Lemmon DR, Schafer JL. PROC LCA: a SAS procedure for latent class analysis. Structural Equation Modeling. 2007; 14: 671–694.
[22] Collins LM, Lanza ST. Latent class and latent transition analysis: with applications in the social, behavioral, and health sciences. 1st edn. Wiley: Hoboken. 2010.
[23] Lanza ST, Bray BC. Transitions in drug use among high-risk women: an application of latent class transition analysis. Advances and Applications in Statistical Sciences. 2010; 3: 203–235.
[24] Asparouhov T, Muthén B. Residual associations in latent class and latent transition analysis. Structural Equation Modeling. 2015; 22: 169–177.
[25] Volz EM, Heckathorn DD. Probability based estimation theory for respondent driven sampling. Journal of Official Statistics. 2008; 24: 79–97.
[26] Vermunt JK, Magidson J. Latent class analysis with sampling weights. Sociological Methods & Research. 2007; 36: 87–111.
[27] Dziak JJ, Bray BC, Zhang J, Zhang M, Lanza ST. Comparing the performance of improved classify-analyze approaches for distal outcomes in latent profile analysis. Methodology. 2016; 12: 107–116.
[28] Hamby S, Turner H, Finkelhor D. Financial Strain Index. Crimes Against Children Research Center: Durham. 2011.
[29] Lee JJ, Katz DA, Glick SN, Moreno C, Kerani RP. Immigrant status and sexual orientation disclosure: implications for HIV/STD prevention among men who have sex with men in Seattle, Washington. AIDS and Behavior. 2020; 24: 2819–2828.
[30] He Y, Dangerfield II DT, Fields EL, Dawkins MR, Turpin RE, Johnson D, *et al*. Health care access, health care utilisation and sexual orientation disclosure among Black sexual minority men in the Deep South. Sexual Health. 2020; 17: 421–428.
[31] Ogden SN, Scheffey KL, Blosnich JR, Dichter ME. "Do I feel safe revealing this information to you?": patient perspectives on disclosing sexual orientation and gender identity in healthcare. Journal of American College Health. 2020; 68: 617–623.
[32] Turpin RE, Akré EL, Williams ND, Boekeloo BO, Fish JN. Differences in health care access and satisfaction across intersections of race/ethnicity and sexual identity. Academic Medicine. 2021; 96: 1592–1597.
[33] Musto R, Siever JE, Johnston JC, Seidel J, Rose MS, McNeil DA. Social equity in human papillomavirus vaccination: a natural experiment in Calgary Canada. BMC Public Health. 2013; 13: 640.
[34] Agénor M, Pérez AE, Peitzmeier SM, Borrero S. Racial/ethnic disparities in human papillomavirus vaccination initiation and completion among U.S. women in the post-affordable care act era. Ethnicity & Health. 2020; 25: 393–407.
[35] Rhee TG, Marottoli RA, Van Ness PH, Levy BR. Impact of perceived racism on healthcare access among older minority adults. American Journal of Preventive Medicine. 2019; 56: 580–585.
[36] Njoku A, Joseph M, Felix R. Changing the narrative: structural barriers and racial and ethnic Inequities in COVID-19 vaccination. International Journal of Environmental Research and Public Health. 2021; 18: 9904.
[37] Williams DR, Cooper LA. Reducing racial inequities in health: using what we already know to take action. International Journal of Environmental Research and Public Health. 2019; 16: 606.
[38] Rolnick SJ, Parker ED, Nordin JD, Hedblom BD, Wei F, Kerby T, *et al*. Self-report compared to electronic medical record across eight adult vaccines: do results vary by demographic factors? Vaccine. 2013; 31: 3928–3935.
[39] Niccolai LM, McBride V, Julian PR. Sources of information for assessing human papillomavirus vaccination history among young women. Vaccine. 2014; 32: 2945–2947.
[40] 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. American Journal of Men's Health. 2018; 12: 819–827.
[41] Oliveira CR, Avni-Singer L, Badaro G, Sullivan EL, Sheth SS, Shapiro ED, *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 Medical Informatics. 2020; 8: e16487.
[42] Grace D, Gaspar M, Paquette R, Rosenes R, Burchell AN, Grennan T, *et al.* HIV-positive gay men's knowledge and perceptions of human papillomavirus (HPV) and HPV vaccination: a qualitative study. PLOS ONE. 2018; 13: e0207953.

How to cite this article: Ramandip Grewal, Shelley L Deeks, Trevor A Hart, Joseph Cox, Alexandra De Pokomandy, Troy Grennan, *et al*. HPV vaccination among gay, bisexual and other men who have sex with men in Canada's three largest cities: a person-centred approach. Journal of Men's Health. 2023; 19(10): 22-33. doi: 10.22514/jomh.2023.097.