Do Age-Disparate Relationships Drive HIV Incidence in Young Women? Evidence from a Population Cohort in Rural KwaZulu-Natal, South Africa

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Background: Based on ethnographic investigations and mathematical models, older sexual partners are often considered a major risk factor for HIV for young women in sub-Saharan Africa. Numerous public health campaigns have been conducted to discourage young women from relationships with older men. However, longitudinal evidence relating sex partner age disparity to HIV acquisition in women is limited.

Methods: Using data from a population-based open cohort in rural KwaZulu-Natal, South Africa, we studied 15- to 29-year-old women who were HIV seronegative at first interview between January 2003 and June 2012 (n = 2444). We conducted proportional hazards analysis to establish whether the age disparity of women's most recent sexual partner, updated at each surveillance round, was associated with subsequent HIV acquisition.

Results: A total of 458 HIV seroconversions occurred over 5913 person-years of follow-up (incidence rate: 7.75 per 100 person-years). Age disparate relationships were common in this cohort; 37.7% of women reported a partner 5 or more years older than themselves. The age disparity of women's partners was not associated with HIV acquisition when measured either continuously [hazard ratio (HR) for 1-year increase in partner's age: 1.00, 95% confidence interval (CI): 0.97 to 1.03] or categorically (man ≥5 years older: HR, 0.98; 95% CI: 0.81 to 1.20; man ≥10 years older: HR, 0.98; 95% CI: 0.67 to 1.43). These results were robust to adjustment for known sociodemographic and behavioral HIV risk factors and did not vary significantly by women's age, marital status, education attainment, or household wealth.

Conclusions: HIV incidence in young women was very high in this rural community in KwaZulu-Natal. Partner age disparity did not predict HIV acquistion. Campaigns to reduce age-disparate sexual relationships may not be a cost-effective use of HIV prevention resources in this setting.

Key Words: HIV, sexual behavior, South Africa, women

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INTRODUCTION

In recent years, there has been much concern in sub-Saharan Africa regarding age-disparate relationships. Most current National Strategic HIV Plans in countries with generalized epidemics name age-disparate relationships as a driver of the HIV epidemic (Table 1). The World Health Organization considers sexual partnerships between young women and substantially older men as an important contributor to young women's risk of HIV infection.[2]

This concern is based on the observation of three types of ecological associations. First, the distribution of HIV incidence and prevalence in predominantly sexually transmitted epidemics is consistently shifted toward higher rates at younger ages for women compared with men. One explanation for this pattern is that HIV is commonly transmitted from an older man to a younger female partner. Second, sub-Saharan Africa has the largest relationship age disparities[3] and the highest HIV prevalence[1] in the world. Third, population-level variation in age disparity and HIV prevalence also appears to positively covary within regions of sub-Saharan Africa.[4]

As a result, numerous public health campaigns have been implemented, aiming to discourage young women from engaging in sexual relationships with substantially older partners or "sugar daddies."[5] The nongovernmental organization Population Services International has run health messaging programs targeting age-disparate relationships in at least 8 sub-Saharan countries.[6] In 2012, the KwaZulu-Natal (KZN) provincial Department of Health in South Africa began

TABLE 1. National Strategic Plans Containing References to Age-Disparate Sexual Relationships

	% HIV Prevalence (15–49 years)*	NSP Period	Age Disparity or "Sugar Daddy" Cited as Risk Factor	Justification Given	Policies Mandated	Explicit Reduction Target Set
Swaziland	26.0	2009–14	Yes	Prevalence of intergenerational sex, especially among out-of-school young women	Mandated, no specific policy	
Botswana	23.4	2010–16	Yes	Older men have longer sexual history; young women having intergenerational sex have lower condom use	Mandated, no specific policy	
Lesotho	23.3	2012–16	Yes	None	Yes†	Increase BCC coverage†
South Africa	17.3	2012–16	Yes	Intergenerational relationships increase risk of HIV exposure	Yes	
Zimbabwe	14.9	2011–15	Yes	Intergenerational sex is a factor that makes women and girls more vulnerable	Mandated, no specific policy	
Namibia	13.4	2011–16	Yes	Sugar daddy phenomenon well known in Namibia. Intergenerational sex associated with STIs, multiple and concurrent partnerships and introduction of HIV into younger cohort	Yes †	
Zambia	12.5	2011–15	Yes	—	Yes	
Mozambique	11.3	2010–14	Yes	Sexual relations between individuals from different generations associated with transactional and less-safe sex		
Malawi	10.0	2009–13†	Yes	—	Yes	
Uganda	7.2	2011/12–14/15	Yes	Prevalence of cross-generational sex (15- to 19-year-old women with men at least 10 years older)†	Yes	Reduce cross-generational sex by 50% by 2015†
Kenya	6.2	2008/09–12/13	No	Transactional relationships may be important but sugar daddy relationships are possibly less frequent than generally thought		
Tanzania	5.8	2008–12	Yes	Prevalence of cross-generational sex, which is linked to transactional sex and multiple concurrent partnerships	Yes	Reduce cross-generational sex by 50% for teenage girls by 2025
Cameroon	4.6	2011–15	Yes	—	No	
Central African Republic	4.6	2006–10	No			
Nigeria	3.7	2010–15	Yes	—	Yes	

TABLE 1. (*Continued*) National Strategic Plans Containing References to Age-Disparate Sexual Relationships

	% HIV Prevalence (15–49 years)*	NSP Period	Age Disparity or "Sugar Daddy" Cited as Risk Factor	Justification Given	Policies Mandated	Explicit Reduction Target Set
Togo	3.4	2012–15	Yes	Prevalence of intergenerational relationships is increasing and is a source of infections among young women	No	
Congo	3.3	2009–13	No			
Chad	3.1	2007–11	Yes	—	No	
Côte d'Ivoire	3.0	2011–15	Yes†	Young people in sexual relationships with older partners lack negotiating power	Mandated, no specific policy	80% of youth adopt lower risk sexual behaviors
Rwanda	2.9	2009–12	Yes	Disparity in HIV prevalence among 20- to 24-year-old men and women attributed to cross-generational sex	Yes	

Based on the most recent NSP available for countries with adults HIV prevalence more than 2% in 2011. No NSPs published since 2002 were available for Angola, Equatorial Guinea, Gabon or Guinea-Bissau.
*HIV prevalence for 2011 from UNAIDS Report on the global AIDS epidemic 2012.[1]
†From an accompanying National Prevention Strategy rather than National Strategic Plan.
BCC, Behaviour change communication; NSP, National Strategic Plan; STI, sexually transmitted infection.

a campaign under the title '"Sugar Daddies" Destroy Lives', aiming to "create a taboo against cross-generational sex" involving 14- to 25-year-old women in order to reduce HIV infection.[7]

Despite these considerable investments, quantitative evidence for a causal relationship between age disparities and HIV remains very limited. Cross-sectional analyses in Rakai, Uganda (1994–1998), Manicaland, Zimbabwe (1998–2000), and nationwide in South Africa (2003) and Kenya (2007) found positive associations between having an older partner and prevalent HIV infection.[8–11] Cross-sectional studies cannot, however, rule out many alternative explanations for an association between age disparity and HIV infection, because measurement of the exposure does not precede the outcome. For example, women could preferentially seek out relationships with older men after they have become HIV-infected—for instance, because older men are better able to support them economically[5,12]—and HIV-infected women who have older partners may live longer because they are economically better off and thus have better access to antiretroviral treatment (ART).

While the evidence to date is limited, there are plausible reasons why age-disparate relationships could be a driver of the HIV epidemic in sub-Saharan Africa.[5] First, HIV incidence rates rise rapidly from youth through middle age among men in sub-Saharan Africa.[1] As a result, young women in age-disparate relationships are, ceteris paribus, at higher risk of HIV exposure than if they were in a relationship with someone their own age.

Second, sexual behaviors may vary with the level of age disparity in sexual relationships; specifically, fewer preventative measures may be taken by age-disparate couples. This risky behavior may arise because the man perceives younger women to be less likely to be HIV-infected or because the economic and social power differentials arising from the age disparity may make it difficult for women to negotiate safe sex with their older partners.[13,14] For example, there is some evidence that men are less likely to use condoms in sexual relationships with younger women.[15,16] The subset of age-disparate relationships involving "sugar daddies"—which are typically defined as economic asymmetric and non-marital—are expected to exhibit particularly risky behaviors.[5,12]

Additionally, theoretical mathematical models have investigated the potential impact of age mixing in relationships on population HIV dynamics and on individual infection risk.[17–20] Predictions from such models have varied in their estimation of the extent to which age disparities are required for the transmission of the epidemic through the generations. Early studies suggested that the impact of age mixing on epidemics would be considerable;[20,21] however, recent analysis has suggested that age-disparate relationships may have only limited effects on community HIV prevalence, and that HIV can reach high endemic levels without a high proportion of age-disparate partnerships.[22]

Given the limited quantitative evidence and the mixed predictions from modeling studies, an empirical longitudinal analysis would represent a significant improvement on existing evidence. We therefore test the hypothesis that age-disparate relationships increase the risk of HIV infection among young women, using one of Africa's largest population-based HIV incidence cohorts. The cohort is located in a rural community in KZN where HIV incidence in young women is extremely high,[23] and male HIV prevalence rises from 8% among 20- to 24-year-olds to a peak of more than 40% between the ages of 30 and 34 years.[24,25]

METHODS

We conducted survival analyses using data from the population-based longitudinal surveillance conducted by the Africa Centre for Health and Population Studies (hereafter Africa Centre) in a predominantly rural community in the uMkhanyakude. district of KZN. The district is one of the most deprived in the country and is characterized by high levels of circular migration and HIV infection.[26] The Africa Centre has been collecting household demographic data since 2000.[26] In addition, since 2003, all adults in the community have been invited each year to participate in confidential HIV testing, and to answer questions relating to their sexual history and behaviors over the past 12 months. These questions are asked face-to-face by fieldworkers recruited from the local community.[23] HIV test results are linked to other information in the database.

Data were available from January 2003 to June 2012. Inclusion criteria for our analysis were that respondents (1) were women; (2) were aged between 15 and 30 years in the study period; (3) were HIV seronegative at first participation in the HIV surveillance; (4) had at least 1 more valid HIV test result recorded; and (5) had participated at least once in the annual General Health surveillance that elicits information on sexual behavior and sexual partners' ages. Individuals entered the cohort at the date of the first interview at which they reported a sexual partnership. If they did not contract HIV over the study observation period, they were right censored at either their 30th birthday or on the date of their most recent interview at which they tested HIV seronegative. We further excluded any person-time during which a respondent indicated not having had sex (eg, the respondent reported no sexual partners in the past year), under the assumption that such a respondent was not at risk of sexually contracting HIV in that period.

The primary outcome was HIV seroconversion; we assumed the date of HIV seroconversion to be midway between the date of an individual's last negative and first positive HIV test. (Results were robust to selecting a random date between the 2 tests). The exposure of interest was the age disparity of each woman's most recent sexual partnership. This exposure was time-varying and updated each time an HIV-uninfected woman reported a new relationship.

We considered multiple functional forms of age disparity. Our primary approach was to use age disparity as a continuous variable; this choice reflected a theoretical orientation toward a continuum of risk, the empirical finding that there was no sharp change in risk at any cutoff, and the statistical advantage of greater flexibility than dichotomous measures. However, we additionally considered step functions to capture age disparities that are more than 5 or more than 10 years, corresponding to common definitions of age-disparate relationships,[5,8,12,16] or more than 20 years as an extreme case.

We considered the following as potential sociodemographic time-varying confounders: current completed education (none or primary, 0–7 years; secondary, 8–12 years; tertiary, >12 years); household wealth (quintiles of the first component identified by principal components analysis of 28 household assets, toilet type, and sources of water, electricity, and energy—defined for all households in the study area); and marital status (never married, engaged, married, previously married). We considered as potential behavioral confounders both age at sexual debut and 3 time-varying measures of sexual behavior in the past 12 months: number of partners (1 vs. >1); any casual partner (yes vs. no); and lowest level of condom use with any partner (never, sometimes, always). See Table 2 for summary statistics on these variables.

We used Cox proportional hazards models, verifying the proportional hazards assumption using the Schoenfeld residuals from each regression. All models included the woman's age (centered at age 15) and their most recent relationship's age disparity. In the main analyses we included linear, quadratic, and cubic terms in age, but only a linear term in age disparity, because tests of functional form showed that this combination generated the best model fit based on Akaike Information Criteria (see **Table, Supplemental Digital Content 1,** http://links.lww.com/QAI/A525). Our models also included indicator variables for the year of observation, which control for unmeasured confounders that change over time (Table 3, model 1). Notably, these time period controls account for the potentially important confounding by differential availability of HIV prevention and treatment services over time.

We then considered whether any effect of age disparity varied by women's age in 3 categories (15–19, 20–24, and 25–29 years old) using indicator variables for disparate relationships in each age group (Table 3, model 2). Finally, we added sociodemographic and sexual behavior covariates to the model (Table 3, models 3 and 4). We reran our analyses after multiple imputation of missing variables in the data set (see **Table, Supplemental Digital Content 2,** http://links.lww.com/QAI/A525).

Ethical approval for the Africa Centre surveillance was granted by the Biomedical Research Ethics Committee, University of KwaZulu-Natal. Informed consent is required separately for the main and sexual behavior questionnaires, and for confidential HIV serotesting. This analysis was exempted from additional ethical review by the Harvard School of Public Health Institutional Review Board because of its use of secondary data anonymized to the study authors.

RESULTS

Between January 2003 and June 2012, 2444 women, contributing 5913 years of person-time, met the inclusion criteria and had full covariate information. Each woman was tested for HIV between 2 and 8 times (41.6% twice, 25.1% 3 times; 16.0% 4 times; 12.6% 5–8 times). The median gap between tests was 365 days (interquartile range, 343–421 days).

Baseline characteristics of the respondents are provided in Table 2, divided into 5-year age cohorts. Most of the young women had never been married, although 22% were engaged by age 25–29 years.

The typical sexual partnership involved a man who was 3 years older than the woman, with a range from 10 years younger to 47 years older. Overall, 922 respondents (37.7%) reported a partner 5 or more years older than themselves at some point in the study period, and 222 (9.1%) reported a partner 10 or more years older.

TABLE 2. Baseline Characteristics of the Study Sample of 15- to 29-Year-Old Women

	All	15–19 Yrs	20–24 Yrs	25–29 Yrs
Sample size	2444	1112	982	350
Number of subsequent seroconversions	458	136	251	71
Age at baseline, yrs	20 (18–23)	18 (17–19)	21 (20–23)	27 (25–28)
Partner age disparity in most recent relationship, yrs	3 (2–5)	3 (2–5)	3 (1–5)	4 (2–6)
Highest educational attainment, %				
None or primary (0–7 yrs)	9.6	13.8	4.3	11.1
Secondary (8–12 yrs)	86.5	84.7	92.0	77.1
Tertiary	3.8	1.4	3.8	11.7
Household wealth quintile, %				
Lowest	19.5	19.1	19.5	20.9
2nd lowest	25.7	23.9	26.6	29.1
Middle	24.9	24.4	25.7	24.6
2nd highest	18.0	19.6	17.2	15.1
Highest	11.9	13.0	11.1	10.3
Marital status, %				
Never Married	87.6	93.5	88.4	66.3
Engaged	10.1	6.2	10.2	22.0
Married	2.3	0.3	1.4	11.4
Divorced/separated/widowed	0.0	0.0	0.0	0.3
Age at sexual debut, yrs	17 (16–18)	16 (15–17)	18 (16–19)	18 (16–19)
Multiple partners in past 12 months, %	1.3	1.2	1.8	0.3
Casual partner in past 12 months, %	4.3	5.8	3.4	2.0
Lowest condom use level in relationships in past 12 months, %				
Never	49.3	45.1	50.7	59.1
Sometimes	27.1	25.0	29.0	28.3
Always	23.6	29.9	20.3	12.6

Data for categorical data are percentages; data for continuous data are medians and (interquartile ranges).

During follow-up, 458 HIV seroconversions were observed (Kaplan–Meier cumulative incidence curve shown in **Figure, Supplemental Digital Content 3,** http://links.lww.com/QAI/A525). The overall incidence rate was 7.75 per 100 person-years [95% confidence interval (CI): 7.07 to 8.49]. The incidence rate per 100 person-years rose from 7.79 (95% CI: 6.59 to 9.22) among those aged less than 20 years to 8.63 (95% CI: 7.63 to 9.77) for those aged 20–24 years, before dropping to 5.63 (95% CI: 4.46 to 7.11) for those aged 25–29 years. A crude comparison of the age disparity of women's most recent sexual partner at baseline and their subsequent risk of seroconverting while under observation (Fig. 1), suggests no obvious correlation.

In survival analysis, we found no significant relationship between age disparity and HIV acquisition, a result that remained robust when we varied the model specification and when we accounted for missing data using multiple imputation. In a model containing only respondent's age and relational age disparity (model 1; Table 3), there was no significant relationship between age-disparity and HIV acquisition [hazard ratio (HR) for a 1-year increase in partner's age, 1.00; 95% CI: 0.97 to 1.03]. The effect of age disparity did not vary significantly by the age of the respondent (model 2). When we added socioeconomic covariates (model 3) and behavioral covariates (model 4) the results remained essentially the same. Analyses using categorical measures of age disparity found similar results (man ≥5 years older: HR, 0.98; 95% CI: 0.81 to 1.20; man ≥10 years older: HR, 0.98; 95% CI: 0.67–1.43; man ≥ 20 years older: HR, 0.61; 95% CI: 0.15 to 2.46).

The results were also robust to multiple imputation of missing values (see **Table, Supplemental Digital Content 4,** http://links.lww.com/QAI/A525). Interactions of age disparity with woman's age did not change our findings (see **Table, Supplemental Digital Content 5,** http://links.lww.com/QAI/A525). No significant effect modification of the relationship between age disparities and HIV infection was seen for marital status or educational attainment (see **Table, Supplemental Digital Content 6,** http://links.lww.com/QAI/A525). For wealth, those in the middle quintile were at greater risk when in an age-disparate relationship; however this finding was only significant when we used a binary measure of age disparity with a cut point of ≥5 years (see **Table, Supplemental Digital Content 6,** http://links.lww.com/QAI/A525).

DISCUSSION

We tested whether age disparities affect HIV incidence in young women using data from one of Africa's largest population-based HIV incidence cohorts. In this high HIV

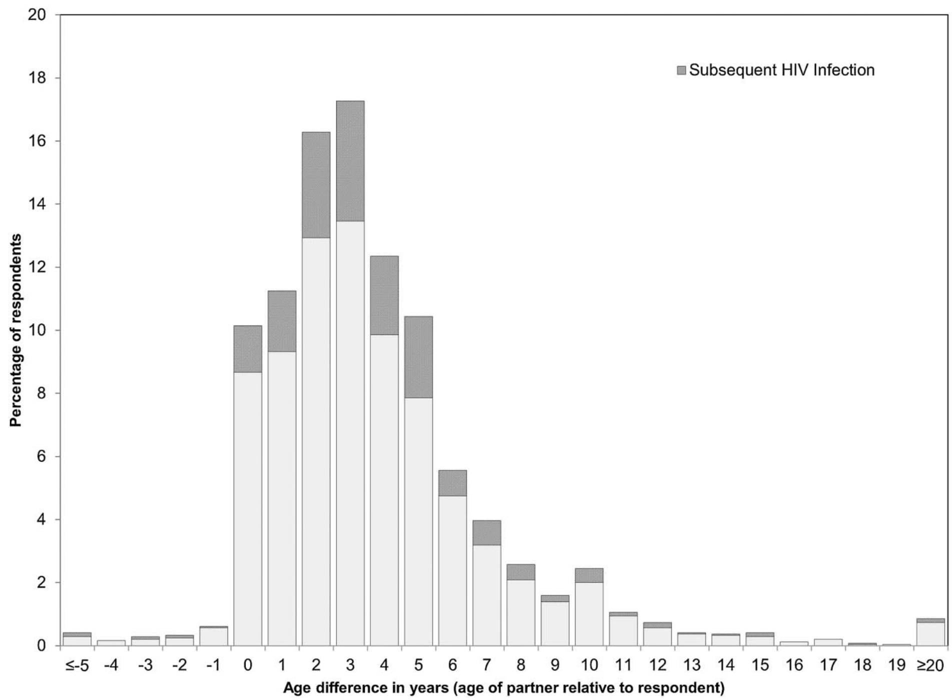

FIGURE 1. Age disparity between female respondent and most recent male sexual partner at baseline (in our analysis this age disparity is updated as respondents report new partners).

prevalence and incidence context, we found no evidence that having an older male partner increases the risk of infection in young women. Our result is not due to low statistical power, as indicated by the very tight confidence intervals around the age disparity point estimates. Age-disparate relationships are common in this community—over the study period, more than one-third of young women had a partner 5 or more years older than themselves (which is comparable to the South African national figure of 32.6%)[10]—and almost 1 in 10 had a partner at least 10 years older (which is similar to the 16.3% seen in rural Uganda).[8] Our results are robust to the functional form of age disparity and to the inclusion of several potentially confounding covariates.

There are several plausible explanations for the absence of significant associations between age-disparate relationships and HIV acquisition risk in this community. First, young women in age-disparate relationships may be more careful in selecting their partners than young women in relationships with men of similar ages. There is evidence that while men have control over partnership sexual practices, including condom use, women have control over partnership formation and dissolution.[16,27] Female control over partnership formation has been demonstrated by the effectiveness of interventions aimed at changing young women's choice of partners using information or financial incentives.[28,29] Careful partner selection could explain our findings if young women select lower risk partners as relationship age disparity increases: if young women are aware that older partners are likely to be more risky in general, they may use knowledge drawn from their social networks to identify lower risk partners from among the pool of older men available to them. Such a strategy is most likely to succeed where dense social networks allow successful identification of risky partners, such as in the cohesive rural community studied here.[30]

Second, age disparities are likely to be more weakly linked to economic disparities in this setting than elsewhere, reducing or eliminating the infection risk that has been hypothesized to exist within age-disparate relationships because of steep differentials in sexual negotiation power.[12,27] Socioeconomic differentials in this poor rural community are far less pronounced than in many other settings, in particular urban areas, limiting the potential for resource transfers from older men to younger women. In fact, most men living in this community were unemployed over the observation period.[31]

Third, although older men are more likely to be HIV-infected than younger men, there are two reasons why there may not be a difference in infectiousness between the age groups. First, younger men are more likely to be recently infected, and therefore more likely to be in the highly infectious period immediately following infection. Second, younger HIV-infected men are less likely to be on ART than older HIV-infected men, and thus less likely to be virally suppressed. Earlier studies which took place in the pre-ART era would not have seen this offsetting effect of treatment, perhaps explaining the discrepant results between our work and previous cross-sectional studies. However, when we stratified our analyses by year of observation time (Table 4), we found no change in the association between age disparity and HIV over time, suggesting that ART provision alone does not explain our null finding.

Much of the debate regarding age-disparate relationships and HIV has focused on the subset of such relationships that is also extramarital and feature economic disparities and transfers of cash or in-kind gifts from the man to the woman, that is, "sugar daddy" relationships.[7,12,16,32,33] Because we do not have information on the male partner's economic situation, or on whether relationships involved the transfer of

TABLE 3. Multivariable Cox Proportional Hazards Models of HIV Acquisition

	Model 1		Model 2*		Model 3		Model 4	
Age disparity (1-yr increase in partner's age)	1.00	0.97 to 1.03			1.00	0.98 to 1.03	1.00	0.98 to 1.03
Respondent aged 15–19 yrs			1.03	0.98 to 1.07				
Respondent aged 20–24 yrs			0.96	0.90 to 1.01				
Respondent aged 25–29 yrs			0.98	0.92 to 1.05				
Age of respondent (centered at 15 years old), yrs†								
Age	1.18	1.07 to 1.29	1.09	0.95 to 1.24	1.19	1.08 to 1.31	1.21	1.09 to 1.33
Age squared	0.73	0.67 to 0.80	0.73	0.67 to 0.81	0.73	0.67 to 0.81	0.74	0.67 to 0.81
Age cubed	1.11	1.05 to 1.17	1.13	1.06 to 1.21	1.11	1.05 to 1.17	1.10	1.05 to 1.17
Highest educational attainment								
None or primary (0–7 yrs)					1.36	0.98 to 1.89	1.29	0.93 to 1.81
Secondary (8–12 yrs)					1.00		1.00	
Tertiary					0.81	0.50 to 1.32	0.82	0.51 to 1.33
Household wealth quintile								
Lowest					1.38	0.95 to 2.00	1.38	0.94 to 2.01
2nd lowest					1.34	0.94 to 1.91	1.36	0.95 to 1.94
Middle					1.54	1.09 to 2.18	1.56	1.10 to 2.22
2nd highest					1.36	0.94 to 1.95	1.36	0.94 to 1.96
Highest					1.00		1.00	
Current marital status of respondent								
Never married					1.00		1.00	
Engaged					0.96	0.69 to 1.32	0.97	0.71 to 1.34
Married					0.10	0.01 to 0.72	0.10	0.01 to 0.73
Divorced/separated/widowed					13.41	1.84 to 98.0	12.34	1.68 to 90.7
Age at sexual debut (1-yr increment)							0.98	0.92 to 1.04
Any casual partner in past 12 months							1.12	0.72 to 1.74
Multiple partners in past 12 months							2.10	1.16 to 3.81
Lowest condom use level in relationships in past 12 months								
Never							1.00	
Sometimes							0.89	0.71 to 1.11
Always							1.08	0.86 to 1.37
Akaike Information Criteria		6482		6484		6472		6474

Values are HRs and 95% CIs. For all models, n = 2444, time at risk = 5913 person-years and there were 458 seroconversions. All models contain indicator variables for year of observation (not shown).

*This model also contains indicator variables for age categories. A joint test for equality on the 3 age-by-age disparity interaction terms was not statistically significant (χ^2 = 2.26, P = 0.324).

†The coefficient on age squared represents a 10-unit change in this variable; the coefficient on age cubed represents a 100-unit change in this variable.

money or in-kind gifts, we could not directly investigate whether economically asymmetrical, age-disparate relationships specifically are a risk factor for HIV. "Sugar daddy" relationships are sometimes conceived as fulfilling basic needs, such as providing funds for food, shelter, or school uniforms. In this case, we might expect the effects of age disparities to be greatest for those women who are least educated and poorest, and thus in greatest need of material support and least able to refuse older men's advances. However, "sugar daddies" have also been described among women of high socioeconomic status, who gain social standing or luxury goods from their relationships.[12,34,35] Our findings of no effect modification by educational attainment of or household wealth suggests that socioeconomic inequalities are unlikely to play a substantial role in causing HIV acquisition in age-disparate relationships in this community.

One concern with our findings might be how the sex-specific HIV prevalence age pattern, peaking for women several years before men, could be generated other than through age-disparate relationships. While our study cannot answer this empirical question, we note that while relationships with large age disparities are sufficient to create this age pattern, they are not necessary. As recently shown in a theoretical modeling study,[22] it is also possible to maintain an HIV epidemic of this type through multiple relationships with relatively small age disparities, or through a core population of high-risk young men having multiple peer-aged relationships.

This study has several strengths, notably the longitudinal nature of the data, collected over almost a decade, and the rich set of covariates, which allow us to rule out many confounding and reverse causation relationships. One benefit of this longitudinal data is that we can capture the exposure of partner age disparity in a time-varying manner, updating each woman's age-disparity information as her sexual relationships change. We also allowed for time-varying sociodemographic variables—

TABLE 4. Sensitivity Analysis Using Stratification by Year of Observation

Year of Observation	Number of HIV Seroconversions	Hazard Ratio for a 1-Yr Increase in Age Disparity	95% CI
2003–05	29	1.00	0.92 to 1.08
2006	80	1.03	0.99 to 1.07
2007	88	0.98	0.94 to 1.03
2008	99	1.00	0.95 to 1.04
2009	75	1.00	0.95 to 1.05
2010	62	1.03	0.98 to 1.09
2011–12	24	0.99	0.90 to 1.08

The first round of observation (2003-05) and last round of observation (January 2011 to June 2012) were grouped together in this sensitivity analysis because observation time-at-risk and observed seroconversions. The hazard ratios are for time-at-risk and seroconversions falling into the calendar time in the first column of this table. The regression model also contains age of respondent (linear, quadratic, and cubic terms centered at 15 years) and all sociodemographic and behavioral covariates from the main analysis.

marital status, educational attainment, and household wealth–to confound or effect modify any age-disparity effect. Finally we accounted for unmeasured, time-varying confounders through the inclusion of year of observation indicator variables, ensuring that the results shown could not have been driven by the differential availability of HIV treatment and prevention interventions over time. Furthermore, the data constitute one of the largest HIV incidence cohorts in young women in Africa, providing very high power to detect significant effects.

We also note some limitations. As with any long-term community-based study, the cohort suffered from attrition and nonresponse. However, nonresponse was limited and our results did not change after accounting for data missingness through multiple imputation. Additionally, age disparity information may be misreported. Evidence from Malawi suggests that women may underestimate their partner's age in relationships with large age disparities, which could bias the results.[36] However, since in South Africa dates of birth are shown in the national identity card, which the vast majority of people in this community owns, knowledge of partners' age is likely to be better than elsewhere in Africa.

Caution is needed in generalizing our findings. Age-disparate relationships are expected to place young women at particularly high risk when they need economic support for survival.[5,12] However, while age-disparate relationships are common in our setting, those displaying economic asymmetries are likely to be less common for two reasons. First, basic survival needs may be greater in other settings: while this setting is one of the poorest in South Africa, it is considerably wealthier than many high HIV-prevalence regions of Africa. Second, since the community is relatively economically homogeneous, the absolute economic differences between partners are not large. The dense social networks in this area may also allow women to differentiate higher and lower risk older men more easily than in more urban or less settled areas, reducing the risk from age-disparate relationships.

In our discussion we have focused primarily on relationships between older men and younger women, since age-disparate partnerships in the community are overwhelmingly of this type. Only 1.8% of relationships were between older women and younger men. Nevertheless, by using a continuous measure of the difference between male and female age as our primary exposure, we also include relationships in which the woman is older than the man, assuming that these relationships are increasingly less risky. This reflects the reality that over the age range we examine, male HIV prevalence is uniformly increasing with age—and thus younger men might be expected to be less risky.

However, an alternative hypothesis might be that any age disparity (either the man or the woman is older) will increase risk if risky behaviors arise in any unequal relationship and any age-disparate relationship contains power differentials. This might be particularly pertinent in settings where older women commonly partner with younger men. To test this hypothesis, we conducted a sensitivity analysis replacing "age-of-male minus age-of-female" with the absolute difference in ages of the partners. The primary relationship remained null in this analysis.

That age-disparate sexual relationships are a primary driver of HIV incidence for young women in sub-Saharan Africa has often been taken as fact, despite limited evidence. Our analysis strongly suggests that in this rural South African community, sexual relationship age disparities do not predict HIV risk for young women. Further research is needed to determine whether this result varies by geographic and social context. Campaigns warning women about the risks of sexual partnerships with older men may well provide social benefits, for instance, if they reduce unwanted pregnancies or school dropout. However, based on our study, such campaigns do not seem to be justified for HIV incidence reduction in settings similar to ours.

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