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ORIGINAL PAPER

Clusters of HIV Risk and Protective Sexual Behaviors in Agincourt, Rural South Africa: Findings from the Ha Nakekela Population-Based Study of Ages 15 and Older

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Abstract

Understanding how sexual behaviors cluster in distinct population subgroups along the life course is critical for effective targeting and tailoring of HIV prevention messaging and intervention activities. We examined interrelatedness of sexual behaviors and variation between men and women across a wide age range in a rural South African setting with a high HIV burden. Data come from the Ha Nakekela population-based survey of people aged 15–85-plus drawn from the Agincourt Health and Socio-Demographic Surveillance System. We used latent class analysis of six sexual behavior indicators to identify distinct subgroup sexual behavior clusters. We then examined associations between class membership and sociodemographic and other behavioral risk factors and assessed the accuracy of a reduced set of sexual behavior indicators to classify individuals into latent classes. We identified three sexual behavior classes: (1) single with consistent protective behaviors; (2) risky behaviors; and (3) in union with lack of protective behaviors. Patterns of sexual behaviors varied by gender. Class membership was also associated with age, HIV status, nationality, and alcohol use. With only two sexual behavior indicators (union status and multiple sexual partners), individuals were accurately assigned to their most likely predicted class. There were distinct multidimensional sexual behavior clusters in population subgroups that varied by sex, age, and HIV status. In this population, only two brief questions were needed to classify individuals into risk classes. Replication in other situations is needed to confirm these findings.

Keywords Clustering · Sexual behavior · HIV · South Africa

Introduction

Information about sexual behaviors across the life course and how behaviors vary by subgroups is critical to informing the targeting and prioritization of at-risk groups and designing prevention messaging and interventions to improve sexual health. Increasing evidence shows that individuals are at risk

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of HIV acquisition throughout the life course—including at older ages (Houle et al., 2018; Rosenberg et al., 2017). However, most studies examine individual risk and protective factors, such as condom use at last sex, instead of considering how sexual behaviors cluster together and vary across the life course by distinct subgroups in the population, such as gender. Studies suggest that patterns of health behaviors are driven by events and decisions made at different life stages, as well as by social experiences, contexts, and disparities (Cockerham, 2005). Structural and social factors influence sexual behaviors—with differential effects across age and gender (Mojola, Williams, Angotti, & Gómez-Olivé, 2015)—including gender norms, migration, and socioeconomic changes (Wellings et al., 2006). Similarly, inequalities in HIV burden persist due to social contexts including limited healthcare access and gender inequalities (Joint United Nations Programme on HIV/AIDS (UNAIDS), 2014). Greater evidence is needed to understand the clustering of sexual behaviors in distinct population subgroups, along with the social drivers of these patterns and their link to HIV risk.

Most studies that have examined clusters across multiple sexual behavior indicators have been in high-income countries (Akers et al., 2016; Cochran, de Leeuw, & Mays, 1995; Danielson et al., 2014; Dariotis et al., 2008; Davies et al., 2014; Hallfors, Iritani, Miller, & Bauer, 2007; Halpern et al., 2004; Haydon, Herring, & Halpern, 2012; Mackesy-Amiti et al., 2014; Masters, Beadnell, Morrison, Hoppe, & Wells, 2013; Masters et al., 2015; McMahon, Stanforth, Devieux, & Jean-Gilles, 2016; Mustanski et al., 2013; Noor, Ross, Lai, & Risser, 2014; Pflieger, Cook, Niccolai, & Connell, 2013; Vasilenko, Kugler, Butera, & Lanza, 2015; Waller et al., 2006; Wu, Witkiewitz, McMahon, & Dodge, 2010) (see Supplementary Figure 1 and Supplementary Table 1). Of the studies in sub-Saharan Africa, most have focused on adolescents (Cederbaum, Gilreath, & Barman-Adhikari, 2014; Tibbits, Caldwell, Smith, Vergnani, & Wegner, 2016) and young adults (Carrasco, Nguyen, & Kaufman, 2018; Wechsberg et al., 2012) or men or women only (Carrasco et al., 2018; Wechsberg et al., 2012, 2017). To the best of our knowledge, no studies have examined sexual behavior clusters in a high HIV prevalence setting in a large sample of both men and women across a wide age range.

South Africa, with the world's largest HIV burden and antiretroviral therapy program (UNAIDS, 2016), represents a crucial setting for greater knowledge of interrelated sexual behaviors and HIV risk. Evidence from former apartheid homeland areas, such as the Agincourt Health and Socio-Demographic Surveillance site (Agincourt) in rural northeast South Africa, highlights the links between social contexts and inequalities in HIV burden and circumstances supporting safer sexual behaviors (Mojola et al., 2015). Agincourt has been impacted by high AIDS-related mortality (Kabudula et al., 2017a) and persistent socioeconomic mortality differentials (Kabudula et al., 2017b). Norms of hegemonic masculinity have been linked to increased HIV risk, multiple sexual partnerships, and interpersonal violence (Gorbach, Drumright, & Holmes, 2005; Hunter, 2007; Varga, 2003). Limited employment opportunities have led to high levels of labor migration (Clark, Collinson, Kahn, Drullinger, & Tollman, 2007; Kahn et al., 2012), thereby impacting relationships (Lurie et al., 2003; Mojola et al., 2015).

We used the Ha Nakekela population-based survey of men and women aged 15–85-plus in Agincourt to examine the interrelatedness of sexual behaviors, variation in behavior clusters between men and women, and how clustering of sexual behavior across age-groups is influenced by sociodemographic and behavioral factors, as well as HIV sero-status.

We used latent class analysis (LCA) to investigate how individuals reporting any sexual partners in the 2 years prior to the survey fall into distinct subgroups/classes with different sexual behavior patterns and evaluated subgroup differences between men and women. We then controlled for sociodemographic and behavioral covariates and examined the effect of gender, age, and HIV status on class membership. Finally, for future screening purposes, we explored how accurately a reduced set of sexual behavior indicators identified class membership.

Method

Participants

Data come from the Agincourt Health and Socio-Demographic Surveillance System (AHDSS). The AHDSS conducts an annual census of the population, collecting information on all vital events as well as sociodemographic statuses (Kahn et al., 2012). At the time of the study, the population under surveillance comprised approximately 90,000 people in 27 villages.

The Ha Nakekela survey was conducted in 2010–2011. It included measures of HIV, non-communicable disease risk factors and biomarkers, and lifetime and recent (past 2 years) sexual behaviors and partners (Gómez-Olivé et al., 2013; Houle et al., 2018). The study targeted a random, sex-age stratified sample of 7662 individuals, including an oversample of older adults, who were resident in 2009 in the AHDSS, of whom 4362 constituted the final analytic sample and 3541 reported at least one sexual partner in the past 2 years.

Measures

Sexual Behavior Indicators

We included respondent formal or informal union status (based on the 2009 AHDSS census, where formal union includes those who are married with lobola (bridewealth) and

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informal union includes those couples living together without lobola), self-reports of ever having been diagnosed with a sexually transmitted infection (STI, excluding HIV) and, in the past 2 years: total number of sexual partners; proportion of partners with whom a condom was used 'mostly/always'; proportion of partners whose HIV status was known the first time they had sex; and whether any partner was casual/anonymous (compared to regular).

Sociodemographic and Behavioral Factors

We included sociodemographic factors of: gender, age, education level, tertile of household socioeconomic status, and nationality (South African or Mozambican/Other) from the 2009 census (Kabudula et al., 2017b). (About a quarter of the population in the 2009 census were former refugees of the Mozambican civil war.) We also included respondent's HIV status from the survey biomarker test, self-report of ever having an HIV test, and alcohol consumption in the past month.

Statistical Analysis

In each of our LCAs, we fit a series of models that included 2–6 classes. We evaluated model fit using a variety of criteria, focusing primarily on the Bayesian Information Criterion (BIC) to select a parsimonious model, as it penalizes model complexity more than other measures (Nylund, Asparouhov, & Muthén, 2007). To identify the number of latent classes, we selected the best model according to the BIC and examined the resulting classes for substantive differences and interpretation. For each respondent and class, LCA estimated the probability that the respondent was a member of that class. It also provided a variable assigning the respondent to the most likely class.

We began by fitting a series of models of the six sexual behavior indicators defined above to the total population. We next fit sex-specific models to test whether men and women were best represented by the same number of classes. Then, to test for differences between men and women, we fit a multigroup LCA model. This model allowed us to test for measurement invariance between men and women. To test for full measurement invariance, we compared the fully unconstrained model (all item-response probabilities (the probability of responding yes to each item given class membership) could vary by sex) with the fully constrained model (all item-response probabilities constrained to be the same for men and women) using a chi-square difference test (Satorra & Bentler, 2010). To test for partial measurement invariance, we substantively reviewed differences between men and women on item-response probabilities for each indicator in the fully unconstrained model, subsequently allowing gender-specific direct effects if there was substantive variation across gender and class and holding the remaining probabilities equal by gender. We selected the resulting (partial) measurement invariant model as the final LCA model.

We included the sociodemographic and behavioral variables defined above in a one-step, complete case LCA multinomial logistic regression with direct effects by gender to predict the probability of latent class membership. We tested two-way interactions between gender and age, gender and HIV status, and age and HIV status. Since the conditional item-response probabilities may be driven by inclusion of covariates and direct effects, we compared the conditional model (with covariates and direct effects) with the unconditional model to ensure the model-building process did not change the substantive meaning of class formation.

We tested the sensitivity of our results to the inclusion of other indicators, including ever having an HIV test and indicators based on just the most recent partner, including: age difference from respondent, discussed HIV before first sex, and condom use at last sex. Finally, we examined whether behaviors clustered differently by HIV status. Our results did not change substantively in these alternative models. We preferred our final model as it included information across all sexual partners in the past two years.

Finally, to determine whether a reduced set of sexual behavior indicators could accurately classify individuals into their most likely predicted class (based on the highest posterior probability), we used simplified measures of the most discriminating indicators (based on substantive review of large differences in item-response probabilities between classes and high or low item-response probabilities) to predict class membership; we then summarized the results using sensitivity and specificity estimates, and positive and negative predictive values (Akobeng, 2006). All analyses were completed using Mplus 8.

Results

Sexual Behavior Classes

The LCA model fitting indicated a three-class solution for the whole population according to BIC and substantive interpretation and for gender subpopulations (Supplementary Figure 2), suggesting that the latent structure did not differ by gender. Comparing the unconstrained multigroup LCA model (LL: $-$11,088.825; $df(59)$; BIC = 22,653.334) to the constrained model (LL: $-$11,162.476; $df(32)$; BIC = 22,582.950) indicated a lack of measurement invariance between men and women ($p < .001$). Allowing union status, then number of sexual partners, then past STI diagnosis probabilities to vary by gender achieved partial measurement invariance (LL: $-$11,107.783; $df(40)$; BIC = 22,538.064; $p = .078$). We chose this as our final measurement model. This model suggests that the pattern of behaviors in Class 1 is the same for both men and

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women, but there are some differences by gender in sexual behavior patterns in Classes 2 and 3.

Figure 1 shows the conditional probabilities for each sexual behavior indicator by most likely predicted class membership (also shown in Supplementary Table 2). We summarize each class using the following descriptive labels.

Class 1: Single with Consistent Protective Behaviors. Class 1 was the second largest group (25%) and had near-zero probability of being in a union/married. Compared to the other classes, Class 1 reported the highest probability of "mostly/always using a condom" with their partners (63%) and also the highest probability of always knowing their partner's HIV status before they first had sex (17%). Class 1 also had a high probability of having mainly regular (74%) versus casual/anonymous partners and having one sexual

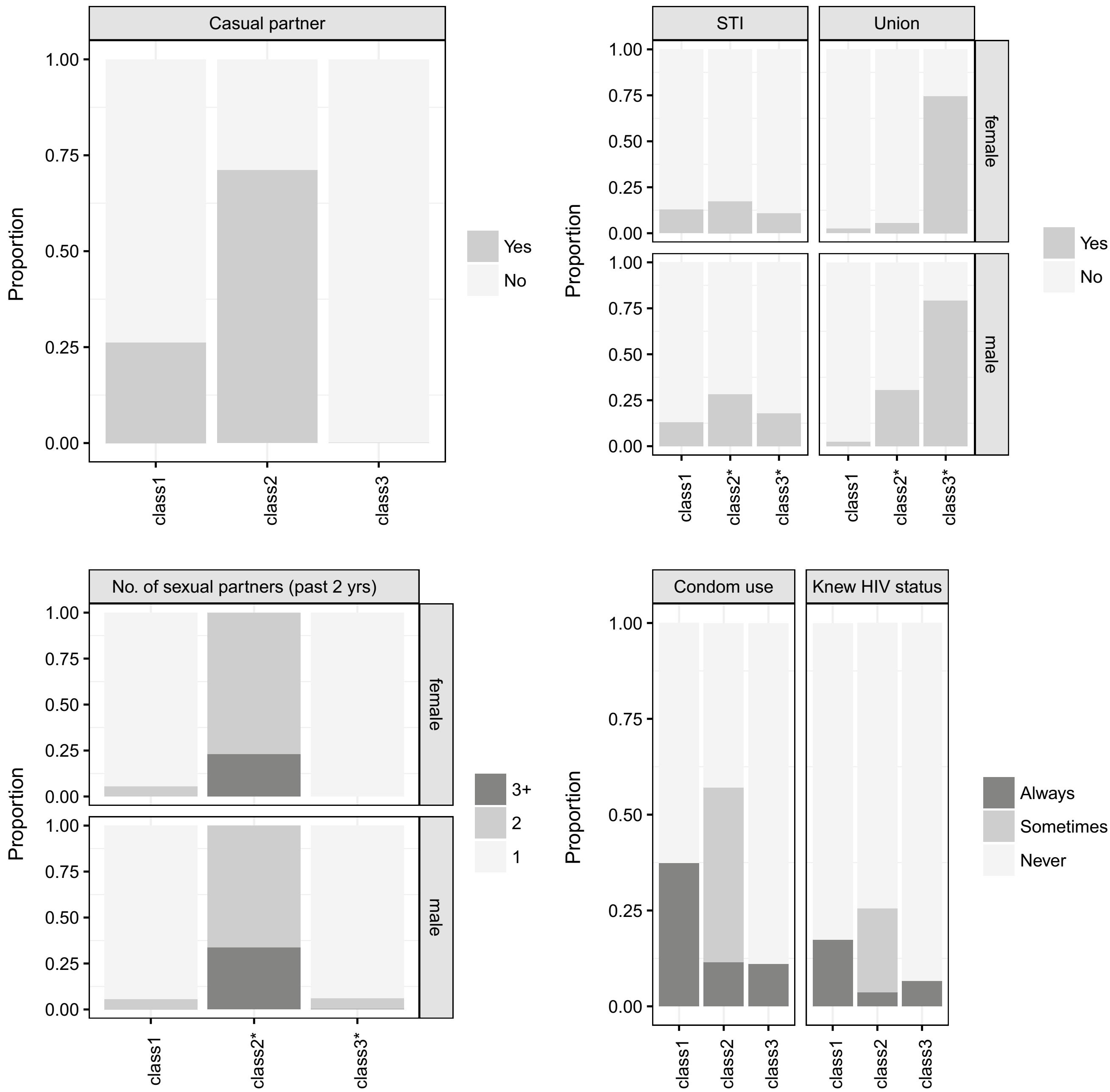

Fig. 1 Conditional probabilities of each sexual behavior by Class, Agincourt, South Africa 2010–2011 ($n = 3173$). Results based on a three-class LCA model in which the probabilities of union status, number of sexual partners, and past STI diagnosis varied by gender for Classes 2 and 3. In union means the respondent is in a formal [those who are married with lobola (bridewealth)] or informal (those couples who are living together without lobola) union. Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

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partner in the past 2 years (94%). There were no differences in the indicators between men and women.

Class 2: Risky Behaviors. Class 2 represented 15% of the sample. Class 2 included a mix of condom use behaviors, with a 12% probability of "mostly/always using a condom" with all partners and a 46% probability of "mostly/always using a condom" with some partners. They had a low (4%) probability of always knowing their partner's HIV status before they first had sex and a 71% probability of having at least one casual partner in the past 2 years. There were differences in some indicators by gender: compared to women, men had higher probabilities of ever being diagnosed with an STI (men = 28%; women = 17%), having 3 or more sexual partners in the past 2 years (men = 34%; women = 23%), and being in a union (men = 31%; women = 6%).

Class 3: In Union with Lack of Protective Behaviors. Class 3 was the most common group, representing over half the sample. Class 3 had a low probability of "mostly/always using a condom" with all partners and knowing their partner's HIV status before they first had sex. They had an almost 100% probability of having only regular partners in the past 2 years. There were slight differences in indicators by gender: compared to women, men had higher probabilities of being in a union (men = 79%; women = 75%), having two partners in the past 2 years (men = 6%; women = 0%), and ever having been diagnosed with an STI (men = 18%; women = 11%).

Associations with Latent Class Membership

We next estimated the model including sociodemographic and behavioral covariates. An interaction between age and HIV status significantly improved model fit (ΔBIC = − 35.278; $p = .014$), resulting in the final model.

Table 1 shows sociodemographic characteristics by most likely predicted sexual behavior class based on the final model. Table 2 shows adjusted odds ratios of being in Classes 1 or 2 compared to Class 3. Those born in South Africa were more likely to be in Class 1 (OR = 1.76 [95% CI 1.31–2.36]) or 2 (OR = 1.68 [95% CI 1.24–2.29]) than in Class 3, compared to non-South Africans. Those who consumed alcohol 1–3 days per month (OR = 1.90 [95% CI 1.19–3.05]) or weekly (OR = 2.54 [95% CI 1.40–4.63]) had a higher likelihood of being in Class 2 than in Class 3, compared to those reporting no alcohol use. Those with the highest education

Table 1 Sociodemographic and behavioral characteristics by most likely predicted class membership ($n = 3173$)

	Overall	Class 1	Class 2	Class 3	*p* value
Population share	3173	1039 (33%)	474 (15%)	1660 (52%)	
Gender					
Female	1850 (58%)	682 (37%)	126 (7%)	1042 (56%)	< .0001
Male	1323 (42%)	357 (27%)	348 (26%)	618 (47%)	
HIV					
Negative	2269 (72%)	638 (28%)	327 (14%)	1304 (58%)	< .0001
Positive	904 (28%)	401 (39%)	147 (16%)	356 (45%)	
Age [Mean (SD)]	38 (16.0)	29 (9.7)	30 (12.0)	47 (15.4)	< .0001
Nationality					
Elsewhere	1002 (32%)	301 (30%)	146 (15%)	555 (55%)	.049
South African	2171 (68%)	738 (34%)	328 (15%)	1105 (51%)	
Ever tested for HIV					
No	1264 (40%)	367 (29%)	227 (18%)	670 (53%)	< .0001
Yes	1909 (60%)	672 (35%)	247 (13%)	990 (52%)	
Education level (in years)					
0 years	548 (17%)	75 (14%)	32 (6%)	441 (80%)	< .0001
1–11 years	1992 (63%)	702 (35%)	350 (18%)	940 (47%)	
12+ years	633 (20%)	262 (41%)	92 (15%)	279 (44%)	
Household assets					
Lowest quintile	1178 (37%)	407 (34%)	198 (17%)	573 (59%)	.007
Middle quintile	1010 (32%)	338 (33%)	137 (14%)	535 (53%)	
Highest quintile	985 (31%)	294 (30%)	139 (14%)	552 (56%)	
Alcohol consumption (per month)					
None	2470 (78%)	844 (34%)	254 (10%)	1372 (56%)	< .0001
1–3 days per month	341 (11%)	108 (32%)	100 (29%)	133 (39%)	
Weekly	362 (11%)	87 (24%)	120 (33%)	155 (43%)	

Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

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Table 2 LCA multinomial logistic regression with direct effects ($n=3173$). Class 3 is the reference group

	Class 1		Class 2	
	OR	95% CI	OR	95% CI
Gender				
Female (base)				
Male	1.83	[1.27–2.65]	7.59	[4.79–12.01]
HIV				
Negative (base)				
Positive	0.08	[0.01–0.91]	0.95	[0.29–3.10]
Age	0.84	[0.76–0.93]	0.88	[0.86–0.90]
Nationality				
Elsewhere (base)				
South African	1.76	[1.31–2.36]	1.68	[1.24–2.29]
Ever tested for HIV				
No (base)				
Yes	0.71	[0.54–0.93]	0.84	[0.62–1.13]
Education level (in years)				
0 years (base)				
1–11 years	0.47	[0.27–0.82]	0.59	[0.34–1.03]
12+ years	0.56	[0.32–0.96]	0.46	[0.24–0.88]
Household assets				
Lowest quintile (base)				
Middle quintile	1.16	[0.83–1.62]	1.16	[0.79–1.69]
Highest quintile	0.93	[0.69–1.25]	0.82	[0.58–1.16]
Alcohol consumption (per month)				
None (base)				
1–3 days per month	1.36	[0.87–2.11]	1.90	[1.19–3.05]
Weekly	1.33	[0.61–2.91]	2.54	[1.40–4.63]
Interaction				
Age * HIV	1.11	[1.01–1.22]	1.02	[0.98–1.05]

Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

were more likely to be in Class 3 relative to those with no education, while SES was not associated with class membership. Men were more likely to be in Class 1 or 2 than in Class 3 compared to women.

Figure 2 shows predicted probabilities of class membership by gender, age, and HIV status. For HIV-negative men, Class 1 had the highest probability until their late twenties, and Class 3 had the highest probability in their early-midthirties. Class 2 had the second highest probability at all ages. For HIV-positive men, Class 2 had the highest probability until their late twenties, and Class 3 had the highest probability in their early-midforties. Class 1 had the second highest probability at all ages. For HIV-negative women, the class with the highest probability changed from Class 1 to Class 3 in their mid-late twenties, with a low probability of being in Class 2 across all ages. For HIV-positive women, the class with the highest probability of membership changed from Class 1 to Class 3 in their midthirties, with a relatively higher probability of being in Class 2 until their mid-late twenties compared to HIV-negative women.

Since the LCA model is restricted to those reporting any sexual partners in the past 2 years, Fig. 3 presents the probabilities of being in one of the latent classes or reporting no sexual partners in the past 2 years, by gender, age, and HIV status. Women in older ages reported a higher probability of no sexual partners compared to men, regardless of HIV status. HIV-positive women reported slightly higher probabilities of no sexual partners at ages 35–64 compared to HIV-negative women.

Finally, we tested the ability of a reduced set of sexual behavior indicators to accurately classify individuals into their most likely predicted class—selecting union status and whether the respondent reported one or more than one sexual partner. This was based on assessing the most discriminating indicators in terms of high and low item-response probabilities across classes. Reporting multiple partners was 100% in Class 2 and very low in Classes 2 and 3. Conversely, being in a union was high in Class 3 and very low in Class 1. Assigning to Class 1 those reporting one partner and not being in a union yielded sensitivity of .96 and specificity of .92. Assigning to Class 2 those reporting more than one sexual partner yielded sensitivity of 1.0 and specificity of .97. Assigning to Class 3 those reporting one sexual partner and being in a union yielded a sensitivity of .86 and specificity of 1.0. Positive and negative predictive values are presented in Table 3.

Discussion

This study is among the first to examine clusters of sexual behavior across gender and a wide age range in a high HIV prevalence setting. The vast majority of young individuals were characterized by being single with consistent protective behaviors, and the majority of older adults were characterized by being in a union which lacked protective behaviors. Clusters of sexual behaviors also varied significantly by age, gender, and HIV status. Shifts in the most common class, from single and consistent protective behaviors (Class 1) or risky behaviors (Class 2) to being in union with lack of protective behaviors (Class 3), occurred at later ages for HIV-positive compared to HIV-negative individuals. Being in the risky behaviors class was associated with alcohol use (Carrasco, Esser, Sparks, & Kaufman, 2016) and was more prevalent among young and middle-aged men compared to women.

Gender differences in the sexual behavior classes suggests that men and women vary in 'who' they partner with but not 'how,' underscoring the importance of an individual's relationship status (Logan, Cole, & Leukefeld, 2002). For instance, the risky behaviors class represents a small group of almost

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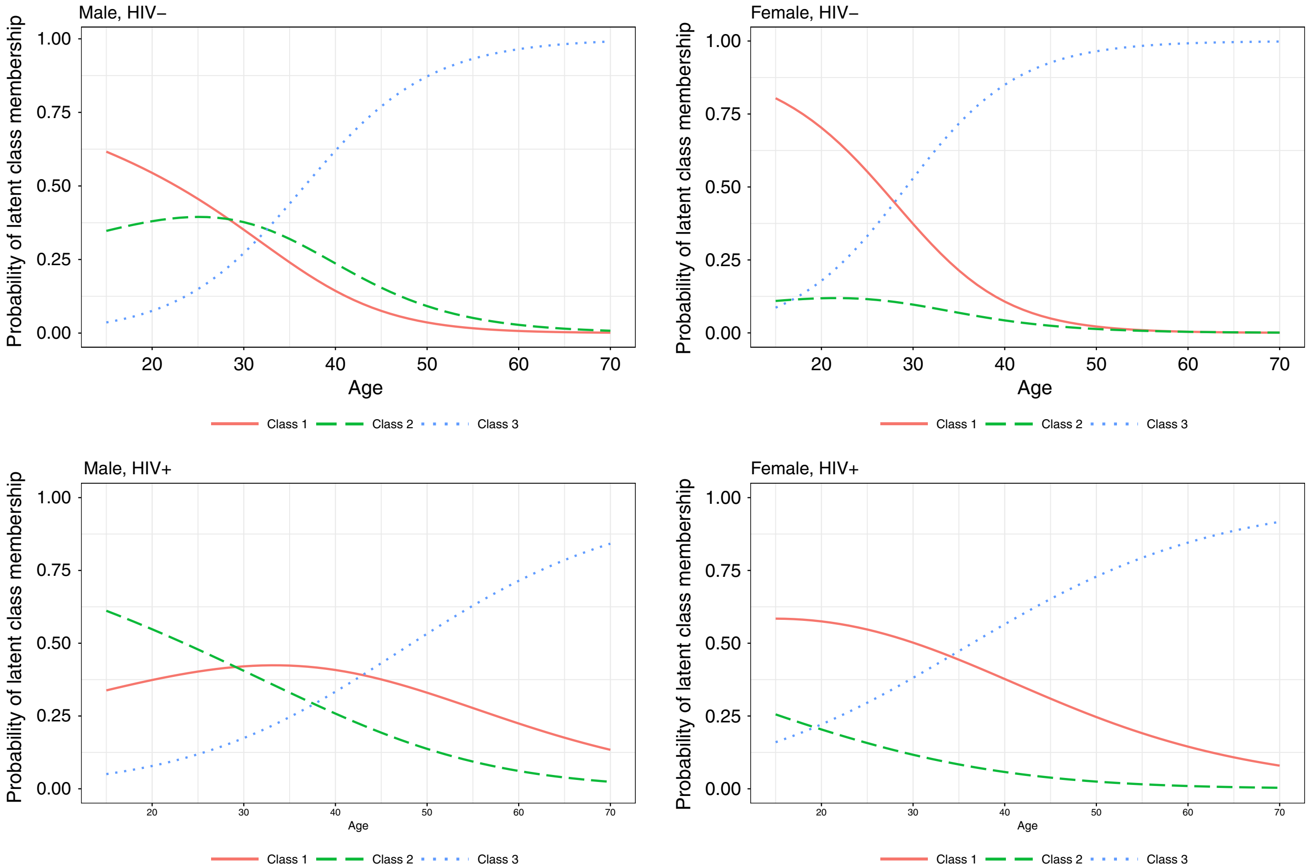

Fig. 2 Predicted probabilities of latent class membership by gender, age, and HIV status, Agincourt, South Africa 2010–2011 ($n = 3173$). Results based on the final LCA multinomial logistic regression model with three classes. All other covariates were set at their mean levels for the estimation sample. Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

entirely single women, but represents a larger group of some men, only some of whom are in a union. As evidence indicates that women tend to have older partners and men younger partners (Houle et al., 2018), this suggests that women in a union with lack of protective behaviors are at risk of HIV due to low rates of condom use with their male partners. Conversely, women aware of their husband's sexual behaviors (Houle et al., 2018) may be employing alternative protective strategies such as celibacy, as indicated by the increasing proportions of sexually inactive women in older ages (Mojola et al., 2015). However, for men in the risky behaviors class with multiple partners, their likely younger female partner(s) are also at risk, with potentially increased difficulty in negotiating safer sex with an older, male partner with higher SES (Bajos & Marquet, 2000; Kordoutis, Loumakou, & Sarafidou, 2000).

Our results showed substantial age variation in HIV risk and sexual behaviors. For younger adults, our findings were similar to a study from Malawi among younger men that also identified low- and high-risk sexual behavior classes (Carrasco et al., 2018). Our results also suggest a 'settling-down' effect in older adults as the probability of being in the union with lack of protective behaviors class increased across age. Longitudinal evidence among U.S. men ages 15–26 showed an increasing transition of men from high-risk to low-risk classes (Dariotis et al., 2008). Our results suggest that the duration of membership in at-risk classes and the pace of transition to lower-risk classes may be important in understanding life-course HIV vulnerability, but longitudinal evidence is needed to clarify transitions in sexual behaviors at different life stages.

While our results demonstrate the patterning of multiple sexual behaviors across individuals, they also suggest that prior studies focusing on individual indicators may not adequately screen for sexual behavior risk. However, using only two indicators—whether the respondent was in a union and whether they reported multiple partners—showed that these quickly obtainable measures divided respondents well into the three risk classes. These findings align with results from the 2016 South Africa Demographic and Health Survey (National Department of Health, 2019). For women, they found that having multiple partners was rare overall and

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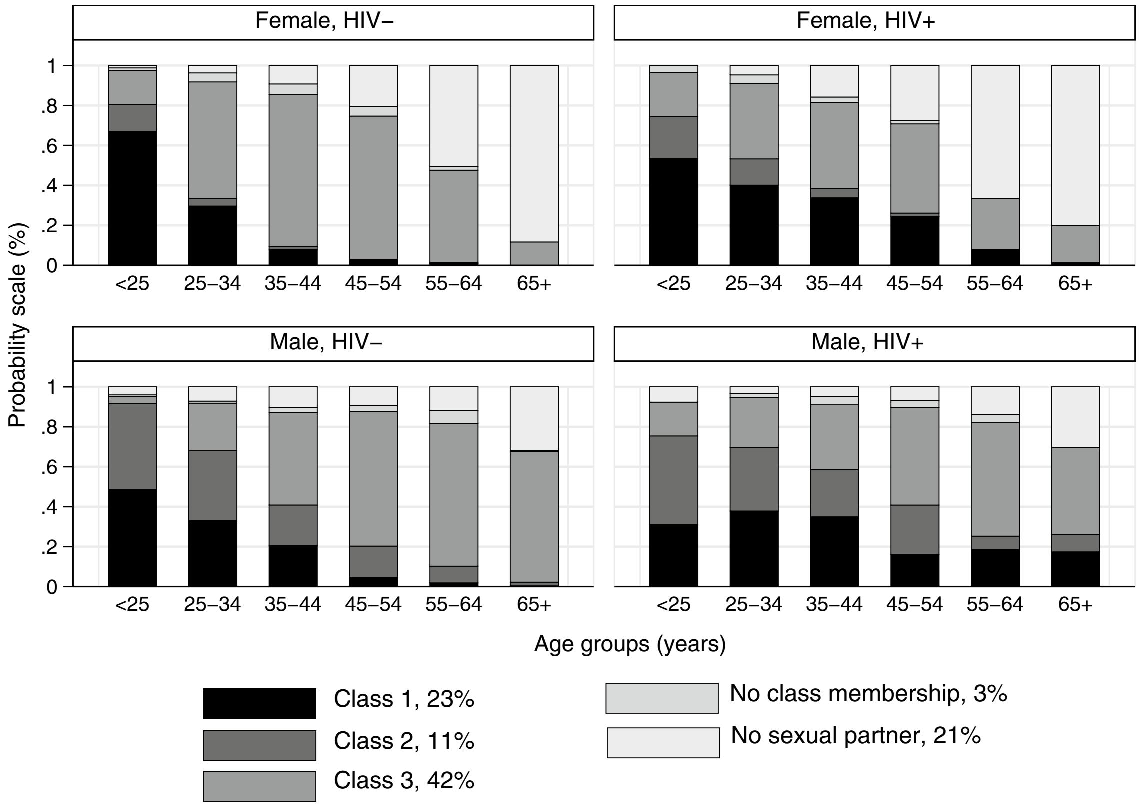

Fig. 3 Posterior probabilities of latent class membership, and proportions of individuals with no class membership due to missing covariate values and those reporting no sexual partners in the past 2 years, by gender, age, and HIV status, Agincourt, South Africa 2010–2011 ($n = 4171$). Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

Table 3 Sensitivity, specificity, and positive/negative predictive values (PPV/NPV) for simplified sexual behavior indicators on predicted latent class memberships ($n = 3173$)

Sexual behavior indicators	Sensitivity 95% CI	Specificity 95% CI	PPV 95% CI	NPV 95% CI
Not in a union and 1 sexual partner (predicting class 1)	96.05% [94.68–97.15]	91.52% [90.25–92.67]	84.65% [82.46–86.66]	97.94% [97.22–98.52]
2 or more sexual partners (predicting class 2)	100% [99.22–100]	96.63% [95.88–97.28]	83.89% [80.60–86.83]	100% [99.86–100]
In a union and 1 sexual partner (predicting class 3)	86.08% [84.33–87.71]	100% [99.76–100]	100% [99.74–100]	86.75% [85.07–88.31]

Class 1: Single with Consistent Protective Behaviors; Class 2: Risky Behaviors; Class 3: In Union with Lack of Protective Behaviors

Sensitivity: For those who belonged to a specific latent class, the proportion of participants to give a positive response to the set of sexual behavior indicators

Specificity: For those who did not belong to a specific latent class, the proportion of participants to give a negative response to the set of sexual behavior indicators

PPV: Given the positive response to the set of sexual behavior indicators, the probability of participants who were truly in a specific latent class

NPV: Given the negative response to the set of sexual behavior indicators, the probability of participants who were not truly in a specific latent class

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particularly among married women. Having multiple partners was also uncommon among married men, but was higher than women (11% vs. 3%). The proportions of those with multiple partners reporting condom use at last sex were also similar to the reported levels for the risky behaviors class in this study. We conclude that these two indicators could be used effectively in screening and assessment activities to identify those in need of further risk and prevention counseling and match them to appropriate intervention approaches.

The multidimensional aspect underlying these measures can also inform HIV prevention, counseling, and intervention design and assessment. Our findings highlight the importance of recognizing the wider social contexts that influence individuals' behavioral patterns at different life stages. For younger adults in the single with consistent protective behaviors class, prevention interventions are needed to address HIV status disclosure before sex. Evidence from Europe suggests that the social context where individuals first meet their partners may be an important determinant to discussions before first sex (Bajos & Marquet, 2000). The relatively lower levels of consistent condom use with one partner aligns with tailored messaging for specific relationship contexts, as adults are less likely to consistently use condoms with regular partners (Logan et al., 2002). Given high levels of intimate partner violence among young women in this setting (Pettifor et al., 2016), structural interventions that reduce poverty and unemployment and address gender norms (Dworkin, Treves-Kagan, & Lippman, 2013) may help reduce power differentials with older men in negotiating safer sex. For men, there is a higher probability of being in the risky behaviors class in age-groups where circular labor migration is also common. Targeting migrant men (and the women with whom they partner) at their workplace (Elwy, Hart, Hawkes, & Petticrew, 2002) and working toward supportive environments in workplace communities (Gilbert & Walker, 2002) could benefit prevention program strategies. For older women, counseling activities are needed that include both partners, and that offer communication strategies supporting celibacy or condom use when men retire or return home (Lurie et al., 2003).

We note some limitations. First, study findings may have limited generalizability as they are based on a rural South African setting in 2010–2011 when ART availability was just becoming widespread (Houle, Clark, Gómez-Olivé, Kahn, & Tollman, 2014; Mee et al., 2014). Sexual behavior patterns in different population subgroups may have changed since then as a result of greater treatment availability; however, more recent evidence on younger (Pettifor et al., 2016) and older adults (Rosenberg et al., 2017) suggests similarities with results from prior work from this study that focused on individual sexual behavior indicators (Houle et al., 2018). For instance, Pettifor et al. (2016) showed relatively low levels of condom use at last sex and older age partners for young women. Among adults ages 40 and older, Rosenberg et al. (2017) showed generally low condom use and multiple partnerships at moderate levels. The timing of ART availability at the time of this study is also important for understanding changes in sexual behavior. While studies of those on ART from generalized epidemic settings indicate a reduction in risky sexual behaviors (Berhan & Berhan, 2012; Doyle et al., 2014; Venkatesh, Flanigan, & Mayer, 2011), less is known in the general population that includes HIV-negative individuals (McGrath, Eaton, Bärnighausen, Tanser, & Newell, 2013). Our results on the multidimensionality of sexual behaviors provides an important comparison for how sexual behaviors might change, including the prevalence of different classes, and how the number and patterns within classes may change differentially by gender in light of the long-term impact of ART on general populations as well as other prevention programs. Our findings provide an important comparison for studies in other settings, as well as comparisons to other time periods when ART became more widespread. Second, the data are cross-sectional; longitudinal data are needed to understand how individuals transition between sexual behavior classes throughout their lives. Longitudinal data are particularly needed to understand how knowledge of one's HIV status and treatment access may change sexual behavior patterns. Third, since individuals self-reported their sexual behaviors to local interviewers, our data may be subject to social desirability and recall biases (Bajos & Marquet, 2000; Houle et al., 2016), and in ways that vary by gender (Nnko, Boerma, Urassa, Mwaluko, & Zaba, 2004). Finally, while our LCA models were robust to inclusion/exclusion of other behavior indicators, the measurement model is inherently limited by the available measures in the survey. Despite our analysis of 11 indicators of recent and lifetime sexual behaviors, there may be other indicators or qualitative data (George, 1993) that may provide new explanatory information (Angotti, Houle, Schatz, & Mojola, 2018) or greater discrimination in selecting the number of sexual behavior classes. We especially point to our lack of information on partner behaviors and believe our findings highlight the importance of including partners' behaviors to contextualize sexual behavior patterns.

Conclusion

We provide one of the most detailed examinations of sexual behavior clusters between men and women across a wide age range in the context of a severe HIV epidemic. Greater understanding of the multidimensional nature of an individual's sexual behaviors is critical to inform the targeting and prioritization of HIV prevention messaging programs and interventions. The aging of the HIV epidemic (Vollmer et al.,

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2017), coupled with demographic and social changes, also highlight the importance of understanding the contexts and life-course stages in which behaviors occur, such as gender roles and socioeconomic disparities. Strategies are needed that address structural determinants and social norms to provide supportive environments promoting safer sexual practices. At a practical level, and in this study's specific context, we find that with only two behavioral indicators (union status and multiple sexual partners) individuals can be assigned to classes of sexual behavior risk that are relevant in considering intervention programs. Replication in other situations is needed to confirm these findings.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval This study received ethical approvals from the University of the Witwatersrand Human Research Ethics Committee and the Mpumalanga Provincial Research and Ethics Committee.

Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed Consent Informed consent (assent for minors) was obtained from all individual participants included in the study.

References

Akers, A. Y., Cohen, E. D., Marshal, M. P., Roebuck, G., Yu, L., & Hipwell, A. E. (2016). Objective and perceived weight: Associations with risky adolescent sexual behavior. *Perspectives on Sexual and Reproductive Health, 48*(3), 129–137. https://doi.org/10.1363/48e11416.

Akobeng, A. K. (2006). Understanding diagnostic tests 1: Sensitivity, specificity and predictive values. *Acta Paediatrica, 96,* 338–341.

Angotti, N., Houle, B., Schatz, E., & Mojola, S. A. (2018). *Classifying and contextualizing sexual behavior practices across the life course: Implications in later life*. Paper presented at the Population Association of America, Denver, CO.

Bajos, N., & Marquet, J. (2000). Research on HIV sexual risk: Social relations-based approach in a cross-cultural perspective. *Social Science and Medicine, 50*(11), 1533–1546.

Berhan, A., & Berhan, Y. (2012). Is the sexual behaviour of HIV patients on antiretroviral therapy safe or risky in Sub-Saharan Africa? Meta-analysis and meta-regression. *AIDS Research and Therapy, 9*(1), 14. https://doi.org/10.1186/1742-6405-9-14.

Carrasco, M., Esser, M., Sparks, A., & Kaufman, M. (2016). HIV-alcohol risk reduction interventions in Sub-Saharan Africa: A systematic review of the literature and recommendations for a way forward. *AIDS and Behavior, 20*(3), 484–503. https://doi.org/10.1007/s10461-015-1233-5.

Carrasco, M. A., Nguyen, T. Q., & Kaufman, M. R. (2018). Low uptake of voluntary medical male circumcision among high risk men in Malawi. *AIDS and Behavior, 22*(2), 447–453. https://doi.org/10.1007/s10461-016-1633-1.

Cederbaum, J. A., Gilreath, T. D., & Barman-Adhikari, A. (2014). Perceived risk and condom use among adolescents in Sub-Saharan Africa: A latent class analysis. *African Journal of Reproductive Health, 18*(4), 26–33.

Clark, S. J., Collinson, M. A., Kahn, K., Drullinger, K., & Tollman, S. M. (2007). Returning home to die: Circular labour migration and mortality in South Africa. *Scandinavian Journal of Public Health, 69,* 35–44. https://doi.org/10.1080/14034950701355619.

Cochran, S. D., de Leeuw, J., & Mays, V. M. (1995). Optimal scaling of HIV-related sexual risk behaviors in ethnically diverse homosexually active men. *Journal of Consulting and Clinical Psychology, 63*(2), 270–279.

Cockerham, W. C. (2005). Health lifestyle theory and the convergence of agency and structure. *Journal of Health and Social Behavior, 46*(1), 51–67.

Danielson, C. K., Walsh, K., McCauley, J., Ruggiero, K. J., Brown, J. L., Sales, J. M., & Diclemente, R. J. (2014). HIV-related sexual risk behavior among African American adolescent girls. *Journal of Womens Health, 23*(5), 413–419. https://doi.org/10.1089/jwh.2013.4599.

Dariotis, J. K., Sonenstein, F. L., Gates, G. J., Capps, R., Astone, N. M., Pleck, J. H., & Zeger, S. (2008). Changes in sexual risk behavior as young men transition to adulthood. *Perspectives on Sexual and Reproductive Health, 40*(4), 218–225. https://doi.org/10.1363/4021808.

Davies, S. L., Cheong, J., Lewis, T. H., Simpson, C. A., Chandler, S. D., & Tucker, J. A. (2014). Sexual risk typologies and their relationship with early parenthood and STI outcomes among urban African-American emerging adults: A cross-sectional latent profile analysis. *Sexually Transmitted Infections, 90*(6), 475–477. https://doi.org/10.1136/sextrans-2013-051334.

Doyle, J. S., Degenhardt, L., Pedrana, A. E., McBryde, E. S., Guy, R. J., Stoové, M. A., … Hellard, M. E. (2014). Effects of HIV antiretroviral therapy on sexual and injecting risk-taking behavior: A systematic review and meta-analysis. *Clinical Infectious*

Author's personal copy

Diseases, 59(10), 1483–1494. https://doi.org/10.1093/cid/ciu602.

Dworkin, S., Treves-Kagan, S., & Lippman, S. (2013). Gender-transformative interventions to reduce HIV risks and violence with heterosexually-active men: A review of the global evidence. *AIDS and Behavior, 17*(9), 2845–2863. https://doi.org/10.1007/s10461-013-0565-2.

Elwy, A. R., Hart, G. J., Hawkes, S., & Petticrew, M. (2002). Effectiveness of interventions to prevent sexually transmitted infections and human immunodeficiency virus in heterosexual men: A systematic review. *Archives of Internal Medicine, 162*(16), 1818–1830.

George, L. K. (1993). Sociological perspectives on life transitions. *Annual Review of Sociology, 19*(1), 353–373.

Gilbert, L., & Walker, L. (2002). Treading the path of least resistance: HIV/AIDS and social inequalities—A South African case study. *Social Science and Medicine, 54*(7), 1093–1110.

Gómez-Olivé, F. X., Angotti, N., Houle, B., Klipstein-Grobusch, K., Kabudula, C., Menken, J., & Clark, S. J. (2013). Prevalence of HIV among those 15 and older in rural South Africa. *AIDS Care, 25*(9), 1122–1128.

Gorbach, P. M., Drumright, L. N., & Holmes, K. K. (2005). Discord, discordance, and concurrency: comparing individual and partnership-level analyses of new partnerships of young adults at risk of sexually transmitted infections. *Sexually Transmitted Diseases, 32*(1), 7–12. https://doi.org/10.1097/01.olq.0000148302.81575.fc.

Hallfors, D. D., Iritani, B. J., Miller, W. C., & Bauer, D. J. (2007). Sexual and drug behavior patterns and HIV and STD racial disparities: The need for new directions. *American Journal of Public Health, 97*(1), 125–132. https://doi.org/10.2105/ajph.2005.075747.

Halpern, C. T., Hallfors, D., Bauer, D. J., Iritani, B., Waller, M. W., & Cho, H. (2004). Implications of racial and gender differences in patterns of adolescent risk behavior for HIV and other sexually transmitted diseases. *Perspectives on Sexual and Reproductive Health, 36*(6), 239–247. https://doi.org/10.1363/psrh.36.239.04.

Haydon, A. A., Herring, A. H., & Halpern, C. T. (2012). Associations between patterns of emerging sexual behavior and young adult reproductive health. *Perspectives on Sexual and Reproductive Health, 44*(4), 218–227. https://doi.org/10.1363/4421812.

Houle, B., Angotti, N., Clark, S. J., Williams, J., Gómez-Olivé, F. X., Menken, J., … Tollman, S. M. (2016). Let's talk about sex, maybe: Interviewers, respondents, and sexual behavior reporting in rural South Africa. *Field Methods, 28*(2), 112–132.

Houle, B., Clark, S. J., Gómez-Olivé, F. X., Kahn, K., & Tollman, S. M. (2014). The unfolding counter-transition in rural South Africa: Mortality and cause of death, 1994–2009. *PLoS ONE, 9*(6), e100420. https://doi.org/10.1371/journal.pone.0112563.

Houle, B., Mojola, S. A., Angotti, N., Schatz, E., Gomez-Olive, F. X., Clark, S. J., … Menken, J. (2018). Sexual behavior and HIV risk across the life course in rural South Africa: Trends and comparisons. *AIDS Care, 30*, 1435–1443. https://doi.org/10.1080/09540121.2018.1468008.

Hunter, M. (2007). The changing political economy of sex in South Africa: The significance of unemployment and inequalities to the scale of the AIDS pandemic. *Social Science and Medicine, 64*(3), 689–700. https://doi.org/10.1016/j.socscimed.2006.09.015.

Joint United Nations Programme on HIV/AIDS (UNAIDS). (2014). *The Gap Report*. Retrieved December 21, 2019, from http://files.unaids.org/en/media/unaids/contentassets/documents/unaidspublication/2014/UNAIDS_Gap_report_en.pdf.

Kabudula, C., Houle, B., Collinson, M., Kahn, K., Gómez-Olivé, F., Clark, S., & Tollman, S. (2017a). Progression of the epidemiological transition in a rural South African setting: Findings from population surveillance in Agincourt, 1993–2013. *BMC Public Health, 17*, 424. https://doi.org/10.1186/s12889-017-4312-x.

Kabudula, C., Houle, B., Collinson, M. A., Kahn, K., Tollman, S., & Clark, S. (2017b). Assessing changes in household socioeconomic status in rural South Africa, 2001–2013: A distributional analysis using household asset indicators. *Social Indicators Research*, *133*, 1047–1073. https://doi.org/10.1007/s11205-016-1397-z.

Kahn, K., Collinson, M. A., Gómez-Olivé, F. X., Mokoena, O., Twine, R., Mee, P., … Khosa, A. (2012). Profile: Agincourt health and socio-demographic surveillance system. *International Journal of Epidemiology, 41*(4), 988–1001.

Kordoutis, P., Loumakou, M., & Sarafidou, J. (2000). Heterosexual relationship characteristics, condom use and safe sex practices. *AIDS Care, 12*(6), 767–782. https://doi.org/10.1080/09540120020014318a.

Logan, T., Cole, J., & Leukefeld, C. (2002). Women, sex, and HIV: Social and contextual factors, meta-analysis of published interventions, and implications for practice and research. *Psychological Bulletin, 128*(6), 851–885. https://doi.org/10.1037//0033-2909.128.6.851.

Lurie, M. N., Williams, B. G., Zuma, K., Mkaya-Mwamburi, D., Garnett, G. P., Sweat, M. D., & Karim, S. S. (2003). Who infects whom? HIV-1 concordance and discordance among migrant and non-migrant couples in South Africa. *AIDS, 17*(15), 2245–2252.

Mackesy-Amiti, M. E., Ouellet, L. J., Finnegan, L., Hagan, H., Golub, E., Latka, M., … Garfein, R. S. (2014). Transitions in latent classes of sexual risk behavior among young injection drug users following HIV prevention intervention. *AIDS and Behavior, 18*(3), 464–472. https://doi.org/10.1007/s10461-013-0601-2.

Masters, N. T., Beadnell, B., Morrison, D. M., Hoppe, M. J., & Wells, E. A. (2013). Multidimensional characterization of sexual minority adolescents' sexual safety strategies. *Journal of Adolescence, 36*(5), 953–961. https://doi.org/10.1016/j.adolescence.2013.07.008.

Masters, N. T., Casey, E., Beadnell, B., Morrison, D. M., Hoppe, M. J., & Wells, E. A. (2015). Condoms and contexts: Profiles of sexual risk and safety among young heterosexually active men. *Journal of Sex Research, 52*(7), 781–794. https://doi.org/10.1080/00224499.2014.953023.

McGrath, N., Eaton, J. W., Bärnighausen, T. W., Tanser, F., & Newell, M.-L. (2013). Sexual behaviour in a rural high HIV prevalence South African community. *AIDS, 27*(15), 2461–2470. https://doi.org/10.1097/01.aids.0000432473.69250.19.

McMahon, R. C., Stanforth, E. T., Devieux, J. G., & Jean-Gilles, M. (2016). HIV risk behavior and internalizing/externalizing psychopathology among adolescents in court-ordered treatment. *The American Journal of Drug and Alcohol Abuse, 42*(2), 187–195. https://doi.org/10.3109/00952990.2015.1132719.

Mee, P., Collinson, M. A., Madhavan, S., Root, E. D., Tollman, S. M., Byass, P., & Kahn, K. (2014). Evidence for localised HIV related micro-epidemics associated with the decentralised provision of antiretroviral treatment in rural South Africa: A spatio-temporal analysis of changing mortality patterns (2007–2010). *Journal of Global Health, 4*(1). https://doi.org/10.7189/jogh.04.010403.

Mojola, S. A., Williams, J., Angotti, N., & Gómez-Olivé, F. X. (2015). HIV after 40 in rural South Africa: A life course approach to HIV vulnerability among middle aged and older adults. *Social Science and Medicine, 143*, 204–212.

Mustanski, B., Byck, G. R., Dymnicki, A., Sterrett, E., Henry, D., & Bolland, J. (2013). Trajectories of multiple adolescent health risk behaviors in a low-income African American population. *Development and Psychopathology, 25*(4 Pt 1), 1155–1169. https://doi.org/10.1017/s0954579413000436.

National Department of Health, Statistics South Africa, South African Medical Research Council, and ICF. (2019). *South Africa demographic and health survey 2016*. Pretoria, South Africa and Rockville, Maryland: NDoH, Stats SA, SAMRC, and ICF.

Nnko, S., Boerma, J., Urassa, M., Mwaluko, G., & Zaba, B. (2004). Secretive females or swaggering males? An assessment of the quality of sexual partnership reporting in rural Tanzania. *Social*

Author's personal copy

Science and Medicine, 59(2), 299–310. https://doi.org/10.1016/j.socscimed.2003.10.031.

Noor, S. W., Ross, M. W., Lai, D., & Risser, J. M. (2014). Use of latent class analysis approach to describe drug and sexual HIV risk patterns among injection drug users in Houston, Texas. *AIDS and Behavior, 18*(Suppl. 3), 276–283. https://doi.org/10.1007/s10461-014-0713-3.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural Equation Modeling: A Multidisciplinary Journal, 14*(4), 535–569. https://doi.org/10.1080/10705510701575396.

Pettifor, A., The, H. p. t., MacPhail, C., Selin, A., Gómez-Olivé, F. X., Rosenberg, M., … Kahn, K. (2016). HPTN 068: A randomized control trial of a conditional cash transfer to reduce HIV infection in young women in South Africa—Study design and baseline results. *AIDS and Behavior, 20*(9), 1863–1882. https://doi.org/10.1007/s10461-015-1270-0.

Pflieger, J. C., Cook, E. C., Niccolai, L. M., & Connell, C. M. (2013). Racial/ethnic differences in patterns of sexual risk behavior and rates of sexually transmitted infections among female young adults. *American Journal of Public Health, 103*(5), 903–909. https://doi.org/10.2105/ajph.2012.301005.

Rosenberg, M. S., Gómez-Olivé, F. X., Rohr, J. K., Houle, B. C., Kabudula, C. W., Wagner, R. G., … Tollman, S. M. (2017). Sexual behaviors and HIV status: A population-based study among older adults in rural south Africa. *Journal of Acquired Immune Deficiency Syndromes, 74*(1), e9–e17.

Satorra, A., & Bentler, P. M. (2010). Ensuring positiveness of the scaled difference Chi square test statistic. *Psychometrika, 75*(2), 243–248. https://doi.org/10.1007/s11336-009-9135-y.

Tibbits, M. K., Caldwell, L. L., Smith, E. A., Vergnani, T., & Wegner, L. (2016). Longitudinal patterns of active leisure among South African youth: Gender differences and associations with health risk behaviours. *World Leisure Journal, 58*(1), 60–68. https://doi.org/10.1080/16078055.2015.1089317.

UNAIDS. (2016). *Country overview: South Africa*. Retrieved December 21, 2019, from http://www.unaids.org/en/regionscountries/countries/southafrica.

Varga, C. A. (2003). How gender roles influence sexual and reproductive health among South African adolescents. *Studies in Family Planning, 34*(3), 160–172. https://doi.org/10.1111/j.1728-4465.2003.00160.x.

Vasilenko, S. A., Kugler, K. C., Butera, N. M., & Lanza, S. T. (2015). Patterns of adolescent sexual behavior predicting young adult sexually transmitted infections: A latent class analysis approach. *Archives of Sexual Behavior, 44*(3), 705–715. https://doi.org/10.1007/s10508-014-0258-6.

Venkatesh, K., Flanigan, T., & Mayer, K. (2011). Is expanded HIV treatment preventing new infections? Impact of antiretroviral therapy on sexual risk behaviors in the developing world. *AIDS, 25*(16), 1939–1949. https://doi.org/10.1097/QAD.0b013e32834b4ced.

Vollmer, S., Harttgen, K., Alfven, T., Padayachy, J., Ghys, P., & Bärnighausen, T. (2017). The HIV epidemic in sub-Saharan Africa is aging: Evidence from the demographic and health surveys in sub-Saharan Africa. *AIDS and Behavior*, *21*(Suppl. 1), 101–113. https://doi.org/10.1007/s10461-016-1591-7.

Waller, M. W., Hallfors, D. D., Halpern, C. T., Iritani, B. J., Ford, C. A., & Guo, G. (2006). Gender differences in associations between depressive symptoms and patterns of substance use and risky sexual behavior among a nationally representative sample of U.S. adolescents. *Archives of Women's Mental Health, 9*(3), 139–150. https://doi.org/10.1007/s00737-006-0121-4.

Wechsberg, W. M., Myers, B., Kline, T. L., Carney, T., Browne, F. A., & Novak, S. P. (2012). The relationship of alcohol and other drug use typologies to sex risk behaviors among vulnerable women in Cape Town, South Africa. *Journal of AIDS and Clinical Research*. https://doi.org/10.4172/2155-6113.s1-015.

Wechsberg, W. M., Peasant, C., Kline, T., Zule, W. A., Ndirangu, J., Browne, F. A., … van der Horst, C. (2017). HIV prevention among women who use substances and report sex work: Risk groups identified among South African women. *AIDS and Behavior, 21*(Suppl. 2), 155–166. https://doi.org/10.1007/s10461-017-1889-0.

Wellings, K., Collumbien, M., Slaymaker, E., Singh, S., Hodges, Z., Patel, D., & Bajos, N. (2006). Sexual behaviour in context: A global perspective. *Lancet, 368,* 1706–1728.

Wu, J., Witkiewitz, K., McMahon, R. J., & Dodge, K. A. (2010). A parallel process growth mixture model of conduct problems and substance use with risky sexual behavior. *Drug and Alcohol Dependence, 111*(3), 207–214. https://doi.org/10.1016/j.drugalcdep.2010.04.013.

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