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A Latent Class Analysis of Seroadaptation among Gay and Bisexual Men

Kiffer G. Card[1,2], **Nathan J Lachowsky**[1,3], **Zishan Cui**[1], **Allison Carter**[1,2], **Heather Armstrong**[1], **Susan Shurgold**[1], **David Moore**[1,3], **Robert S. Hogg**[1,2], and **Eric A. Roth**[5,6]

[1]BC Centre for Excellence in HIV/AIDS, Vancouver, British Columbia, V6Z 1Y6, Canada

[2]Faculty of Health Science, Simon Fraser University, Vancouver, British Columbia, Canada

[3]Faculty of Medicine, University of British Columbia, Vancouver, British Columbia, Canada

[5]Department of Anthropology, University of Victoria, Victoria, British Columbia, Canada

[6]Centre for Addiction Research of British Columbia, University of Victoria, Victoria, British Columbia, Canada

Abstract

Initial research into seroadaptive strategies suggests that, individually, they are potentially effective behavioral methods to reduce risk of HIV transmission. Combining strategies, therefore, has the potential to increase risk reduction. The aim of this study was to determine how gay and bisexual men (GBM) combine strategies. To this end, a total of 774 sexually active GBM, aged ≥16 years, in Metro Vancouver, Canada were recruited. Stratified by self-reported HIV status, latent class analysis of self-reported condom use, strategic positioning, anal sex avoidance, serosorting, viral-load sorting, and withdrawal were conducted. Multinomial logistical regression identified explanatory variables of class membership (i.e., sensation seeking, treatment optimism, sexual altruism, relationship status, number of partners, anal sex preference). Four latent classes were identified: Condom Users, Multiple Prevention Users, Viral-Load Sorters, and Serosorters. The majority of HIV-negative/unknown men (72%) and a large proportion of HIV-positive men (42%) belonged to the Condom Users class. Class membership was associated with age, relationship status, treatment optimism, sexual altruism, sensation seeking, number of recent male anal sex

Compliance with Ethical Standards

Ethical Approval:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committees at Simon Fraser University, The University of British Columbia, and the University of Victoria and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study.

This article does not contain any studies with animals performed by any of the authors.

Conflict of Interest:

Kiffer G. Card declares that he has no conflict of interest.

Nathan J. Lachowsky declares that he has no conflict of interest.

Zishan Cui declares that she has no conflict of interest.

Allison Carter declares that she has no conflict of interest.

Susan Shurgold declares that she has no conflict of interest.

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partners, and recent condomless anal sex with a serodiscordant or unknown-status partner. Understanding these distinct patterns allows for tailored interventions addressing GBM's sexual health needs.

Keywords

Seroadaptation; Latent Class Analysis; Gay and Bisexual Men; HIV

INTRODUCTION

Since the beginning of the HIV epidemic, North American gay, bisexual, and other men who have sex with men have been at a disproportionately higher risk for HIV infection compared to other North American men and women. Providing a partial explanation for this epidemic, a 2010 meta-analysis comparing condomless anal sex (CAS) to vaginal sex estimated that the per-contact probability of HIV-transmission was approximately 18 times greater during CAS (Baggaley, White, & Boily, 2010). However, the authors of that analysis, along with other commentators (Grulich & Zablotska, 2010), have noted that the risk for HIV transmission during CAS may be greatly reduced by biomedical interventions (Cohen et al., 2011; Grant et al., 2010; Roland et al., 2005) and associated seroadaptive practices (Vallabhaneni et al., 2012).

Seroadaptive practices consist of a range of sexual behaviors which take into account the known, perceived, or assumed HIV status (Jin et al., 2012; McFarland et al., 2011, 2012; Snowden, Wei, McFarland, & Raymond, 2014) or viral-load status (Cassels & Katz, 2013; Davidovich, van den Boom, Witlox, & Stolte, 2011; Horvath, Smolenski, Iantaffi, Grey, & Rosser, 2012; Mitchell, 2013) of individuals and their partners. While seroadaptive behavior may include avoiding any sexual intercourse with HIV-positive partners, the present study focuses specifically on seroadaptive behaviors that respond to risk associated with anal sex between serodiscordant or unknown-status partners (i.e., condom use, strategic positioning, anal sex avoidance, serosorting, viral-load sorting, withdrawal). This focus acknowledges the reality that (a) anal sex is the primary route of HIV transmission among gay and bisexual men, and (b) men may not necessarily know their or their partner's HIV or viral-load status. Regardless of the specific practices used, the overall aim of these strategies is to reduce the risk of HIV transmission in serodiscordant partnerships (Rönn, White, Hughes, & Ward, 2014) or during casual sexual encounters (Berry, Raymond, Kellogg, & McFarland, 2008).

Recent research assessing the prevalence of seroadaptive behavior found that while these strategies are likely the result of intentional risk management, fewer than one in three gay and bisexual men adhered consistently to any intended strategy, and no strategy was used by more than half of sampled participants (Cassels & Katz, 2013; McFarland et al., 2012). Meanwhile, other studies have found that gay and bisexual men, in fact, use a range of seroadaptive strategies—employing different strategies to meet different contextual needs (Noor, Coleman, Brennan, Gardner, & Hart, 2015; Otis et al., 2016). The diversity of available strategies and the complex rationale underpinning their use may thus explain why

individuals report low adherence to any one specific strategy and why some strategies appear to be used by only a small proportion of the population.

Hoping to articulate the complex motivators for seroadaptation, several researchers (Noor et al., 2015; Otis et al., 2016) have used a person-centered analytic approach known as latent class analysis (LCA; Lanza, Collins, Lemmon, & Schafer, 2007). This method uses a three-step approach to identify unmeasured characteristics, referred to as "latent classes." In the context of seroadaptation, these latent classes may represent distinct risk contexts or perceptions that shape the sexual behavior of individuals belonging to these classes. By identifying these unmeasured classes and modeling the correlates associated therewith, public health and community leaders can tailor HIV prevention efforts for individuals whose risk management behavior (or lack thereof) might predispose them to increased risk for HIV.

While the etiology of seroadaptive behaviors remains unclear, existing literature highlights several important constructs that influence the sexual decisions of gay and bisexual men (Neville & Adams, 2009). Among these, sensation seeking (S. C. Kalichman & Rompa, 1995), treatment optimism (Van de Ven, Crawford, Kippax, Knox, & Prestage, 2000), and sexual altruism (O'Dell, Rosser, Miner, & Jacoby, 2008) have been shown to be predictive of condomless anal sex, with the last of these having a protective effect. Sensation seeking, for example, is conceptualized as a stable personality trait that corresponds with an attraction towards novel and thrilling sexual practices. Treatment optimism is a construct that measures the degree to which advances in biomedical HIV treatment and prevention has reduced the perceived risk of condomless sex (Van de Ven et al., 2000). Sexual altruism, coined by Nimmons (1998), measures the degree to which an individual's values and risk-management behavior are motivated by altruistic (i.e., other-centered) concern for others (Nimmons & Folkman, 1999; O'Dell et al., 2008). In addition to these psycho-social motivators, other more tangible measures such as relationship status (Lachowsky, Dewey, et al., 2015), partner concurrency (Lachowsky, Saxton, et al., 2015), and anal sex positioning preference (Zhang et al., 2015) have also been shown to influence sexual behavior and risk management among gay men (Brady, Iantaffi, Galos, & Rosser, 2013). As the correlation between these etiologies and condom use has been well-established and finding little rationale to conceptualize seroadaptive behavior as wholly distinct from other risk management approaches, it is possible that these constructs likewise predict seroadaptive behavior.

Consistent with the observations, the present study aims to (1) use LCA to examine the patterns of how GBM in Vancouver, Canada use seroadaptive behaviors, and (2) use multinomial regression to determine whether factors predicting condom use (i.e., treatment optimism, sexual altruism, sexual sensation seeking, number of partners, relationship status, anal sex preference) are similarly associated with patterns of seroadaptive behavior. We hypothesize that LCA will identify distinct groups of GBM characterized by differing patterns of seroadaptive behavior and motivated by similar cognitive and contextual factors previously correlated with condom use.

METHODS

Study Setting

Eligible participants were (1) gay, bisexual, and other men who have sex with men, (2) aged 16 years and older, (3) residing in the Metro Vancouver area, (4) who reported sex with another man in the past six months, (5) were able to complete a questionnaire in English, and (6) were recruited through the use of respondent-driven sampling (RDS; Heckathorn, Semaan, Broadhead, & Hughes, 2002). Initial RDS seeds were recruited through community-based AIDS service organizations and later through a popular sex-seeking smartphone application. After confirming eligibility and securing written informed consent to participate, seeds were given up to six vouchers to use to recruit other eligible men into the study. Individuals presenting study vouchers at the downtown study office were screened for eligibility, provided written informed consent, completed the study protocol, and then were given vouchers of their own to recruit participants from within their social and/or sexual networks. Participants received $50 CAD honoraria for the study visits and could earn an additional $10 CAD honorarium for each recruit who successfully enrolled in the study. Honoraria could be taken as cash or used to purchase $10 draw tickets for either a monthly drawing for a $250.00 CAD gift card or a semi-annual drawing for a $2000.00 CAD travel voucher. Ethics approval for this study was received from research ethics boards at Simon Fraser University, the University of British Columbia, and the University of Victoria.

Study Design

Recruitment and baseline cross-sectional data collection began in February 2012 and closed in February 2014. Participants completed a 60- to 90-minute computer-administered questionnaire which collected data on a variety of sociodemographic, behavioral, and psychosocial measures. A study nurse administered a short clinical questionnaire and tested for HIV, hepatitis C, and syphilis; tests for chlamydia and gonorrhea were also available upon request.

Seroadaptation Measures

Participants were asked whether they used any of six seroadaptive strategies (i.e., consistent condom use, strategic positioning, anal sex avoidance, serosorting, viral-load sorting, and withdrawal) to prevent HIV transmission. It should be noted that the seroadaptive strategies used in the present analysis represent behaviors specifically relating to anal sex and condomless anal sex, while other research has sometimes included oral sex strategies and so called “pure” serosorting strategies, where partners with discordant serostatus are avoided for all types of sexual behavior and not just condomless anal sex (Cassels & Katz, 2013). In the Momentum questionnaire, these questions were introduced by saying: “Some guys use strategies to prevent getting/transmitting HIV. Do you do any of the following to prevent getting/transmitting HIV? (check ALL that apply)” with wording differences due to HIV status as reported by participants. The response text describing each seroadaptive strategy is provided in Table 1. While two items were asked similarly for HIV-negative/unknown and HIV-positive men, four items were asked in a manner specific to HIV status. Considering (a) the serostatus specific motivations underlying sexual behavior (Seth C. Kalichman, Cain, &

Simbayi, 2010; Rönn et al., 2014) and (b) the rejection of the assumption of measurement invariance restriction in our LCA model-building procedure, all analyses were stratified by self-reported HIV status (negative/unknown vs. positive).

Explanatory Measures

The present analysis included six demographic factors: age (continuous in years), sexual orientation (gay identified versus non-gay identified), education (≤ high school diploma, some college, > college degree), race/ethnicity (white versus non-white), annual income (< $30,000, $30,000–59,999, ≥ $60,000 CAD), and relationship status (monogamous, open, single).

To assess the relationship between sexual behavior and seroadaptation, participants were asked to report their anal sex preference (versatile, bottom, top, no anal sex), number of anal sex partners in the past six months (continuous), and whether they engaged in any CAS during the past six months (no, concordant CAS, serodiscordant/unknown CAS [sdCAS]). Based on previous work investigating socio-cognitive motivators underpinning HIV prevention related behavior (Adam, Husbands, Murray, & Maxwell, 2005; O'Dell et al., 2008; Roberti, 2004; Rowniak, 2009), three scales were used to assess sexual sensation seeking, treatment optimism, and HIV-prevention altruism. Additional information regarding these three scales is provided below:

- *Sexual Sensation Seeking (11 items)*. Participants rated their level of agreement with questions designed to assess sensation seeking personality traits (e.g., "I am interested in trying out new sexual experiences.") using a 4-point Likert scale from "Not at all like me" to "Very much like me" (S. C. Kalichman & Rompa, 1995). Final scores were calculated from the zero-shifted sum of all items and range from 11–44, with higher scores indicating higher sexual sensation seeking (study α=0.73).
- *Treatment Optimism-Skepticism (12 items)*. Participants rated their level of agreement with items that assessed their attitudes towards HIV treatment and sexual risk (e.g., "If every HIV-positive person took the new treatments, the AIDS epidemic would be over.") using a 4-point Likert scale from "Strongly Agree" to "Strongly Disagree" (Van de Ven et al., 2000). Final scores were calculated from the zero-shifted sum of all items and range from 0 "highly skeptical" to 23 "highly optimistic" (study α=0.82).
- *Personal and Communal Sexual Altruism (13 items)*. Participants rated their level of agreement with 7 items assessing their personal-/partner-related motivations (e.g., "Having safer sex shows I care about my partner", α=.81) and 6 items assessing community-related motivations (e.g. "I have safer sex because I want the gay community to survive") for safer sex using a 5-point Likert scale from "Strongly Agree" to "Strongly Disagree" (O'Dell et al., 2008). Final scores were calculated by calculating the zero-shifted sum of all items divided by the number of items in the scale. Possible scores ranged from 0–4, with higher scores indicating greater altruism. (study α=.88)

Statistical Analysis

All statistical analyses were conducted using *SAS* 9.4. To understand better the seroadaptive patterns of gay and bisexual men, latent class analysis (LCA; Lanza et al., 2007; Muthén & Muthén, 2000) was used to group participants based on self-reported seroadaptive behaviors. This method for identifying unmeasured class characteristics among study populations has recently been used to model partner frequency and concurrency (Ashenhurst, Wilhite, Harden, & Fromme, 2016), patterns of masculinity in heterosexual men (Casey et al., 2015), HIV-related stigma (Brinkley-Rubinstein & Craven, 2014), substance use (McCarty-Caplan, Jantz, & Swartz, 2014), and risk reduction (Noor et al., 2015) among gay and bisexual men. As applied in the present study, LCA allows us to consider the distinct behavioral repertoires gay and bisexual men use to manage their HIV risk.

LCA was conducted using the PROC LCA sub-routine. For each model, LCA creates a posterior class membership probabilities based on the model's indicator variables. The number of classes included in this new categorical variable is determined by comparing goodness-of-fit statistics for each potential model and with consideration to interpretability and conceptual significance (Dias, 2006). For each fit statistic, a lower value indicates better model fit. In the present analysis, LCA models were conducted grouping by self-reported HIV status: HIV-positive and HIV-negative/unknown men. The assumption of measurement invariance restriction was rejected (p-value < 0.001), resulting in an unrestricted LCA solution, allowing indicators to load differently across HIV-negative/unknown and HIV-positive groups. Four models ranging from two to five classes were compared.

A four-class solution was selected for several reasons. First, a 42% drop of G-squared fit statistics was observed from a three-class model to a four-class model. Second, Akaike information criterion (AIC), adjusted Bayesian information criterion (aBIC), and the likelihood ratio tests (LRT) all showed that the four-class model was the best fit (see Table 2). Third, the four-class model was considered theoretically and conceptually appropriate as it clearly distinguished between each class. To assure the HIV-negative/unknown and HIV-positive men structured similarly, further stratified LCA models were generated, where the fit statistics led to four-class models for both groups.

Using the final four-class solution, each participant was assigned to the latent classes by the membership probabilities, and bivariable and multivariable multinomial logistic regression was then conducted using the PROC LOGISTIC command with AIC minimization and Type III p-values to build three multivariable models for each HIV status to identify important explanatory variables for each class membership using the largest class as the referent. In these procedures, the explanatory measures included in the section above were treated as the independent variables, and LCA class membership was treated as a multi-level dependent variable.

RESULTS

Descriptive Statistics

Of the 774 men enrolled in our study, four did not answer the questions regarding the six seroadaptive behaviors that comprised our outcome variable and were therefore excluded

from this analysis. Overall, the sample's median age was 34 years (Q1–Q3: 26–47), and the majority of men self-identified as gay (79.9%), made less than $30,000 CAD per year (72.9%), had a high school diploma or equivalent (71.0%), and were white (68.5%). Additional stratified sample characteristics are provided in Table 3 with *p*-values indicating significant differences between HIV-negative/unknown and HIV-positive men. Of note, HIV-positive men had higher treatment optimism and sensation seeking, and lower personal and community altruism. HIV-positive men also reported having had more recent male anal sex partners and were more likely to engage in sdCAS.

Regarding seroadaptation, Table 4 shows the proportion of HIV-positive and HIV-negative/unknown men reporting each seroadaptive behavior overall and by each latent class. A higher proportion of HIV-positive men than HIV-negative/unknown men reported inconsistent condom use ($p < 0.001$), no anal sex avoidance (p = 0.001) strategic positioning ($p = 0.012$), serosorting ($p < 0.001$), and viral-load sorting ($p < 0.001$). There were no statistically significant differences in the proportion who reported withdrawal ($p = 0.276$)

Latent Class Analysis

A four-class LCA model (Figure 1) was selected as described. Upon considering the frequencies of seroadaptive behavior reported by each class, our study team named each of the four LCA classes as follows: (a) Condom Users, (b) Multiple Prevention Users, (c) Viral-load Sorters, and (d) Serosorters. More information about each class is provided below:

Class 1: Condom Users—The first, and most common latent class, represented 81% of HIV-negative/unknown men, but only 42% of HIV-positive men. Among men in this class, 63% of HIV-positive men and 81% of HIV-negative/unknown men reported "always using condoms." The next most prevalent seroadaptive behavior among men in this class was anal sex avoidance, which was used by 41% of HIV-negative/unknown men and 47% of HIV-positive men. Aside from these, no other seroadaptive strategy was reported by more than one-third of the men in this class. Despite high rates of reported consistent condom use, 23% (n = 88/385) of HIV-negative/unknown men and 19% (n = 17/90) of HIV-positive men reported concordant CAS. Further, 26% (n = 98/385) of HIV-negative/unknown men and 33% (n = 29/90) of HIV-positive men in this class reported serodiscordant/unknown CAS.

Class 2: Multiple Prevention Users—The second latent class represented nearly 9% of HIV-negative/unknown and 9% of HIV-positive men. Individuals in this class are described as Multiple Prevention Users due to moderate to high reported rates of multiple prevention strategies including anal sex avoidance, serosorting, strategic positioning, viral-load sorting, withdrawal, and consistent condom use. In this class, a higher proportion of HIV-positive men reported withdrawal, serosorting, and viral-load sorting; while a higher proportion of HIV-negative men reported consistent condom use, strategic positioning, and anal sex avoidance.

Class 3: Viral-load Sorters—The third latent class represented only 8% of HIV-negative/unknown men and 14% of HIV-positive men. This class was characterized by low

levels of consistent condom use and high levels of viral-load sorting, which was more common among HIV-positive men than HIV-negative/unknown men ($p < 0.001$). A higher proportion of HIV-positive men also reported withdrawal and anal sex avoidance compared to HIV-negative/unknown men ($p < 0.001$); while a higher proportion of HIV-negative men reported serosorting in this class ($p < 0.001$).

Class 4: Serosorters—The fourth latent class represented 11% of HIV-negative/unknown men, but 35% of HIV-positive men. In both the HIV-positive and the HIV-negative/unknown LCA models, 100% men belonging to this class reported using serosorting. Consistent condom use was reported by only 12% of HIV-negative/unknown men and by 0% of HIV-positive men in this class. Among HIV-positive Serosorters, 46% reported viral-load sorting, while none of the HIV-negative Serosorters did so. Conversely, only 17% of HIV-positive Serosorters reported anal sex avoidance compared to 61% of HIV-negative Serosorters.

Multinomial Logistic Regression

Table 5 provides the multivariable multinomial logistic regression models identifying the correlates of class membership, with Condom Users as the referent group. Among HIV-negative/unknown men, class membership was associated with age, relationship status, treatment optimism, personal altruism, sensation seeking, number of recent male anal sex partners, and recent sdCAS. Similarly, among HIV-positive men, class membership was associated with relationship status, treatment optimism, community altruism, number of recent male anal sex partners, and recent sdCAS.

DISCUSSION

In the present study, we identified four classes of gay and bisexual men who employed distinct patterns of seroadaptive behavior: Condom Users, Multiple Prevention Users, Viral-load Sorters, and Serosorters. While fundamental differences in study design make it difficult to compare our findings to those of previous studies, Noor et al. (2015) and Otis et al. (2016) serve as valuable comparisons. For example, Noor et al. (2015) identified three latent classes based on five risk management strategies. Their LCA described three classes of men who (i) did not consistently use any risk management strategies (44%), (ii) were inconsistent in employing these strategies (33%), and (iii) consistently employed multiple strategies (23%). While not directly analogous to the LCA model presented in the present study, this work describes the frequency and consistency of gay and bisexual men's use of risk management behavior and alludes to the presence of underlying motivators for such behavior.

Offering a more direct comparison, Otis et al. (2016), presented a five class LCA model, in which all participants used a range of seroadaptive behaviors. While Otis et al. (2016) argues that 72% of the sample—those in the "strict-serosorting" and "condom using" classes—were sufficiently protected by their seroadaptive behaviors, three smaller classes (i.e., "anal sex serosorters," "strategic positioners," and "viral-load sorters") were exposed to unique risks attributable to their seroadaptive behavior. While recent evidence suggests that viral-load sorting may also offer sufficient protection against HIV—as so long as individuals can

accurately gauge their partner's HIV and viral load status (*See* Rodger et al., 2016), our findings support Otis's overall conclusion that seroadaptive strategies can serve to reduce the HIV risks associated with anal sex among gay and bisexual men. Similarly, our findings support McFarland's (2011) assertion that gay and bisexual men are able to achieve a high level of risk reduction by using a combination of seroadaptive behaviors. In their study, McFarland et al. (2011) estimated that less than 2% of sexual episodes actually exposed individuals to a high level of risk for HIV acquisition or transmission.

Consistent with these studies, the present analysis suggests that gay and bisexual men attempt to protect themselves through diverse combinations of seroadaptive behaviors, including condom use. Indeed, while 42% of men in the present study and 18% of men in Otis et al. (2016) were classified as "Condom Users," our results indicate that seroadaptation is an important component of risk management for the majority of gay and bisexual men. Even among those who were identified as consistent Condom Users a sizeable proportion of men practiced other seroadaptive strategies to reduce their risk. Further, the reported prevalence of CAS (n = 232) among Condom Users was higher than the total number of men in this class who reported not engaging in consistent condom use (n = 109). This indicates that while individuals may report "always using condoms," some may not actually use condoms consistently. This agrees with previous research by McFarland et al. (2012) suggesting that intentions to engage in risk management have low consistent adherence. In their study, 71% of HIV-negative men and 42% of HIV-positive men reported the intention to always use condoms, and yet, only 30% of HIV-negative men and 20% of HIV-positive men who intended to adhere to this strategy actually reported doing so after 1 year of follow-up.

When taken together, the results presented here, suggest that seroadaptation is used for context-specific risk reduction and is highly dependent on the needs of individuals and their partners (Rönn et al., 2014). Indeed, Otis et al. (2016) found that class membership was associated with a variety of factors, including relationship status and the serostatus of partners. In our study, this is made clear when looking at our second latent class (Multiple Prevention Users). These men practiced a wide range of seroadaptive behaviors and this class is somewhat analogous to the "inconsistent" LCA class presented in Noor et al. (2015). For instance, 100% of HIV-negative/unknown Multiple Prevention Users reported avoidance of anal sex and 91.2% reported strategic positioning. As these two strategies are incompatible we argue that these individuals are sometimes using strategic positioning, and sometimes avoiding anal sex — employing each strategy when they feel it is most appropriate or when contextual and/or interpersonal factors may otherwise necessitate one strategy over another.

Indeed, our multivariable results indicate that context-dependent and interpersonal factors have direct influence on seroadaptive behavior and are correlated with membership in a given class. For example, compared to Condom Users, HIV-negative/unknown Multiple Prevention Users and HIV-positive Viral-load Sorters were much more likely to be in a monogamous relationship compared to being single. This indicates that HIV-positive men in monogamous relationships may be more likely to rely on viral-load sorting with their committed partners to reduce the risk of HIV-transmission (Rönn et al., 2014). For HIV-

negative men, this may indicate a more diverse repertoire of seroadaptive behaviors among men who are single and who may have a greater number of sexual partners. These finding are consistent with previous research finding that relationship status, partner concurrency, and personal sexual preferences are all important predictors of sexual behavior (Lachowsky, Saxton, et al., 2015; Zhang et al., 2015). For Instance, Zhang et al. (2015) found that men who prefer to be the receptive partner during anal sex were less likely to engage in CAS; and Lachowsky, Dewey, et al., (2015) found that more frequent condom use was associated with men with more sexual partners and shorter relationships. With respect to seroadaptive behavior, these findings are further supported by McFarland et al., (2011), who identified different patterns of seroadaptation with main partners and non-main partners, and by our own recent work indicating that men with more partners use seroadaptive strategies as a way to offset the risks associated with CAS (Card et al., 2016). We also note that both HIV-positive and HIV-negative/unknown Viral-load Sorters were also more likely to have more sexual partners. Together, these findings suggest that interpersonal dynamics (as measured by relationship status and number of partners) have significant influence on the types of risk management strategies used by individuals to protect themselves and their partners (Brady et al., 2013; Braine, van Sluytman, Acker, Friedman, & Des Jarlais, 2011; Leung, Poon, & Lee, 2014; Ryzin, Johnson, Leve, & Kim, 2010). This framework captures a growing body of literature that suggests seroadaptive practices are the result of myriad complex personal, interpersonal, and situational factors (Cassels & Katz, 2013; McFarland et al., 2012; Rönn et al., 2014).

Several approaches have been used to describe the influence of complex situational, psychosocial, and intrapersonal factors on condom use (McKechnie, Bavinton, & Zablotska, 2013) and when expanded to other seroadaptive behaviors (Rönn et al., 2014), these models may help explain how attitudes, intentions, and beliefs influence gay and bisexual men's seroadaptive strategies to prevent HIV transmission (Albarracín, Johnson, Fishbein, & Muellerleile, 2001). For instance, we observed that when compared to Condom Users, treatment optimism was higher among HIV-negative/unknown Multiple Prevention Users, Viral-load Sorters, and Serosorters, as well as HIV-positive Viral-load Sorters. This finding suggests that reduced HIV risk perceptions and optimistic attitudes towards HIV treatment may influence an individual's willingness to engage in inconsistent condom use and uptake other seroadaptive strategies instead (Brennan et al., 2010; Stephenson, White, & Mitchell, 2015). This is particularly clear when noting that the strongest effect for treatment optimism was seen among Viral-Load Sorters—a behavioral strategy directly linked with awareness of HIV-prevention and risk awareness (Rodger et al., 2016). Another clear example of the influence that psychosocial and cognitive factors have on sexual behavior was the observation that higher sexual altruism was associated with being a Condom User, at least when compared to HIV-negative/unknown Viral-load Sorters and HIV-positive Serosorters. In this case, it seems to indicate that altruistic traits move individuals towards "safer" seroadaptation strategies, such as condom use (O'Dell et al., 2008). Conversely, higher sensation seeking was associated with being a Multiple Prevention User for HIV-negative men. In this case, sensation seeking may be driving more frequent sexual partnering and abandonment of condoms (Roberti, 2004). In turn, and contrary to research suggesting that men with high sensation seeking do not care about HIV prevention (Crawford et al., 2003),

the increased risk profile of these individuals may be a core motivator for the robust repertoire of prevention behavior exhibited in this class. This would be consistent with earlier qualitative work by Van de Ven et al. (2002) which found that among the minority of gay and bisexual men who engaged in condomless anal sex seroadaptation was employed as a risk reduction strategy.

Strengths and Limitations

Readers should be cautious when interpreting our results as the reported use of seroadaptive behaviors does not necessarily mean that individuals are successfully managing their risk for HIV transmission. Not only are some strategies not necessarily effective in stopping the risk of HIV transmission (e.g. withdrawal), but individuals may also be unable to properly adhere to these strategies due to contextual restraints (e.g., condom availability, power dynamics) or due to inaccurate perceptions of their or their partner's HIV-status. The problem of window-periods, combined with infrequent testing, may further make it difficult for individuals to successfully seroadapt. This is especially true in environments with high rates of HIV seroconversion. Additionally, due to the cross-sectional nature of this analysis and simplicity of our study measures, it is not clear whether behaviors within each class are used concurrently, how frequently behavioral strategies are used, or whether behaviors are adopted and relinquished over time. Further, as our sample (n = 774), was stratified both by HIV-status and then again by class membership, some classes and factors had small counts —increase the probability of Type I and Type II errors in this analyses. Our study may also be limited by the use of LCA, which may produce differing class structures in different populations. Further, as noted by Vermunt (2010), the use of a three-step LCA approach, as opposed to a single step approach, may underestimate the correlation between explanatory factors and class membership. Additionally, the seroadaptive anal sex strategies used to construct our LCA models do not fully characterize all potential seroadaptive approaches (e.g., PrEP, nPEP, "pure" serosorting, etc.) and differences in how seroadaptive behaviors are defined may result in significantly different LCA classes. For example, biomedical prevention strategies, especially HAART and PrEP, may have significant influence on the sexual decisions of gay and bisexual men (Chen, Snowden, McFarland, & Raymond, 2016). This is especially true given their potential to reduce or eliminate the risk of HIV infection (Grant et al., 2010; Rodger et al., 2016). Finally, we also note that some associations may be attributable to the nature of scale items rather than to a meaningful relationship between constructs. For example, the communal sexual altruism scale refers directly to "safe-sex," meaning it's possible that conflation between "safe-sex" and "condom use" (rather than other seroadaptive strategies) may explain the observed associations.

Future Research

Considering these limitations, future research efforts should identify the most acceptable and effective strategies, or combination of strategies, for preventing HIV transmission, especially in settings where HIV incidence remains high and where individuals feel that condoms detract from their sexual needs. Further, our findings necessitate the need for a better understanding of how these strategies are used by each class of GBM and whether seroadaptive class membership is stable over time. We hope that our results will be used in the development of longitudinal and event-level analyses, and in preparation for qualitative

work that will better inform us as to the nature of seroadaptive behavior and how to promote effective seroadaptation among gay and bisexual men.

CONCLUSION

In Conclusion, this research highlights a variety of factors that shape patterns of seroadaptation and suggests that gay and bisexual men intentionally use a variety of risk reduction strategies, especially in the absence of consistent condom use, to prevent HIV transmission. Further, these findings suggest that individual prevention strategies appear in concert with other strategies as part of empirically distinct patterns of behavior. For instance, Serosorters and Viral-load Sorters were unlikely to report engaging in consistent condom use, while Condom Users did not report engaging in viral-load sorting. These findings suggest that when seroadaptive strategies are considered as part of a holistic and combination approach to reducing HIV transmission, biomedical interventions and other prevention campaigns might be more effective than traditional single-strategy programs. Antecedent to this, our findings also highlight the need to educate men regarding the effectiveness of seroadaptive behaviors, especially when considering that some strategies (i.e., viral-load sorting) are likely to be very effective at preventing seroconversion (Cohen et al., 2011; Rodger et al., 2016), while other behaviors (i.e., withdrawal or strategic positioning) may still allow for viral transmission even when consistently used. Combination prevention campaigns which include seroadaptive behavior as a component of program messaging must also aim to promote regular and appropriate HIV testing, as the successful implementation of all seroadaptive behaviors relies on an individual's ability to accurately gauge their and their partner's HIV status.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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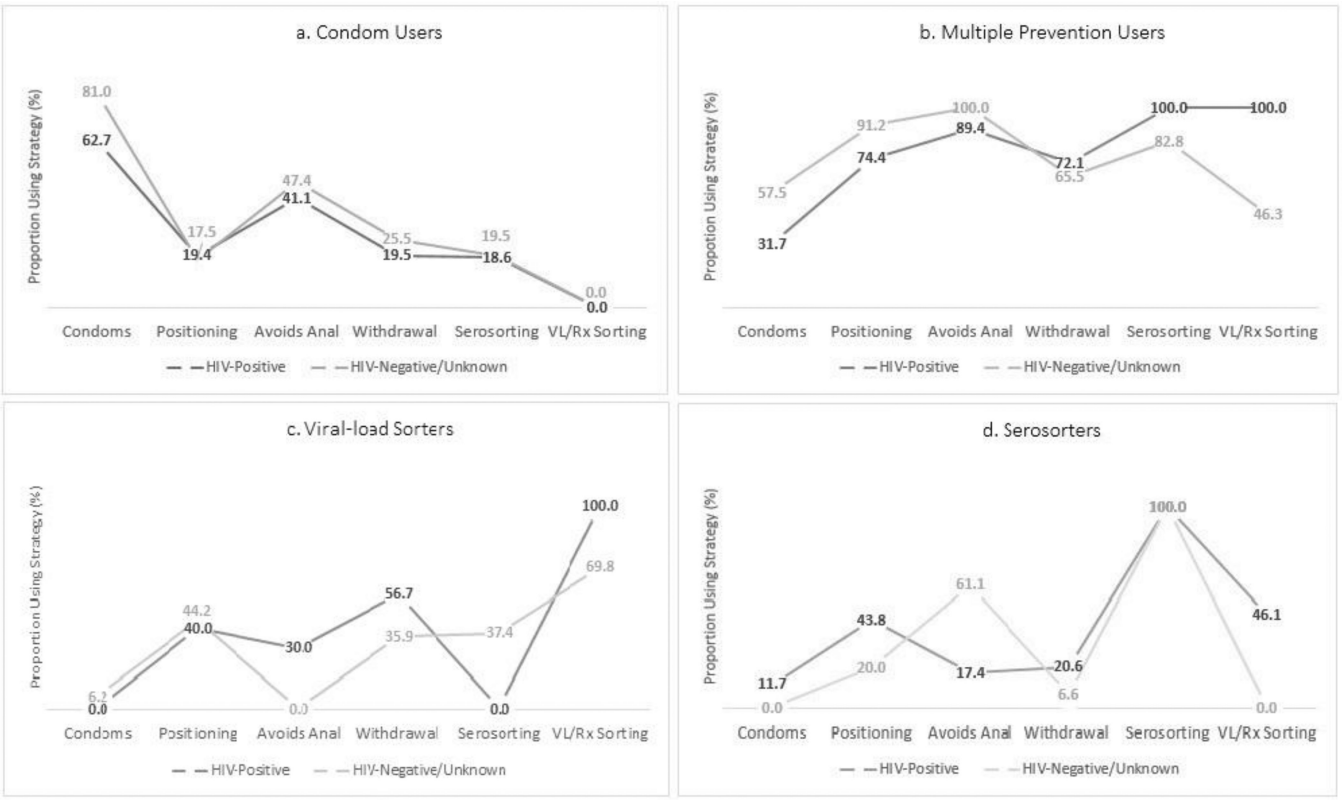

Figure 1.

Prevalence of the seroadaptive strategies employed in each latent class stratified/separated by HIV status.

Table 1

Seroadaptive strategy questions

HIV-Negative/Unknown	
Consistent Condom Use	“Always using condoms for anal sex”
Strategic Positioning	“Being the top for anal sex”
Anal Sex Avoidance	“Having sex which doesn’t include anal sex”
Serosorting	“Having anal sex without condoms only with guys I know are HIV-negative”
Viral Load Sorting	“Having anal sex without condoms with HIV-positive guys who have low viral loads or are on HIV treatment”
Withdrawal	“Not letting my sex partners cum inside me”
HIV-Positive	
Consistent Condom Use	“Always using condoms for anal sex”
Strategic Positioning	“Being the bottom for anal sex”
Anal Sex Avoidance	“Having sex which doesn’t include anal sex”
Serosorting	“Having anal sex without condoms only with guys I know are HIV-positive”
Viral Load Sorting	“Having anal sex without condoms if my viral load is low or I’m on HIV treatment”
Withdrawal	“Not cumming inside my sex partners”

Table 2

Goodness-of-fit statistics for LCA Model selection

# of Latent Class	2	3	4	5
HIV-Negative/Unknown				
Seeds	**100/100**	8/100	66/100	5/100
G-squared	146	81	41	**28**
Akaike information criterion	172	121	**95**	96
Bayesian information Criterion	228	**207**	211	243
Adjusted Bayesian information Criterion	187	**143**	126	135
Likelihood Ratio Test		<.0001	**<.0001**	0.0756
HIV-Positive				
Seeds	**100/100**	9/100	54/100	12/100
G-squared	93	70	47	**39**
Akaike information criterion	119	110	**101**	107
Bayesian information Criterion	**163**	178	192	222
Adjusted Bayesian information Criterion	122	115	**107**	114
Likelihood Ratio Test		0.0015	**0.0015**	0.2978
Grouped				
Seeds	**100/100**	8/100	39/100	12/100
G-squared	239	151	88	**66**
Akaike information criterion	291	231	**196**	202
Bayesian information Criterion	**412**	417	447	518
Adjusted Bayesian information Criterion	330	290	**275**	302
Likelihood Ratio Test		<.0001	**<.0001**	0.0949

Bolded text indicated selected LCA model.

Table 3

Descriptive statistics for HIV-negative/unknown (n=556) and HIV-positive men (n=218)

Continuous Variables	HIV-negative N (%)	HIV-positive N (%)	p-value
Age	30 (24,39)[1]	47 (39,51)[1]	<0.001
Sexual Orientation			
Gay Identified	470 (84.5)	185 (84.9)	0.879
Non-Gay Identified	86 (15.5)	33 (15.1)	
Ethnicity			
White	412 (74.6)	171 (78.4)	0.268
Non-White	140 (25.4)	47 (21.6)	
Education			
≤High school diploma	112 (20.3)	112 (42.4)	0.012
Some college	162 (29.3)	58.0 (22.0)	
≥College degree	278 (50.4)	94.0 (35.6)	
Annual Income			
<$30,000	328 (59.0)	157 (72.0)	0.003
$30,000 – $59,999	154 (27.7)	46 (21.1)	
≥$60,000	74 (13.3)	15 (6.9)	
Relationship Status			
Monogamous Relationship	92 (16.7)	33 (15.1)	0.823
Open Relationship	123 (22.3)	47.0 (21.6)	
Single	337 (61.1)	138.0 (63.3)	
Anal Sex Preference			
Versatile	141 (25.4)	69 (31.7)	0.192
Bottom	184 (33.1)	74 (33.9)	
Top	206 (37.1)	66 (30.3)	
No Anal Sex	25 (4.5)	9 (4.1)	
Treatment Optimism Scale	24 (20, 27)[1]	28 (25, 32)[1]	<0.001
Personal Sexual Altruism	3.57 (3.14, 3.86)[1]	3.43 (2.71, 3.86)[1]	0.001
Community Sexual Altruism	3.67 (3, 4)[1]	3.17 (2.33, 4)[1]	<0.001
Sexual Sensation Seeking	30 (28, 33)[1]	32 (29, 35)[1]	0.001
No. of Male Anal Sex Partners[2]	3 (1,6)[1]	4 (2,19)[1]	0.008
Condomless Anal Sex (CAS)[2]			0.002
No Condomless Anal Sex	211 (38.9)	57 (26.8)	
Concordant CAS	140 (25.8)	57 (26.8)	
Serodiscordant/Unknown CAS	192 (35.4)	99 (46.5)	

[1] Median (Q_1,Q_3)

[2] in the past six months

Table 4

Latent class model for HIV-negative/unknown (n=552) and HIV-Positive men (n=218)

	Overall	Condom Users	Multiple Prevention Users	Viral-load Sorters	Serosorters
Prevention Strategies	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
HIV-Negative/Unknown		397 (71.9)	50 (9.0)	46 (8.3)	59 (10.8)
Consistent Condom Use	353 (64.0)	**322 (81.0)**	**29 (57.5)**	3 (6.2)	0 (0.0)
Strategic Positioning	147 (26.6)	70 (17.5)	**45 (91.2)**	20 (44.2)	12 (20.0)
Anal Sex Avoidance	274 (49.6)	188 (47.4)	**50 (100.0)**	0 (0.0)	**36 (61.1)**
Serosorting	195 (35.3)	77 (19.5)	**41 (82.8)**	17 (37.4)	**59 (100.0)**
Viral-load Sorting	55 (10.0)	0 (0.0)	23 (46.3)	**32 (69.8)**	0 (0.0)
Withdrawal	154 (27.9)	101 (25.5)	**33 (65.5)**	16 (35.9)	4 (6.6)
HIV-Positive		92 (42.3)	20 (9.2)	30 (13.8)	76 (34.8)
Consistent Condom Use	73 (33.5)	**58 (62.7)**	6 (31.7)	0 (0)	9 (11.7)
Strategic Positioning	78 (35.8)	18 (19.4)	**15 (74.4)**	12 (40.0)	33 (43.8)
Anal Sex Avoidance	78 (35.8)	38 (41.1)	**18 (89.4)**	9 (30.0)	13 (17.4)
Serosorting	113 (51.8)	17 (18.6)	**20 (100.0)**	0 (0.0)	**76 (100.0)**
Viral-load Sorting	85 (39.0)	0 (0.0)	**20 (100.0)**	**30 (100.0)**	35 (46.1)
Withdrawal	65 (29.8)	18 (19.5)	**14 (72.1)**	**17 (56.7)**	16 (20.6)

Bolded text indicates behaviors used by a majority of the participants belonging to each given class.

Table 5

Multivariable multinomial logistic regression models, with Condom Users as the referent group

	Multiple Prevention aOR[1] (95% CI[2])	Viral-load Sorters aOR[1] (95% CI[2])	Serosorters aOR[1] (95% CI[2])
HIV-Negative/Unknown			
Age	1.00 (0.98, 1.03)	**1.04 (1.01, 1.07)**	1.00 (0.97, 1.02)
Relationship Status			
Monogamous Relationship	1.00	1.00	1.00
Open Relationship	0.63 (0.25, 1.61)	0.59 (0.20, 1.78)	0.50 (0.23, 1.10)
Single	**0.40 (0.17, 0.93)**	0.39 (0.15, 1.03)	0.98 (0.94, 1.02)
Treatment Optimism	**1.08 (1.01, 1.16)**	**1.17 (1.09, 1.27)**	**1.11 (1.04, 1.18)**
Personal Altruism	1.56(0.74, 3.28)	**0.46 (0.23, 0.90)**	0.63 (0.35, 1.13)
Sexual Sensation Seeking	**1.09 (1.01, 1.18)**	1.01 (0.91, 1.10)	1.04 (0.96, 1.12)
No. of Anal Sex Partners[3]	1.02 (1.00, 1.03)	**1.02 (1.01, 1.04)**	0.98 (0.94, 1.02)
sdCAS (vs. none)[3,4]	**2.87 (1.47, 5.62)**	**8.60 (3.35, 22.06)**	1.33 (0.69, 2.57)
HIV-Positive			
Relationship Status			
Monogamous Relationship	1.00	1.00	1.00
Open Relationship	0.58 (0.11, 3.12)	0.69 (0.18, 2.58)	1.61 (0.50, 5.17)
Single	0.40 (0.10, 1.61)	**0.13 (0.04, 0.46)**	1.28 (0.56, 3.54)
Treatment Optimism	1.05 (0.95, 1.16)	**1.15 (1.05, 1.26)**	1.03 (0.97, 1.09)
Community Altruism	0.64 (0.36, 1.13)	0.63 (0.37, 1.06)	**0.59 (0.41, 0.86)**
No. of Anal Sex Partners[1]	1.02 (1.00, 1.03)	**1.02 (1.01, 1.04)**	0.98 (0.94, 1.02)
sdCAS (vs. none)[1,2]	**4.82 (1.55, 14.99)**	**5.29 (1.89, 14.76)**	1.56 (0.79, 3.07)

Bivariable multinomial logistic regression models, with Condom Users as the referent group, comparing covariates of class membership.

	Multiple Prevention	Viral-load Sorters	Serosorters
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
HIV-Negative/Unknown			
Age	1.01 (0.98, 1.04)	**1.04 (1.01, 1.06)**	1.00 (0.98, 1.03)
Non-Gay Identity (vs. Gay)	0.78 (0.33, 1.84)	0.53 (0.19, 1.46)	0.83 (0.38, 1.8)
Non-White Ethnicity (vs. White)			
Education			
≤High school diploma	1.00	1.00	1.00
Some college	1.76 (0.66, 4.72)	0.57 (0.22, 1.46)	1.29 (0.56, 2.95)
≥College degree	2.16 (0.86, 5.38)	1.11 (0.52, 2.37)	1.46 (0.68, 3.12)
Annual Income			
<$30,000			

Bivariable multinomial logistic regression models, with Condom Users as the referent group, comparing covariates of class membership.

	Multiple Prevention	Viral-load Sorters	Serosorters
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
$30,000 – $59,999	1.45 (0.73, 2.86)	1.31 (0.62, 2.74)	1.66 (0.92, 3.01)
≥$60,000	2.13 (0.96, 4.75)	2.85 (1.31, 6.17)	1.05 (0.42, 2.62)
Relationship Status			
Monogamous Relationship	1.00	1.00	1.00
Open Relationship	0.85 (0.35, 2.07)	0.69 (0.27, 1.76)	0.53 (0.25, 1.11)
Single	0.51 (0.23, 1.13)	0.52 (0.23, 1.15)	**0.22 (0.12, 0.44)**
Anal Sex Preference			
Bottom (vs. Versatile)	**0.34 (0.14, 0.81)**	0.80 (0.34, 1.86)	0.96 (0.47, 1.94)
Top (vs. Versatile)	0.90 (0.46, 1.79)	1.35 (0.62, 2.91)	0.93 (0.46, 1.90)
No Anal Sex (vs. Versatile)	0.57 (0.13, 2.55)	0.03 (0.00, 34.7)	0.47 (0.09, 2.56)
Treatment Optimism Scale	**1.11 (1.04, 1.18)**	**1.26 (1.18, 1.35)**	**1.13 (1.07, 1.20)**
Personal Sexual Altruism	0.98 (0.5, 1.91)	**0.22 (0.12, 0.39)**	**0.50 (0.3, 0.85)**
Community Sexual Altruism	0.72 (0.43, 1.2)	**0.27 (0.17, 0.45)**	**0.54 (0.34, 0.85)**
Sexual Sensation Seeking	**1.14 (1.07, 1.23)**	**1.15 (1.07, 1.24)**	1.06 (0.99, 1.13)
No. of Male Anal Sex Partners[8]	**1.03 (1.01, 1.04)**	**1.04 (1.02, 1.05)**	0.98 (0.94, 1.02)
sdCAS (vs. none)[8,2]	**4.32 (2.35, 7.97)**	**17.80 (7.48, 42.39)**	**9.94 (3.48, 28.39)**
HIV-Positive			
Age	0.97 (0.92, 1.02)	1.01 (0.97, 1.06)	1.01 (0.97, 1.04)
Non-Gay Identity (vs. Gay)	0.80 (0.23, 2.84)	0.60 (0.19, 1.91)	**0.37 (0.14, 0.95)**
Non-White Ethnicity (vs. White)	0.49 (0.13, 1.93)	0.62 (0.22, 1.84)	0.91 (0.44, 1.87)
Education			
≤High school diploma	1.00	1.00	1.00
Some college	**7.28 (1.51, 35.13)**	2.11 (0.70, 6.31)	2.06 (0.90, 4.73)
≥College degree	4.41 (0.95, 20.51)	1.72 (0.64, 4.64)	**2.08 (1.01, 4.29)**
Annual Income			
<$30,000	1.00	1.00	1.00
$30,000 – $59,999	2.27 (0.78, 6.66)	**3.21 (1.24, 8.28)**	0.91 (0.40, 2.06)
≥$60,000	0.26 (0.01, 12.31)	3.25 (0.81, 13.09)	1.03 (0.30, 3.60)
Relationship Status			
Monogamous Relationship	1.00	1.00	1.00
Open Relationship	0.74 (0.15, 3.68)	1.10 (0.35, 3.50)	1.63 (0.53, 5.03)
Single	0.71 (0.20, 2.55)	**0.30 (0.10, 0.89)**	1.52 (0.58, 3.98)
Anal Sex Preference			
Bottom (vs. Versatile)	1.67 (0.53, 5.30)	**3.89 (1.11, 13.60)**	1.40 (0.67, 2.06)
Top (vs. Versatile)	0.84 (0.24, 2.98)	**3.75 (1.11, 12.73)**	0.70 (0.32, 1.53)
Treatment Optimism Scale	1.09 (0.99, 1.20)	**1.19 (1.09, 1.30)**	**1.06 (1.00, 1.12)**
Personal Sexual Altruism	**0.45 (0.22, 0.90)**	**0.50 (0.27, 0.93)**	**0.52 (0.32, 0.84)**
Community Sexual Altruism	**0.56 (0.33, 0.98)**	**0.55 (0.34, 0.89)**	**0.53, 0.35, 0.77)**

Bivariable multinomial logistic regression models, with Condom Users as the referent group, comparing covariates of class membership.

	Multiple Prevention	Viral-load Sorters	Serosorters
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**
Sexual Sensation Seeking	**1.14 (1.02, 1.28)**	**1.12 (1.01, 1.23)**	**1.09 (1.02, 1.17)**
No. of Male Anal Sex Partners[8]	1.01 (1.00, 1.02)	1.01 (0.99, 1.02)	1.01 (1.00, 1.02)
sdCAS (vs. none)[8,2]	**4.94 (1.70, 14.38)**	**4.81 (1.96, 11.80)**	1.86 (0.99, 3.52)

[1]Past six months

[2]Serodiscordant/Unknown Condomless Anal Sex

Bolded text indicates p<0.05.

[1]Past six months

[2]Serodiscordant/Unknown Condomless Anal Sex

Bolded text indicates p<0.05.