Longitudinal Event-Level Sexual Risk and Substance Use Among Gay, Bisexual, and other Men who have Sex with Men

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**Abstract:** (1)Background**:** Condomless anal sex and substance use are associated with STI risk among gay, bisexual, and other men who have sex with men (gbMSM). Our first study objective was to describe event-level sexual risk and substance use trends among gbMSM. Our second study objective was to describe substances associated with event-level sexual risk. (2) Methods**:** Data come from the Momentum Health Study in Vancouver, British Columbia and participants were recruited from 2012-2015, with follow up until 2018. Stratified by self-reported HIV status, we used generalized estimating equations to assess trends of sexual event-level substance use and assessed interactions between substance use and time period on event-level higher risk sex defined as condomless anal sex with an HIV sero-different or unknown status partner. (3) Results**:** Event-levelhigher risk anal sex increased across the study period among HIV-negative/unknown (baseline prevalence: 13% vs study end prevalence: 29%) and HIV-positive gbMSM (baseline prevalence: 16% vs study end prevalence: 38%). Among HIV-negative/unknown gbMSM, event-level erectile drug use increased while alcohol use decreased over the study period. Overall interactions between substance use and time on higher risk anal sex were not statistically significant, regardless of serostatus. However, we found a number of time-specific significant interactions, for erectile drugs, poppers, GHB, crystal methamphetamine and ecstasy/MDMA use among HIV-negative/unknown gbMSM**.** (4)Conclusion**:** Significant differences in substance use trends and associated risks exist and are varied among gbMSM by serostatus. These findings provide a more comprehensive understanding on the effects of event-level substance use on sexual risk though longitudinal follow-up of nearly six years.

**Keywords:** sexual risk; Trends; Event-Level; Substance use; MSM; STI

1. Introduction

Rates of sexually transmitted infections (STI) are rising in Canada and are highly concentrated among gay, bisexual, and other men who have sex with men (gbMSM) [1]. Further, disparities in STI prevalence including diagnoses of chlamydia, gonorrhea, syphilis, and lymphogranuloma venereum (LGV) suggest HIV serostatus plays an important role in STI transmission [1, 2]. Serosorting is a common practice among gbMSM, where individuals select sexual partners based on HIV status. However, serosorting based on HIV status may increase rates of STIs as gbMSM may forgo condoms with same HIV serostatus partners, concentrating STI rates among HIV-positive gbMSM [3]. Moreover, higher rates of serodiscordant condomless anal sex (CAS) are reported among HIV-positive gbMSM compared to HIV-negative gbMSM [4] with serodiscordant CAS identified as a main factor in STI diagnoses among HIV-positive among gbMSM [5]. Within Canada, a study of gbMSM living with HIV found increased risk of chlamydia and gonorrhea was associated with multiple HIV-positive partners as well as recreational drug use [6]. Collectively, STI’s may be more prevalent among certain sexual networks of gbMSM and considerations of HIV serostatus on STI risk are important to further understand sexual risk.

Substance use is a significant factor in influencing sexual risk-taking behaviours such as CAS. Previous literature on substance use patterns among gbMSM indicate variability in different substance types and distinct classes of substances such as club drug use, sex drug use and conventional drug use [7]. A systematic review on sexualized drug use among gbMSM found multiple factors that may promote engagement in sexualized drug use such as, coping with stressful events, increasing intimacy, fulfilling community belonging and enhancing sexual performance and functioning [8]. Related, chemsex refers to certain recreational drugs (particularly combinations of crystal methamphetamine, mephedrone and gammahydroxybutrate/gammabutyrolactone (GHB/GBL)) used before or during sex, which help facilitate or enhance sex [9]. Among gbMSM living with HIV, multiple studies have found chemsex significantly associated with serodiscordant CAS, serodiscordant CAS with a partner who has a detectable viral load, increased number of sexual partners, and increased STI diagnoses [10, 11]. Among HIV-negative gbMSM, existing literature found chemsex was associated with serodiscordant/HIV-unknown CAS, STI diagnoses, a greater number of sexual partners and group sex events [12]. Mixed-method research from the United Kingdom help contextualize findings as gbMSM report difficulty negotiating safer sex while under the influence of substances and perceptions about HIV and STI sexual risk may also be skewed [13].

The association between substance use and sexual risk relates to situational events which are highly contextual and may vary in terms of substances used, partner characteristics, condom usage, and sexual acts. To address these limitations, various event-level approaches focusing on specific sexual encounters and substance use within highly restricted time periods before or during sex may provide nuanced understanding [14]. A review of the literature on event-level substance use and sexual behaviours among gbMSM found consistent associations of sexual risk with methamphetamine use and alcohol binge drinking among gbMSM [15]. However, inconsistencies in event-level measurement and analysis may limit generalizability in findings. For example, using both retrospective and prospective event-level data, Rendina et al. (2015) found event-level substance use, in particular club drugs such as ketamine, ecstasy/3,4-methylenedioxymethamphetamine (MDMA), GHB, cocaine/crack, or methamphetamine increased odds of sex and engaging in CAS [16]. Among gbMSM living with HIV, Sullivan and colleagues found self-reported heavier alcohol users reported less frequent condom use [17]. Associations between substance use and CAS are also not limited by age as consistent event-level diary findings among young gbMSM, also found associations between alcohol use and CAS with casual partners [18]. While event-level substance use has been associated with CAS among gbMSM, Melendez-Torres et al. (2015) found overall event-level substance use was not associated with perceived control or pleasure during sex. However, the authors found crystal methamphetamine specifically was associated with both CAS and lower perceived control during sex [19]. Taken together, various event-level approaches highlight evidence for associations between substance use and sexual risk. However, research within a Canadian context is limited.

Using event-level longitudinal data to measure STI sexual risk, our first study objective was to describe event-level sexual risk and substance use trends in Vancouver during Treatment as Prevention scale-up (TasP) over a six-year period [20]. Our second objective was to describe individual and partner substance use associated with event-level sexual risk and to determine whether there have been any changes in the significance of certain substances as they relate to condom use over the study period.

2. Materials and Methods

2.1. Study Protocol and Participants

Data are from the Momentum Health Study, a prospective longitudinal, bio-behavioural study of gbMSM in Vancouver, British Columbia. Participants were recruited from February 2012 to February 2015 using respondent-driven sampling (RDS). RDS recruitment involved initial “seed” participants who were recruited through community partner agencies and online advertisements on gbMSM social networking websites and apps. Full RDS methodology of our study has been published elsewhere [21]. To be eligible, participants had to gender identify as a man, be 16 years of age or older, report having sex with another man in the past six months, currently live in Metro Vancouver, and be able to complete the questionnaire in English. Participants completed a 90-minute in-person study visit every six-months which included a computer-assisted self-interview (CASI) and study nurse visit. Participants received a $50 CAD honorarium for their participation and could receive an additional $10 CAD for each eligible participant they referred that completed the study (maximum of six). Study visits up to February 2018 are included in this analysis. All participants signed an Informed Consent form about the study and their involvement. The research protocol and human ethics clearances were approved by The University of British Columbia, Simon Fraser University, and The University of Victoria.

2.2. Outcome Variable

The primary outcome variable was higher risk anal sex, which was defined as any CAS with an HIV sero-different or unknown status partner. Participants were asked to complete a “partner matrix” of a repeating set of questions about their last sexual encounter with each of up to five of their most recent sexual partners within the past six months (maximum of five partners). Sexual encounters that did not include anal sex were excluded in this analysis. Condom use was reported for each partner, and participants indicated their use/non-use as the receptive and insertive partner. Any form of CAS (receptive or insertive) was included in this analysis. Partner’s HIV serostatus was obtained by asking participants if they knew their partner(s)’s HIV status before having sex, what the partner’s status was, and how they knew their partner’s status (if they knew). From these, we determined if partner’s serostatus was positive, negative, or unknown.

2.3. Explanatory Variables

The primary explanatory factors were time (for trend analyses) and substance use. Time of event was assessed with a six-month period prevalence between study visits, over the course of almost six years. Event-level factors were collected for each partner and reported sexual event. Participants indicated the number of male sexual partners, the number of months since they first had sex with each partner, and the number of times they had anal sex with each partner in the past six months (per act). Participants indicated the month and year of the last sexual event with each partner, which was used to conduct a change over time analysis. For each sexual event, participants indicated their anal sex positions (receptive, insertive, or both), their level of certainty regarding their partner’s HIV status before sex, whether they expected they would have sex with this partner again, and whether they received any goods, money, drugs, or services in return for sex. Participants reported their own and their partner’s substance use in the two hours prior to and during each sexual event, which included any alcohol, cannabis, erectile drugs, poppers (amyl nitrate), crystal methamphetamine, GHB, and MDMA.

Psychosocial variables included the HIV Treatment Optimism-Skepticism Scale (12 questions, range: 12-48, study α=0.85) [22], the 11-item Sexual Seeking Scale (revised) (range: 11-44, study α=0.73) [23], the 7-item personal (range: 1-5, α=0.75) and 6-item communal subscales for the Sexual Altruism Scale (range: 1-5, study α=0.77) [24], and the 10-item Alcohol Use Disorders Identification Test (AUDIT) (range: 0-40, study α=0.86) [25].

Demographic variables included participants’ age, sexual orientation, race/ethnicity, annual income, education, residence, and relationship status. We also asked a series of potential HIV prevention or risk reductions practices (i.e., always using condoms, sero-positioning, sero-sorting, viral load sorting, abstinence, withdrawal, asking HIV status before sex), PrEP usage, escort work and attending group sex events in the past six months. For HIV-positive gbMSM, we utilized the study linkage to the BC Centre for Excellence in HIV/AIDS’s Drug Treatment Program administrative database to assess treatment adherence and viral load [20].

2.4. Analysis

We limited our analyses to the sexual-event level and stratified participants by self-reported HIV status. Generalized estimating equations (GEE) were used to construct hierarchical logistic regression models, adjusting for participant inter-dependence in the data (events within participants as main clusters and each visit as sub-clusters). We examined trends over time with higher risk anal sex and substance use. Furthermore, we also tested interactions for substances and time to assess whether their associations with higher risk anal sex significantly changed over the study period. Odds ratio per six-months are presented and significance was assessed as a *p-*value *<*0.05. RDS weighting was not applied, given that the analysis is based on event-level data. We included post-hoc lost-to-follow-up analyses (LTFU) to determine significant differences between participants who did not complete the study and our final sample. All analyses were conducted using SAS version 9.4 (SAS, Cary, NC).

3. Results

3.1. Descriptive Results

The median follow-up time for participants was 3.03 years. 549 HIV-negative/unknown gbMSM reported 8121 anal sexual events, of which 17.9% included CAS with a sero-different or unknown status partner. Among the 213 HIV-positive gbMSM at baseline, 3454 anal sexual events were reported, of which 27.9% included CAS with a sero-different or unknown status partner. Full descriptive statistics on the sample stratified by HIV status can be found in Table 1.

**Table 1.** Baseline Participant-Level Descriptives of gbMSM in Metro Vancouver, Stratified by Self-Reported HIV Status.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Overall** | | **HIV- Negative/Unknown** | | **HIV-Positive** | |
|  | **N** | | **n** | **%** | **n** | **%** |
|  | 762 | | 549 | 72 | 213 | 28 |
| Age |  |  |  |  |  |  |
| 16-29 | 288 | 37.8 | 277 | 50.5 | 11 | 5.2 |
| 30-39 | 254 | 33.3 | 180 | 32.8 | 74 | 34.7 |
| 40+ | 220 | 28.9 | 92 | 16.8 | 128 | 60.1 |
| Sexual Orientation |  |  |  |  |  |  |
| Gay | 647 | 84.9 | 464 | 84.5 | 183 | 85.9 |
| Bisexual | 69 | 9.1 | 50 | 9.1 | 19 | 8.9 |
| Other | 46 | 6.0 | 35 | 6.4 | 11 | 5.2 |
| Ethnicity |  |  |  |  |  |  |
| White | 577 | 75.7 | 408 | 74.3 | 169 | 79.3 |
| Asian | 74 | 9.7 | 62 | 11.3 | 12 | 5.6 |
| Indigenous | 46 | 6.0 | 28 | 5.1 | 18 | 8.5 |
| Latino | 35 | 4.6 | 28 | 5.1 | 7 | 3.3 |
| Other | 30 | 3.9 | 23 | 4.2 | 7 | 3.3 |
| Born in Canada |  |  |  |  |  |  |
| No | 176 | 23.1 | 140 | 25.5 | 36 | 16.9 |
| Yes | 586 | 76.9 | 409 | 74.5 | 177 | 83.1 |
| Neighbourhood |  |  |  |  |  |  |
| Downtown/West End | 375 | 49.2 | 234 | 42.6 | 141 | 66.2 |
| Elsewhere Vancouver | 238 | 31.2 | 192 | 35.0 | 46 | 21.6 |
| Outside Vancouver | 149 | 19.6 | 123 | 22.4 | 26 | 12.2 |
| Formal Education |  |  |  |  |  |  |
| Some or completed high school | 170 | 22.3 | 109 | 19.9 | 61 | 28.6 |
| Any post-secondary training | 592 | 77.7 | 440 | 80.2 | 152 | 71.4 |
| Annual Income |  |  |  |  |  |  |
| <$30,000 | 476 | 62.5 | 324 | 59.0 | 152 | 71.4 |
| at least $30,000 | 286 | 37.5 | 225 | 41.0 | 61 | 28.6 |
| Current Regular Partner |  |  |  |  |  |  |
| No | 470 | 61.7 | 337 | 61.4 | 133 | 62.4 |
| Yes, but not common law/married | 163 | 21.4 | 120 | 21.9 | 43 | 20.2 |
| Yes, Common law/married | 129 | 16.9 | 92 | 16.8 | 37 | 17.4 |
| Usage of PrEP |  |  |  |  |  |  |
| No | 141 | 23.7 | 85 | 19.0 | 56 | 38.1 |
| Yes | 1 | 0.2 | 0 | 0.0 | 1 | 0.7 |
| Never heard of PrEP | 453 | 76.1 | 363 | 81.0 | 90 | 61.2 |
| Escort Work |  |  |  |  |  |  |
| No | 625 | 82.0 | 481 | 87.6 | 144 | 67.6 |
| Yes, in P6M | 47 | 6.2 | 30 | 5.5 | 17 | 8.0 |
| Yes, not in P6M | 90 | 11.8 | 38 | 6.9 | 52 | 24.4 |
| Attended Group Sex P6M |  |  |  |  |  |  |
| No | 565 | 74.2 | 427 | 77.8 | 138 | 64.8 |
| Yes | 197 | 25.9 | 122 | 22.2 | 75 | 35.2 |
| AUDIT Zone |  |  |  |  |  |  |
| Low risk (scores 0 to 7) | 455 | 60.0 | 293 | 53.5 | 162 | 76.8 |
| Medium risk (scores 8 to 15) | 203 | 26.8 | 170 | 31.0 | 33 | 15.6 |
| Harmful (scores 16 to 19) | 54 | 7.1 | 45 | 8.2 | 9 | 4.3 |
| Possible dependence (scores 20 and over) | 47 | 6.2 | 40 | 7.3 | 7 | 3.3 |
| On ART Ever |  |  |  |  |  |  |
| No | 3 | 1.4 |  |  | 3 | 1.4 |
| Yes | 213 | 98.6 |  |  | 210 | 98.6 |
| Treatment Adherence P12M |  |  |  |  |  |  |
| 95% or greater | 120 | 55.6 |  |  | 120 | 56.3 |
| <95% | 53 | 24.5 |  |  | 53 | 24.9 |
| Never on ARV/Start within 12M | 43 | 19.9 |  |  | 40 | 18.8 |
| Latest Viral Load <200 copies/mL |  |  |  |  |  |  |
| No | 37 | 17.1 |  |  | 34 | 16.0 |
| Yes | 179 | 82.9 |  |  | 179 | 84.0 |
| Prevention Strategies |  |  |  |  |  |  |
| Always Using Condoms |  |  |  |  |  |  |
| No | 334 | 44.1 | 190 | 34.9 | 144 | 67.6 |
| Yes | 424 | 55.9 | 355 | 65.1 | 69 | 32.4 |
| Sero-positioning |  |  |  |  |  |  |
| No | 539 | 71.1 | 400 | 73.4 | 139 | 65.3 |
| Yes | 219 | 28.9 | 145 | 26.6 | 74 | 34.7 |
| No Anal Sex |  |  |  |  |  |  |
| No | 411 | 54.2 | 275 | 50.5 | 136 | 63.9 |
| Yes | 347 | 45.8 | 270 | 49.5 | 77 | 36.2 |
| Sero-sorting |  |  |  |  |  |  |
| No | 453 | 59.8 | 352 | 64.6 | 101 | 47.4 |
| Yes | 305 | 40.2 | 193 | 35.4 | 112 | 52.6 |
| Viral Load Sorting |  |  |  |  |  |  |
| No | 617 | 81.4 | 490 | 89.9 | 127 | 59.6 |
| Yes | 141 | 18.6 | 55 | 10.1 | 86 | 40.4 |
| Withdrawal |  |  |  |  |  |  |
| No | 538 | 71.0 | 392 | 71.9 | 146 | 68.5 |
| Yes | 220 | 29.0 | 153 | 28.1 | 67 | 31.5 |
| Asking Status |  |  |  |  |  |  |
| No | 314 | 41.4 | 211 | 38.7 | 103 | 48.4 |
| Yes | 444 | 58.6 | 334 | 61.3 | 110 | 51.6 |
| Event-Level Outcomes | n | % | n | % | n | % |
| Higher Risk Anal Sex |  |  |  |  |  |  |
| No | 606 | 79.7 | 453 | 82.5 | 153 | 72.5 |
| Yes | 154 | 20.3 | 96 | 17.5 | 58 | 27.5 |
| Alcohol |  |  |  |  |  |  |
| No | 434 | 57.0 | 295 | 53.7 | 139 | 65.3 |
| Yes | 328 | 43.0 | 254 | 46.3 | 74 | 34.7 |
| Cannabis |  |  |  |  |  |  |
| No | 515 | 67.6 | 401 | 73.0 | 114 | 53.5 |
| Yes | 247 | 32.4 | 148 | 27.0 | 99 | 46.5 |
| Erectile Drugs |  |  |  |  |  |  |
| No | 663 | 87.0 | 497 | 90.5 | 166 | 77.9 |
| Yes | 99 | 13.0 | 52 | 9.5 | 47 | 22.1 |
| Poppers |  |  |  |  |  |  |
| No | 598 | 78.5 | 466 | 84.9 | 132 | 62.0 |
| Yes | 164 | 21.5 | 83 | 15.1 | 81 | 38.0 |
| Ecstasy/MDMA |  |  |  |  |  |  |
| No | 723 | 94.9 | 524 | 95.5 | 199 | 93.4 |
| Yes | 39 | 5.1 | 25 | 4.6 | 14 | 6.6 |
| GHB |  |  |  |  |  |  |
| No | 720 | 94.5 | 532 | 96.9 | 188 | 88.3 |
| Yes | 42 | 5.5 | 17 | 3.1 | 25 | 11.7 |
| Crystal Methamphetamine |  |  |  |  |  |  |
| No | 685 | 89.9 | 520 | 94.7 | 165 | 77.5 |
| Yes | 77 | 10.1 | 29 | 5.3 | 48 | 22.5 |
| Continuous Variables | Median | Q1, Q3 | Median | Q1, Q3 | Median | Q1, Q3 |
| Male Sex Events Number P6M | 4 | 1,15 | 4 | 2,20 | 3.5 | 1,12 |
| Anal Sex Events Number P6M | 2 | 0,8 | 2 | 0,9 | 2 | 1,8 |
| Treatment Optimism-Skepticism Scale | 25 | 21,28 | 24 | 20,27 | 28 | 25,32 |
| Sexual Altruism Scale (Communal) | 3.5 | 2.8,4 | 3.5 | 3,4 | 3.2 | 2.5,4 |
| Sexual Altruism Scale (Personal) | 3.4 | 3,3.9 | 3.6 | 3.1,3.9 | 3.3 | 2.7,3.9 |
| Sexual Sensation Seeking Scale | 31 | 28,34 | 30 | 28,33 | 32 | 29,35 |

3.2. Analytical Results

In our GEE, higher risk anal sex was significantly associated with greater use of poppers, erectile drug use, ecstasy/MDMA use, GHB use, and crystal methamphetamine use among HIV-negative/unknown gbMSM; only poppers use was significantly associated with greater odds of higher risk anal sex for HIV-positive gbMSM. Full results can be found in Table 2.

**Table 2.** Univariable Generalized Estimating Equations assessing Higher Risk Anal Sex among gbMSM in Metro Vancouver, 2012-2017.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **HIV-Negative/Unknown** | | | | | **HIV-Positive** | | | | |
|  | **Higher Risk Anal Sex (Yes 1457 vs. No 6664)** | | | | | | **Higher Risk Anal Sex (Yes 1457 vs. No 6664)** | | | |
|  | **OR** | **95% CI** | | **p** | **OR** | | | **95% CI** | | **p** |
| Age |  |  |  |  |  | | |  |  |  |
| 16-29 | Ref |  |  |  | Ref | | |  |  |  |
| 30-39 | 1.44 | 1.13 | 1.83 | 0.003 | 0.80 | | | 0.51 | 1.27 | 0.351 |
| 40+ | 1.39 | 0.98 | 1.97 | 0.069 | 0.56 | | | 0.35 | 0.88 | 0.013 |
| Sexual Orientation |  |  |  |  |  | | |  |  |  |
| Gay | Ref |  |  |  | Ref | | |  |  |  |
| Bisexual | 1.39 | 0.99 | 1.96 | 0.056 | 0.73 | | | 0.52 | 1.03 | 0.071 |
| Other | 1.02 | 0.72 | 1.44 | 0.915 | 1.06 | | | 0.76 | 1.46 | 0.736 |
| Ethnicity |  |  |  |  |  | | |  |  |  |
| White | Ref |  |  |  | Ref | | |  |  |  |
| Asian | 0.57 | 0.38 | 0.86 | 0.008 | 1.37 | | | 0.79 | 2.40 | 0.264 |
| Indigenous | 1.20 | 0.66 | 2.20 | 0.545 | 0.94 | | | 0.48 | 1.85 | 0.861 |
| Latino | 1.16 | 0.69 | 1.96 | 0.577 | 1.26 | | | 0.51 | 3.10 | 0.611 |
| Other | 0.89 | 0.45 | 1.77 | 0.738 | 3.05 | | | 1.85 | 5.04 | <.0001 |
| Born in Canada |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.04 | 0.77 | 1.41 | 0.787 | 0.81 | | | 0.55 | 1.19 | 0.284 |
| Neighbourhood |  |  |  |  |  | | |  |  |  |
| Downtown/West End | Ref |  |  |  | Ref | | |  |  |  |
| Elsewhere Vancouver | 0.72 | 0.57 | 0.90 | 0.004 | 1.26 | | | 0.95 | 1.67 | 0.106 |
| Outside Vancouver | 0.94 | 0.72 | 1.23 | 0.649 | 1.34 | | | 0.98 | 1.84 | 0.067 |
| Formal Education |  |  |  |  |  | | |  |  |  |
| Some or completed high school | Ref |  |  |  | Ref | | |  |  |  |
| Any post-secondary training | 0.78 | 0.56 | 1.09 | 0.144 | 1.51 | | | 0.97 | 2.35 | 0.066 |
| Annual Income |  |  |  |  |  | | |  |  |  |
| <$30,000 | Ref |  |  |  | Ref | | |  |  |  |
| at least $30,000 | 1.21 | 0.99 | 1.48 | 0.058 | 1.47 | | | 1.12 | 1.92 | 0.005 |
| Current Regular Partner |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes, but not common law/married | 0.93 | 0.76 | 1.13 | 0.452 | 1.29 | | | 0.97 | 1.71 | 0.085 |
| Yes, Common law/ married | 0.87 | 0.67 | 1.12 | 0.274 | 1.19 | | | 0.92 | 1.55 | 0.185 |
| Usage of PrEP |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  |  | | |  |  |  |
| Yes | 2.20 | 1.41 | 3.42 | 0.001 |  | | |  |  |  |
| Never heard of PrEP | 0.81 | 0.66 | 0.98 | 0.033 |  | | |  |  |  |
| Escort Work |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes, in P6M | 1.77 | 1.18 | 2.65 | 0.006 | 1.17 | | | 0.72 | 1.90 | 0.531 |
| Yes, not in P6M | 1.72 | 1.20 | 2.48 | 0.004 | 1.29 | | | 0.88 | 1.90 | 0.193 |
| Attended Group Sex P6M |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.44 | 1.21 | 1.73 | <.0001 | 1.15 | | | 0.91 | 1.45 | 0.238 |
| AUDIT Zone |  |  |  |  |  | | |  |  |  |
| Low risk (scores 0 to 7) | Ref |  |  |  | Ref | | |  |  |  |
| Medium risk (scores 8 to 15) | 1.01 | 0.84 | 1.21 | 0.935 | 1.02 | | | 0.73 | 1.43 | 0.903 |
| Harmful (scores 16 to 19) | 1.21 | 0.89 | 1.65 | 0.234 | 0.93 | | | 0.56 | 1.56 | 0.788 |
| Possible dependence (scores 20 and over) | 1.57 | 1.09 | 2.28 | 0.017 | 0.88 | | | 0.46 | 1.67 | 0.684 |
| On ART Ever |  |  |  |  |  | | |  |  |  |
| No |  |  |  |  | Ref | | |  |  |  |
| Yes |  |  |  |  | 2.65 | | | 0.35 | 19.90 | 0.343 |
| Treatment Adherence P12M |  |  |  |  |  | | |  |  |  |
| 95% or greater |  |  |  |  | Ref | | |  |  |  |
| <95% |  |  |  |  | 1.15 | | | 0.90 | 1.48 | 0.266 |
| Never on ARV/Start within 12M |  |  |  |  | 1.38 | | | 0.92 | 2.07 | 0.116 |
| Viral Load <200 |  |  |  |  |  | | |  |  |  |
| No |  |  |  |  | Ref | | |  |  |  |
| Yes |  |  |  |  | 0.91 | | | 0.63 | 1.30 | 0.601 |
| Prevention Strategies | OR | 95% CI | | p | OR | | | 95% CI | | p |
| Always Using Condoms |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 0.38 | 0.32 | 0.45 | <.0001 | 0.42 | | | 0.31 | 0.58 | <.0001 |
| Sero-positioning |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.69 | 1.39 | 2.06 | <.0001 | 1.77 | | | 1.41 | 2.23 | <.0001 |
| No Anal Sex |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 0.76 | 0.65 | 0.90 | 0.001 | 0.77 | | | 0.63 | 0.95 | 0.013 |
| Sero-sorting |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.18 | 1.00 | 1.39 | 0.046 | 1.09 | | | 0.89 | 1.35 | 0.403 |
| Viral Load Sorting |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 2.77 | 2.18 | 3.53 | <.0001 | 1.89 | | | 1.50 | 2.38 | <.0001 |
| Withdrawal |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.08 | 0.90 | 1.30 | 0.410 | 1.44 | | | 1.14 | 1.81 | 0.002 |
| Asking Status |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.08 | 0.90 | 1.30 | 0.410 | 0.98 | | | 0.81 | 1.19 | 0.860 |
| Event-Level Variables | OR | 95% CI | | p | OR | | | 95% CI | | p |
| Alcohol |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 2.26 | 1.82 | 2.82 | <.0001 | 1.11 | | | 0.89 | 1.40 | 0.346 |
| Cannabis |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.75 | 1.47 | 2.07 | <.0001 | 1.02 | | | 0.76 | 1.37 | 0.879 |
| Erectile Drugs |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.67 | 1.25 | 2.23 | 0.001 | 1.03 | | | 0.83 | 1.29 | 0.765 |
| Poppers |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 2.44 | 1.70 | 3.52 | <.0001 | 1.29 | | | 1.00 | 1.66 | 0.049 |
| Ecstasy/MDMA |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 2.59 | 1.77 | 3.79 | <.0001 | 1.17 | | | 0.67 | 2.06 | 0.583 |
| GHB |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 2.26 | 1.82 | 2.82 | <.0001 | 0.98 | | | 0.71 | 1.33 | 0.879 |
| Crystal Methamphetamine |  |  |  |  |  | | |  |  |  |
| No | Ref |  |  |  | Ref | | |  |  |  |
| Yes | 1.75 | 1.47 | 2.07 | <.0001 | 1.06 | | | 0.80 | 1.40 | 0.696 |
| Continuous Variables | OR | 95% CI | | p | OR | | | 95% CI | | p |
| Male Sex Number P6M | 1.00 | 1.00 | 1.01 | 0.001 | 1.00 | | | 1.00 | 1.01 | 0.267 |
| Anal Sex Number P6M | 1.01 | 1.00 | 1.02 | 0.001 | 1.00 | | | 1.00 | 1.01 | 0.038 |
| Treatment Optimism-Skepticism Scale | 1.09 | 1.07 | 1.12 | <.0001 | 1.07 | | | 1.05 | 1.10 | <.0001 |
| Sexual Altruism Scale (Communal) | 0.56 | 0.49 | 0.64 | <.0001 | 0.76 | | | 0.66 | 0.87 | <.0001 |
| Sexual Altruism Scale (Personal) | 0.54 | 0.47 | 0.63 | <.0001 | 0.77 | | | 0.65 | 0.90 | 0.001 |
| Sexual Sensation Seeking Scale | 1.12 | 1.09 | 1.16 | <.0001 | 1.09 | | | 1.05 | 1.13 | <.0001 |

P6M=Past 6 Months; P12M= Past 12 months.

For trends among HIV-negative/unknown gbMSM, we found that higher risk anal sex events increased over time (first time period prevalence:13%, last time period prevalence: 29%) (OR=1.006; 95% CI=1.002, 1.011, *p*=0.009). We found event-level CAS increased over the study period (OR=1.015; 95% CI=1.011, 1.019, *p*<0.001), anal sex with HIV-negative partners increased over the study period (OR=1.013; 95% CI=1.009, 1.017, *p*<0.001), and anal sex with HIV-positive gbMSM increased over the study period (OR=1.012 95% CI=1.006, 1.017, *p*=0.000). In relation to event-level substance use among HIV-negative/unknown gbMSM over the study period, event-level alcohol use decreased (first time period prevalence: 46%, last time period prevalence: 27%) (OR=0.989; 95% CI=0.985, 0.993, *p*<0.001), and erectile drug use increased (first time period prevalence: 6%, last time period prevalence: 9%) (OR=1.010; 95%CI=1.001, 1.020, *p*=0.031). Full results can be found in Figure 1.

Chart, line chart

Description automatically generated

**Figure 1.** Percentage Trends of Sexual Events Reporting Substance Use and Higher Risk Anal Sex among HIV-negative/unknown gbMSM in Metro Vancouver.

For trends among HIV-positive gbMSM, our model found higher risk anal sex increased over time (first time period prevalence:16%, last time period prevalence: 38%) (OR=1.006; 95% CI=1.001, 1.012, *p*=0.025). In relation to event-level substance use, we found that popper use decreased over time (first time period prevalence: 38%, last time period prevalence: 31%) (OR=0.991; 95% CI=0.984, 0.998, *p*=0.007). Full results can be found in Figure 2.

Chart, line chart

Description automatically generated

**Figure 2.** Percentage Trends of Sexual Events Reporting Substance Use and Higher Risk Anal Sex among HIV-positive gbMSM in Metro Vancouver.

We did not find any significant interactions between time and substance use on the likelihood of event-level higher risk anal sex. However, we did find a number of time-specific significant interactions. Full results can be found in Table 3.

**Table 3.** Univariable Temporal Trends and Interactions of Substance use and Higher Risk Anal Sex Prevalence Among gbMSM in Metro Vancouver, 2012-2017.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **TREND** | **HIV-Negative/Unknown** | | | | | | | | **HIV-Positive** | | | | | |
|  | **OR** | **95% CI** | | | | **p** | | | **OR** | | **95% CI** | | p | |
| Higher Risk Anal Sex | 1.006 | 1.002 | | | 1.011 | 0.009 | | | 1.006 | | 1.001 | 1.012 | 0.025 | |
| Condomless Anal Sex | 1.015 | 1.011 | | | 1.019 | <.0001 | | | 1.002 | | 0.997 | 1.007 | 0.389 | |
| Knew Neg vs. Unknown | 1.013 | 1.009 | | | 1.017 | <.0001 | | | 1.005 | | 0.999 | 1.012 | 0.104 | |
| Knew Pos vs. Unknown | 1.012 | 1.006 | | | 1.018 | 0.000 | | | 0.998 | | 0.992 | 1.004 | 0.495 | |
| Alcohol | 0.989 | 0.985 | | | 0.993 | <.0001 | | | 0.996 | | 0.990 | 1.002 | 0.207 | |
| Cannabis | 1.004 | 0.999 | | | 1.010 | 0.146 | | | 0.995 | | 0.989 | 1.001 | 0.095 | |
| Erectile Drugs | 1.010 | 1.001 | | | 1.020 | 0.031 | | | 0.999 | | 0.992 | 1.007 | 0.866 | |
| Poppers | 0.998 | 0.990 | | | 1.005 | 0.561 | | | 0.991 | | 0.984 | 0.998 | 0.007 | |
| Ecstasy/MDMA | 1.012 | 1.000 | | | 1.024 | 0.053 | | | 0.997 | | 0.976 | 1.018 | 0.760 | |
| GHB | 1.000 | 0.986 | | | 1.015 | 0.952 | | | 1.001 | | 0.990 | 1.012 | 0.869 | |
| Crystal Methamphetamine | 0.997 | 0.984 | | | 1.011 | 0.705 | | | 0.998 | | 0.991 | 1.006 | 0.649 | |
| **INTERACTION** |  | |  | | | |  |  | |  | | | |  |
|  | **OR** | | **95% CI** | | | | **p** | **OR** | | **95% CI** | | | | **p** |
| Alcohol X Trend | 1.002 | | 0.994 | 1.010 | | | 0.580 | 0.994 | | 0.985 | | 1.004 | | 0.248 |
| 01/2012: User vs Not | 1.051 | | 0.778 | 1.419 | | | 0.746 | 1.372 | | 0.942 | | 1.997 | | 0.099 |
| 12/2017: User vs Not | 1.228 | | 0.891 | 1.694 | | | 0.210 | 0.918 | | 0.591 | | 1.424 | | 0.701 |
| Cannabis X Trend | 1.004 | | 0.995 | 1.013 | | | 0.410 | 1.004 | | 0.995 | | 1.014 | | 0.358 |
| 01/2012: User vs Not | 0.958 | | 0.664 | 1.381 | | | 0.817 | 0.868 | | 0.560 | | 1.345 | | 0.527 |
| 12/2017: User vs Not | 1.267 | | 0.855 | 1.878 | | | 0.239 | 1.188 | | 0.761 | | 1.856 | | 0.448 |
| Erectile Drugs X Trend | 1.007 | | 0.994 | 1.020 | | | 0.319 | 0.997 | | 0.987 | | 1.008 | | 0.617 |
| 01/2012: User vs Not | 1.797 | | 1.100 | 2.936 | | | 0.019 | 1.145 | | 0.715 | | 1.833 | | 0.574 |
| 12/2017: User vs Not | 2.890 | | 1.679 | 4.975 | | | 0.000 | 0.942 | | 0.626 | | 1.419 | | 0.776 |
| Poppers X Trend | 1.000 | | 0.991 | 1.010 | | | 0.971 | 1.001 | | 0.989 | | 1.012 | | 0.905 |
| 01/2012: User vs Not | 1.737 | | 1.254 | 2.404 | | | 0.001 | 1.258 | | 0.797 | | 1.987 | | 0.325 |
| 12/2017: User vs Not | 1.759 | | 1.137 | 2.720 | | | 0.011 | 1.322 | | 0.803 | | 2.178 | | 0.273 |
| Ecstasy/MDMA X Trend | 1.012 | | 0.993 | 1.031 | | | 0.226 | 0.981 | | 0.962 | | 1.000 | | 0.054 |
| 01/2012: User vs Not | 1.109 | | 0.560 | 2.198 | | | 0.767 | 2.229 | | 0.941 | | 5.280 | | 0.069 |
| 12/2017: User vs Not | 2.543 | | 1.171 | 5.523 | | | 0.018 | 0.568 | | 0.250 | | 1.287 | | 0.175 |
| GHB X Trend | 0.989 | | 0.966 | 1.013 | | | 0.360 | 0.992 | | 0.977 | | 1.007 | | 0.293 |
| 01/2012: User vs Not | 3.506 | | 1.680 | 7.317 | | | 0.001 | 1.315 | | 0.639 | | 2.705 | | 0.457 |
| 12/2017: User vs Not | 1.610 | | 0.544 | 4.770 | | | 0.390 | 0.735 | | 0.440 | | 1.227 | | 0.240 |
| Crystal Methamphetamine X Trend | 0.978 | | 0.957 | 1.000 | | | 0.054 | 0.994 | | 0.982 | | 1.006 | | 0.312 |
| 01/2012: User vs Not | 5.048 | | 2.376 | 10.726 | | | <.0001 | 1.324 | | 0.903 | | 1.941 | | 0.150 |
| 12/2017: User vs Not | 1.065 | | 0.391 | 2.900 | | | 0.901 | 0.845 | | 0.449 | | 1.592 | | 0.602 |

We conducted a post hoc lost to follow-up analysis and found that participants LTFU reported less higher risk anal sex among HIV-negative/unknown gbMSM and more ecstasy/MDMA use among HIV-positive gbMSM.

4. Discussion

Our research explored temporal trends and associations between substance use and higher risk sex during anal sex events among gbMSM in Vancouver, BC. We found that event-level sexual risk increased over time for both HIV-negative/unknown gbMSM and HIV-positive gbMSM over nearly six years of follow-up. However, HIV-negative/unknown gbMSM reported more frequent CAS with sero-different or unknown status partners compared to HIV-positive gbMSM. Although we did not find longitudinally significant interactions between substance use and time on higher risk anal sex, we found a number of time-specific associations that warrant further exploration.

We found event-level higher risk anal sex increased over time for both HIV-negative/unknown gbMSM and HIV-positive gbMSM. Among HIV-negative/unknown gbMSM, we also found increasing trends of overall CAS. Trends of gbMSM gaining regular partnerships and fewer sex partners may better explain this finding [26]. As gbMSM are more likely to have a regular partner, they may also be less likely to wear condoms with their regular partner over time [27]. Additionally, we found increasing trends of CAS with known HIV-negative versus unknown partners, and CAS with known HIV-positive versus unknown partners. We hypothesize that based on increasing trends of HIV testing across Canada [28], gbMSM are also reporting fewer unknown HIV status partners over time.

Exploring substance use trends among HIV-negative/unknown gbMSM, we found alcohol use decreased and erectile drugs increased over time. The cohort ageing effect may explain decreases in alcohol as findings indicate alcohol consumption and use of illicit substances tend to decrease across the lifespan [29]. In relation to erectile drug use, evidence suggests erectile drugs are commonly used by gbMSM who are more sexually active and who use erectile drugs specifically to enhance sexual performance and duration [30]. The longitudinal nature and aging cohort effect may further explain increases in erectile drug use over time. However, we did not find these trends among HIV-positive gbMSM. Instead, we found poppers use decreased over time among HIV-positive gbMSM. This finding is significant because in 2013, Canada banned the sale of poppers, which may have precipitated this decline. Although the sale of poppers has been banned, critics argue that this ban is not supported by science and that this has led to an unregulated market, increasing risk of dangerous off-market products, and forcing access to poppers in potentially dangerous ways [31]. A recent analysis on popper use among young gbMSM found high lifetime and recent popper use, yet dependency symptoms and risky consumption or problems arising from using poppers were low [32]. Overall, differences in substance use trends among gbMSM by serostatus have been identified elsewhere, yet further research is needed to delineate unique event-level substance use factors by serostatus [33].

We identified noteworthy findings from our univariable analyses. First, our findings for PrEP usage should be interpreted with caution given the limited number of gbMSM reporting ever using PrEP, which was less than 2% of participants reporting using PrEP at any point in our study. Recently in British Columbia, PrEP became publicly funded and freely available in January 2018 [34]. Thus, our analysis provides a basis for further exploration of PrEP use, substance use and sexual risk as PrEP use increases. It is important to note that biomedical interventions, such as PrEP, are changing gbMSM’s notions of “safe” and “risky” sex, as CAS with a serodiscordant or unknown partner may not place increased HIV risk to individuals on PrEP. However, also important to consider is that biomedical interventions only protect against HIV, and STI risk may still be associated with CAS. Thus, condoms still provide relevant protection and should be paired with health promotion and programming that embraces a broader STBBI framework. Second, we did not find a significant difference between viral load status and higher risk anal sex, which is inconsistent with previous findings [35]. We hypothesize that these differences may be explained by the low proportion of gbMSM with a detectable viral load in our study. At Baseline only 16% of HIV-positive gbMSM reported a viral load ≥200 and this rate is expected to have gone down as TasP scale up increased. Third, our results found greater endorsement of HIV treatment optimism was associated with higher odds of sexual risk. Previous research exploring HIV treatment optimism among gbMSM found increasing trends of HIV-optimism over time, but no longitudinal differences in higher risk anal sex for both HIV-negative and HIV-positive men [36]. Differences may be explained by our focus on event-level sexual risk and variations in sexual behaviours with specific partners versus overall sexual risk behaviours.

We did not find statistically significant interactions between time and substance use on higher risk anal sex. However, we found that erectile drug use and poppers use were consistently associated with higher risk anal sex throughout the study period for HIV-negative/unknown gbMSM. These findings are consistent with previous literature which demonstrates individual associations between erectile drug use and poppers use on sexual risk [37, 38]. Interestingly, we found GHB, crystal methamphetamine, and ecstasy/MDMA use associated with sexual risk at one point in our study (baseline or end of study) but the associations were not maintained throughout the study period. We hypothesize that interactions between substance use and sexual risk over time were not significant because as rates of substances may have varied over time with different partners. As such, gbMSM who engage in multiple sex partners may have had significant sexual risk at one point in our study, but sexual partners and substances used may have changed over time. Alternatively, gbMSM may have had fewer sexual partners over time, whereby sexual risk and substance use decreased with time and partnership.

This research is subject to limitations. First, although our research used sexual event-level data, these are likely not representative of all sexual events between partners and is subject to recall bias. Still, our focus on event-level data is advantageous in comparison to cross-sectional data to causally examine the relationship between substance use and sexual risk. Second, our findings may not be comparable outside of Vancouver, British Columbia, especially given the TasP context and promotion in the city. Third, we did not distinguish between different partner types (e.g., casual or main partners) which may influence the use of substances, sexual behaviours, and the relationship between these. Fourth, we could not distinguish between medically prescribed erectile drugs and non-medically prescribed. However, prevalence of recreational erectile drug use among gbMSM is high and erectile drug use (regardless of prescription) has been identified as an important indicator of sexual risk in existing literature [39, 40]. Fifth, many of our significant findings for substance use and higher risk anal sex diminished over time. We theorized this may be due to LTFU of high risk/high substance using participants and completed post-hoc analyses to assess this. We found two significant differences for participants LTFU and these findings may limit the scope of interpretation for these results.

5. Conclusions

Our findings indicate that sexual risk is associated with event-level substance use, behavioural and psychosocial factors. These findings provide a more comprehensive understanding on the effects of event-level substance use on sexual risk among Canadian gbMSM though longitudinal follow-up. Moreover, future interventions must address increasing rates of sexual risk through continued education on STIs, increased access to safer sex materials, and continued preventative screening. Understanding the nuances of individual substances as well as polysubstance use will be beneficial in developing targeted interventions for substance-using gbMSM in managing sexual risk. By focusing on separate sexualized events with different partners and substances used, sexual risk programs can target strategies for reducing risk in certain scenarios and how individuals can apply this knowledge to future sexual events.

**Author Contributions:** RSH, NJL and DMM are co-principal investigators for this study and take responsibility for the integrity and accuracy of the data and have the final decision in the submission of the manuscript. EAR is a co-investigator for this study and developed the event-level questionnaire matrix. NJL and JMS conceptualised the idea for the analysis, PS prepared the data set and ZC ran the analysis. JMS interpreted the results from the analysis and wrote the initial drat and tables. HLA, AL, GO, helped collect data and provided key feedback on the manuscript along with KGC and all co-authors.

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**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of The University of British Columbia, Simon Fraser University and University of Victoria (H11-00691, Approved April 15, 2019).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

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