Marriage in the era of antiretroviral therapy: HIV status and marital change in rural Uganda

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Abstract: Growing awareness about HIV and increasing access to antiretroviral therapy (ART) may be profoundly changing the social implications of HIV in generalized epidemic settings. In particular, ART may impact the association between HIV and marital change, including the formation and dissolution of marriages. This paper describes the relationship between HIV status and marriage transitions both before and after the availability of ART. Our data contain linked marital partnerships and marital histories over 13 years (1999-2011) from a general population cohort with sero-surveillance in southwestern Uganda. We find that patterns of marriage formation and dissolution are highly dependent on HIV status, but also document changes following the introduction of ART. Historically, unions with an HIV-positive partner had higher dissolution rates via both widowhood and divorce, and the remarriage rate of HIV-positive men and women tended to be lower than those of HIV-negative men and women. Since the introduction of ART, seroconcordant positive unions have stabilized and the remarriage rates of HIV-positive men have increased. The availability of treatment does not seem to have affected the divorce rates in serodiscordant couples, or the remarriage rates of HIV-positive women. These HIV- and gender-based differences in marital change have important implications not only for the onward transmission of the virus, but also for the social and economic wellbeing of people living with HIV or living in HIV-affected households.

Keywords: HIV/AIDS, Sub-Saharan Africa, Remarriage, Marital Dissolution, Antiretroviral Therapy

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1 INTRODUCTION

With the expansion of antiretroviral therapy programs, HIV is no longer a death sentence, and no longer debilitates adults in their economic prime. The potential impact of ART is also large: Under the 2013 WHO guidelines an estimated 21.2 million people are eligible for ART in Sub-Saharan Africa, 7.6 million of whom were already receiving treatment as of 2012 (UNAIDS 2013). There are still important gains to be made in improving access to ART, but as the number of people on treatment increases, it is important that we begin to document the social impacts of ART.

Marriage is one domain where ART is likely to have profound effects. ART may not only increase the longevity of HIV-positive individuals – and therefore reduce the incidence of widowhood – but it may also reduce the risks of HIV transmission within unions. Lower transmission risk may alter some of the concerns that men and women have about staying in a union with an HIV-positive partner or about forming new partnerships with someone who is HIV-positive. In other words, we expect that marriage patterns involving HIV-positive individuals will change over time, as awareness increases and treatment is rolled out.

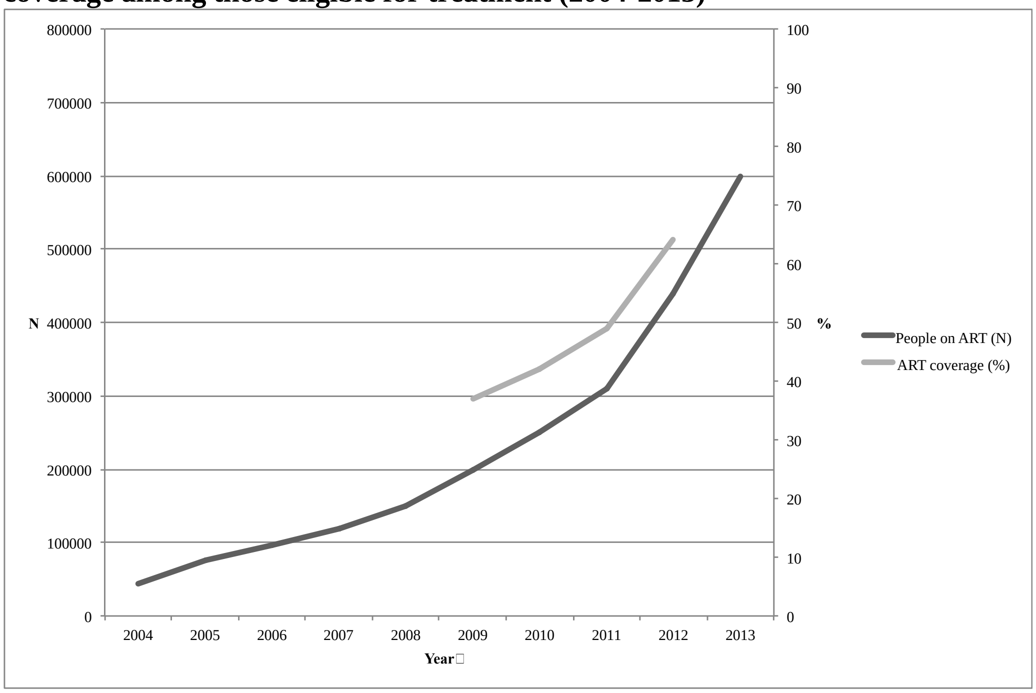
Our current knowledge of the association between marital change and HIV is based on data preceding the availability of ART (Carpenter et al. 1999; Grinstead 2001; Porter et al. 2004; Reniers 2008), or on analyses that control for changes over time but do not make time trends the object of inquiry (Anglewicz and Reniers 2014). As a result, the downstream effects of ART scale-up on marriage dynamics have not yet been described in a generalized epidemic setting. This paper fills this gap, using individual longitudinal data with linked marital partnerships from the pre- and post-ART periods to examine how ART is impacting the association between HIV status and marital change.

We use data between 1999 and 2011 from a demographic and HIV surveillance site in rural Uganda. This period covers the pre-ART era as well as seven years during which ART was locally available at no cost to the patients in the study site. The immediate roll-out of ART to all respondents in the study site who met WHO eligibility guidelines, compared to the slow resource-constrained scale-up of most other settings, makes this study-site the ideal location to examine the impact of ART. We examine three aspects of HIV status-based partnership mixing before and after ART: (i) the association between couples' HIV status and marriage dissolution, (ii) the association between HIV status and remarriage, and (iii) the HIV status configuration of new partnerships among those remarrying. This association between HIV status and marital change is likely to have important implications for the onward transmission of HIV, as well as the social and economic wellbeing of families.

2 HIV AND MARRIAGE IN THE PRE- AND POST-ART PERIODS

Marriage – including customary, religious, civil, or informal union – is a central institution for social organization. Among married couples in Uganda, either one or both partners were HIV-positive in 9.7% of marriages in 2011 (Uganda Ministry of Health and ICF International 2012). The number of HIV-positive men and women on treatment in Uganda has also been increasing exponentially over time. Figure 1 shows the number of men and women on ART in Uganda from 2004 to 2013 and ART coverage among those needing treatment based on WHO 2010 eligibility guidelines. By 2013, an estimated 600,000 men and women – or 1.6% of the total population – were on ART. As of 2012, approximately 64% of those needing treatment were receiving treatment. As more men and women access treatment, the potential impact of ART on the association between marital change and HIV is becoming increasingly important. In the next section, we summarize the evidence for the association between HIV infection and marital dissolution and formation, and discuss how ART may alter these relationships.

Figure 1 Antiretroviral therapy access in Uganda: Number of people on treatment and ART coverage among those eligible for treatment (2004-2013)



Source: Data for the number of people on ART come from from AIDSinfo by UNAIDS (http://www.unaids.org/en/dataanalysis/datatools/aidsinfo) and ART coverage estimates come from the World Development Indicators (http://data.worldbank.org/data-catalog/world-development-indicators)
Note: ART coverage estimates are based on the WHO 2010 guidelines for treatment eligibility, and not the WHO 2013 guidelines that increased the CD4 count eligibility from 350 to 550.

2.1 Selection out of Marriage: Separation, Divorce and Widowhood

Previous longitudinal analyses have documented a clear association between HIV infection and marital dissolution, including both divorce and widowhood. Examining women's marital histories in Rakai (Uganda), Porter et al. (2004) found that HIV-positive women experienced a very high risk of widowhood (OR 7.56, p<0.001) and an elevated risk of divorce or separation (OR 1.94, p<0.001), compared to the risk of the marriage staying intact. The association between HIV infection and marital instability holds for individuals who are HIV-positive (Anglewicz & Reniers 2014; Porter et al. 2004) as well as for couples where one or both partners are HIV-positive (Porter et al. 2004). Marriages in which only the wife is HIV-positive (F+M-) are at an elevated risk of divorce compared to seroconcordant negative unions (F-M-), but there is no difference in the risk of divorce for marriages in which only the husband was HIV-positive (F-M+). Widowhood is more common in seroconcordant positive (F+M+) unions and male-positive serodiscordant unions than in seroconcordant negative unions.

The elevated rates of widowhood are not surprising given AIDS-related mortality, but the mechanisms through which HIV can affect separation and divorce are more complex. HIV infection and the fear of HIV transmission can destabilize unions in both direct and indirect ways. Perceptions of HIV risk have been found to be associated with a higher likelihood of divorce among young women who recently married (Grant and Soler-Hampejsek 2014). HIV may also precipitate marital discord through morbidity-induced economic stress, interference with reproductive ambitions, alcohol use, and sexual dissatisfaction (Nabaitu, Bachengana, & Seeley 1994). In addition, the association between divorce and HIV may be endogenous since some behaviors, such as extra-marital sex, are associated with both HIV infection and union dissolution (Reniers 2008).

We expect that the association between HIV-positive status and divorce is stronger for women than for men because HIV-positive women face greater stigma than HIV-positive men, in part due to women's extra-marital partnerships being less socially acceptable than men's (Amuyunzu-Nyamongo, Okeng'O, Wagura, & Mwenzwa 2007; Hutchinson & Mahlaela 2006; Simbayi et al. 2007), making men more likely to leave HIV-positive wives. Women, in contrast, may have a harder time leaving an HIV-positive husband due to their economic dependence on their partners and the power differential between husbands and wives.

While there is a clearly documented association between marital dissolution and HIV, almost all research to date has used data from the early and mid-2000's, before the wide-scale introduction of ART. The roll-out and scale-up of ART has fundamentally changed the outlook for people living with HIV (PLHIV) and their partners. Once on and adhering to ART, the risk that an individual will transmit HIV is nominal; incidence rates in serodiscordant couples have started to decline (Biraro et al. 2013; Cohen et al. 2011) and ART has drastically increased the expected number of years one can live with HIV (Mills et al. 2011). We therefore expect to see reductions in marriage dissolution rates through both declines in widowhood from lower ART-associated mortality and declines in divorce from reduced HIV transmission risk. Moreover, as more people live, and live healthily, on ART, social perceptions of the consequences of HIV may begin to shift. For example, ART may change childbearing prospects for HIV-infected couples and make HIV-positive partners a more promising choice. However, if ART makes HIV infections easier to hide (Mbonye et al. 2013), it is also possible that partnerships may become more stable because spouses might be unaware of their partners' HIV status.

This paper hypothesizes that while HIV has been historically associated with higher levels of marital dissolution, ART will be associated with a stabilization of HIV-positive marriages. We expect to see the greatest declines in widowhood as ART has a direct effect on mortality. Because the uptake of ART services and treatment outcomes are better for women than for men (Cornell et al. 2012; Druyts et al. 2013; Hawkins et al. 2011; May et al. 2010; Mills et al. 2011; Muula et al. 2007), we expect the changes in widowhood following ART scale-up to be larger for men than for women. We also hypothesize that divorce will have decreased following ART, but more so for seroconcordant positive than serodiscordant couples.

2.2 Selection into Marriage: Remarriage

HIV prevalence in Uganda is highest among formerly married men and women. Divorced or separated women have a prevalence of 17.8%, and widowed women a prevalence of 32.4%. Both are substantially higher than the 7.2% prevalence among currently married women (Uganda Ministry of Health and ICF International 2012). Similarly, divorced and separated men have a prevalence of 14.9%, widowed men a prevalence of 31.4%, while currently married men's prevalence is 7.6% (Uganda Ministry of Health and ICF International 2012). One potential explanation for these high rates is that HIV-positive men and women are being selected out of marriages and are less likely to remarry.

Due to the high rates of HIV infection among formerly married men and women, remarriage poses a significant avenue for future HIV transmission if HIV-infected partners in serodiscordant partnerships are not on ART. These riskier unions are also the most common; most marriages where at least one partner was formerly married were found to be serodiscordant, rather than seroconcordant positive (De Walque & Kline 2012), posing a potential risk to the HIV-negative spouse. While remarriage may play an important role in onward HIV transmission, we do not know the frequency of remarriage. Cross-sectional data across 13 Sub-Saharan African countries indicate that remarried individuals made up 10% of the adult population of reproductive age (De Walque & Kline 2012), and, in Uganda, 18.8% of all marriages were remarriages (MEASURE DHS 2012). These percentages are influenced not only by the likelihood of remarriage, but also by the rates of marital dissolution that determine the proportion of the population exposed to remarriage. Despite the uncertainty of remarriage rates, remarriages comprise an important share of all marriages.

There is evidence to suggest that HIV-positive individuals are less likely to remarry. Widows in Malawi were found to have much lower rates of remarriage, which could be due to their status as widows, or due to the strong association between widowhood and HIV infection (Reniers 2008). More recent research in Malawi has found that HIV-positive women - but not men - were less likely to remarry compared to HIV-negative men and women (Anglewicz & Reniers 2014). Lower remarriage rates may be driven by fears of HIV transmission, but this may change with ART as the risk of transmission among those on treatment is minimal (Cohen et al. 2011). Moreover, those accessing treatment are more likely to interact with HIV clinics and service providers, creating opportunities to meet other HIV-positive people. Previous qualitative research in Uganda (Seeley et al. 2009), Malawi (Gombachika 2012), and Nigeria (Rhine 2009) found that HIV-positive men and women expressed a preference for finding a partner who was also HIV-positive. Treatment may not only decrease the risk of partnering with someone who is HIV-positive, but also facilitate finding partners who would want to marry someone who is HIV-positive.

This paper hypothesizes that remarriage rates are lower for HIV-positive men and women compared to HIV-negative individuals, but that this difference will have attenuated since ART became available. The lower rates of remarriage among HIV-positive individuals may be based on direct selection due to fears of partnering with someone who is HIV-positive. Alternatively, indirect selection could be occurring if HIV is correlated with other attributes that are less desirable for remarriage, such as widowhood or a high number of previous sexual partners. ART could affect the association between HIV and remarriage by decreasing the risk associated with marrying an HIV-positive partner.

3 METHODS AND MEASUREMENT

Data for this analysis come from the General Population Cohort (GPC) in the Masaka district in rural southwest Uganda. The GPC study consists of an annual population census, a medical survey, and sero-survey that has been conducted in the area since 1989. It comprises a rural open population cohort with approximately 20,000 adult and child respondents from 25 villages. Details of the population and methodology have been described elsewhere (Nunn et al. 1997; Nakibinge et al. 2009; Asiki et al. 2013). This paper draws on data from 1999-2011 (census rounds 9-22), when data were collected on linked marital partnerships. The dataset includes information on individual demographic variables, sexual behavior and marriage histories, and HIV status. The census had a participation rate of 95-99%, while the adult medical survey had a 63-75% participation rate, varying over the 13 rounds in this sample (Asiki et al. 2013).

Among those participating in the adult medical survey, HIV status is missing for 18-35% of respondents in each round. The irreversible nature of HIV infection allows for backwards imputation of negative HIV status and forward imputation of positive HIV status. When HIV status is missing in rounds between a negative and a positive HIV test, the assumption is made that HIV seroconversion occurred at the mid-point of the interval for missing data gaps of three years or less. When the gap between a negative and a positive HIV test is greater than three years, a negative HIV test is imputed forward a maximum of two person-years, and a positive HIV test is imputed backwards a maximum of two person-years. All other missing HIV data are not imputed. The results presented in this paper are not sensitive to this method of imputation. Similar methods of imputation have been employed by other studies using the GPC and other similar sero-surveillance sites (e.g. Reniers et al. 2014). After imputation of HIV status, 23% of men's person-years and 14% of women's person-years still have missing HIV status among ever-married adults. They are hence excluded from the analysis.

Union status information is collected during the adult survey and is self-reported by respondents. Marriage is defined in the GPC as both formal (religious, customary and civil) and informal unions. Respondents are asked if they are married, and if there is someone whom they consider to be their husband or wife. Respondents report the names of their marital partners during the adult survey. If their marital partner was ever included in the GPC census, they have a unique identification number that is recorded in the original survey questionnaire. For this analysis, marital identification numbers are derived from individual identification numbers in order to construct an analytic sample based on couples.

There are 1,154 cases of discrepant reports of marital status between husbands and wives out of the 20,591 couple observation-years. To address these discrepant reports we use residential status and past and future marital status reports to determine the most likely status of the marital union. Unions are considered to have ended if at least one of the spouses reported dissolution and they were no longer co-residing in a household in the current or following census round. When there is disagreement in the timing of dissolution, it is assumed that dissolution occurred at the mid-point between the two reports. Census data from the study site are used to confirm reported cases of widowhood. In 15.3% of discrepant cases we find no evidence to indicate the union had dissolved. We resolve all discrepant reports of marital status through place of residence, reported deaths and migrations, and differential timing in reports on union dissolution. All analyses are run excluding discrepant marital status reports and this does not change any of the findings. As such, the results presented in this paper include resolved discrepant reports.

The GPC survey does not consistently record the date of union formation or the previous number of marriages across survey rounds, resulting in a large amount of missing data on marital duration. This study therefore makes use of observed, rather than actual, marital duration as the measure of exposure. Duration is counted from the first year in which a couple is observed in the study, though it is possible the union formed prior to the couple's inclusion in the study, potentially biasing interpretation of duration estimates. Analyses restricted to marriages that started between 1999-2011 yield similar results, but come with a loss in statistical power.

3.1 Marital Dissolution

To examine trends in marital dissolution, we construct a dataset based on couples to include all currently married respondents aged 15 years and older with a matched spouse in the study site. We exclude from the dataset those couples where either one or both partners have missing HIV status (12% of couples' person-years among linked partnerships). Over the 13 years of observation, there were 3,647 couples. Men and women could contribute multiple marriages to the analysis through either polygyny or remarriage. 3,440 women and 2,772 men contributed to the couples' analysis, for a total of 20,591 marital person-years.

Table 1 presents background characteristics for the couples' sample along with percentages experiencing divorce or widowhood. Of the 3,647 marriages, 645 ended in divorce/separation and 247 in widowhood. For simplicity, we use the term divorce to encompass both divorce and separation. Not surprisingly, widowhood was more common in partnerships with at least one HIV-positive spouse. Divorce was more common in serodiscordant marriages; divorce was equally prevalent in seroconcordant negative marriages as seroconcordant positive marriages. Both divorce and widowhood were more common when there were large age differences between spouses, with divorce being more likely when the wife was older, and widowhood when the husband was older.

Table 1: Background characteristics of marital partnerships in Masaka, Uganda (1999-2011)

	Couples Sample		
	All	Percent experiencing event	
		Divorce	Widowhood
Couple's Characteristics			
Number of Couples	3,647		
Number of Women	3,440		
Number of Men	2,772		
Marriage-years of observation	20,591		
Marital dissolution			
Divorce/Separation	645		
Widowhood	247		
Observed marital duration			
<=1 year	137	11.7%	0.7%
2-5 years	1,812	25.1%	7.0%
6-10 years	817	14.4%	10.2%
11-14 years	881	6.5%	4.1%
HIV status (at last observation)			
(F- M-)	3,083	16.9%	5.4%
(F- M+)	166	21.1%	12.0%
(F+ M-)	166	30.1%	9.6%
(F+ M+)	232	16.8%	19.4%
Age difference between spouses			
Wife >= 10 years younger	1,257	16.9%	9.1%
Wife 5-9 years younger	1,118	16.2%	4.9%
Wife < 5 years younger or older	1,132	17.8%	6.0%
Wife >= 5 years older	140	35.0%	6.4%
Wives' Characteristics			
Age (at last observation)			
15-24	821	20.8%	1.1%
25-34	1,175	18.4%	3.4%
35-44	777	16.6%	8.9%
45-54	470	16.8%	8.7%
55+	404	12.4%	21.8%
Observed number of marriages			
First marriage	3,467	17.5%	6.8%
2-3 previous marriages	170	20.0%	6.5%
4+ previous marriages	10	30.0%	10.0%
Ethnicity			
Muganda	2,239	16.2%	5.4%
Munyanrwanda	516	20.7%	5.4%
Other/Unknown	892	19.7%	10.9%
Education			
No Education	312	21.5%	19.9%
Some Primary	2,399	18.3%	6.7%
Some Secondary	748	13.2%	2.5%
Unknown	188	20.7%	2.7%
Husbands' Characteristics			
Age (at last observation)			
15-24	182	19.8%	1.1%
25-34	1,051	20.8%	1.9%
35-44	968	18.5%	5.2%
45-54	582	16.7%	6.4%
55+	864	13.5%	16.0%
Observed number of marriages			
First marriage	2,042	29.6%	11.3%
2-3 previous marriages	630	6.3%	2.4%
4+ previous marriages	50	0.0%	2.0%
Ethnicity			
Muganda	2,283	17.0%	3.8%
Munyanrwanda	421	19.0%	4.3%
Other	943	18.7%	15.2%
Education			
No Education	168	23.2%	18.5%
Some Primary	2,368	19.3%	6.4%
Some Secondary	978	13.8%	5.0%
Unknown	133	9.8%	12.0%

To establish whether marriages where one or both partners are HIV-positive are more likely to dissolve, we use a multinomial logistic regression model (Eq. 1). This model estimates the log odds of the hazard of divorce ($h_{ct}^{(r=1)}$) and hazard of widowhood ($h_{ct}^{(r=2)}$)), relative to the hazard of the couple staying married ($h_{ct}^{(r=0)}$). The subscript *c* denotes couples and the superscript *r* denotes marital outcome, where *r* = 0, 1, and 2 represents no dissolution, divorce, and widowhood, respectively, and *t* refers to the observed duration married. Marriages that are intact at the time of the last contact with a fieldworker, or that have one or both spouses migrate outside of the study site, are censored.

Couples' lagged HIV status (at time *t-1)* is the primary predictor of interest, with seroconcordant negative couples (F-M-) as the reference category. Three models compare how the association between couples' HIV status and union dissolution changes over time. Model 1 includes the controls for couples' lagged HIV status (F-M+, F+M-, and F+M+), with seroconcordant negative couples as the reference category (F-M-). Model 2 adds a dummy variable control for whether the observation falls into the time period after ART became available. ART was first introduced in the study site in 2004, after which point all participants in the GPC had access to free ART. In the analyses, we use a simple dichotomy (pre/post ART). Other specifications of time are tested, including a variable with an additional category identifying the rollout phase, and a continuous time variable with 2004 as the reference year. These do not change the results and are not included.

Model 3 (shown in Eq. 1) includes interaction terms between the post-ART dummy and the couples' lagged HIV status. The first three parameters ($\beta_1^{(r)}$ to $\beta_3^{(r)}$) estimate the relative risk of each outcome among seroconcordant positive and serodiscordant couples in the pre-ART period, compared to the relative risk of each outcome among seroconcordant negative couples in the pre-ART period. The following four parameters ($\beta_4^{(r)}$ to $\beta_7^{(r)}$) predict how the relative risk of divorce and widowhood differs in the post-ART period, compared to the pre-ART risk for couples of the same HIV status.

In Eq. 1 the time-invariant control variables are estimated with the vector $\gamma^{(r)}$, including husbands' and wives' education and ethnicity, and the age difference between spouses. $\delta_t^{(r)}$ is a vector of time-varying covariates, including a linear and quadratic term for the observed duration married. Age, age-squared, husbands' and wives' marital order, age at first marriage and age at first sex are removed from the models presented here as they did not improve model fit. The model also includes a constant, $\alpha^{(r)}$.

(1)

$$log\left[\frac{h_{ct}^{(r)}}{h_{ct}^{(0)}}\right] = \alpha^{(r)}$$

$$+ \beta_1^{(r)}\Big((F + M+)_{c(t-1)} + \beta_2^{(r)}(F + M -)_{c(t-1)}$$

$$+ \beta_3^{(r)}(F - M +)_{c(t-1)} + \beta_4^{(r)}PostART_t \times (F - M -)_{c(t-1)}$$

$$+ \beta_5^{(r)}PostART_t \times (F + M +)_{c(t-1)}$$

$$+ \beta_6^{(r)}PostART_t \times (F + M -)_{c(t-1)}$$

$$+ \beta_7^{(r)}PostART_t \times (F - M +)_{c(t-1)}\Big) + \boldsymbol{\gamma}^{(r)} + \boldsymbol{\delta}_t^{(r)}$$

The multinomial regression model is based on the assumption of independent observations, but, since both men and women contribute multiple marriages to the analysis, the observations are correlated. This is typically addressed through the inclusion of random effects in the model. However, since both men and women contribute multiple marriages, marriages are not nested hierarchically under individuals, but rather are crossed (Rabe-Hesketh & Skrondal 2012). A multinomial model with crossed-effects cannot be run using conventional statistical software (e.g., Stata 13). Instead, we choose to randomly sample from men and women's marriages so as to include only one marriage per respondent in the sample in the following manner: First, one marriage is randomly selected from men who contribute multiple marriages to the analysis. This procedure is then repeated among women using only the marriages that are selected in the men's random sample. The resulting sample consists of 2,627 marriages contributing 15,556 marriage-years of observations (reduced from 3,647 marriages contributing 20,591 marriage-years of observations in the full sample). We estimate robust standard errors clustered at the couple level. The results using this sample are compared with (1) randomly selecting women's marriages first, and then men's, and (2) separate logit models to analyze divorce and widowhood with sex-specific random effects on the full set of marriages. The results from these alternative model specifications and those presented in this paper are not substantively different.

3.2 Remarriage

To study the association between HIV status and remarriage among formerly married individuals, we limit our dataset to individuals between 15 and 60 years of age, as remarriage is rare in older ages. We also look only at selection into higher order marriages, excluding first marriages. Given the near universal experience of first marriage in rural Uganda, we expect HIV to matter more for more selective higher-order marriages. Table 2 provides background characteristics of formerly married men and women, including the percentage that remarries.

An unmarried episode is defined as the time between the end of a previous marriage (or someone is first observed as unmarried in the study and reported being formerly married) and remarriage. There are 2,226 women who were formerly married, contributing a total of 2,674 unmarried episodes, and 1,198 men contributing 1,509 unmarried episodes. Men's unmarried episodes are more likely to result in remarriage: 47.1% of men's unmarried episodes resulted in marriage, but only 34.9% of women's. Remarriage is more common among those who were divorced, rather than widowed, and among those with higher education levels.

Table 2: Characteristics of formerly married respondents in Masaka, Uganda (1999-2011)

	Individual Sample			
	Female		Male	
	N	Percent experiencing remarriage	N	Percent experiencing remarriage
Formerly married episodes	2,674		1,509	
Formerly married respondents	2,226		1,198	
Person-years formerly married	9,341		4,459	
Remarriages	934		711	
Observed number of times formerly married				
1	1,855	20.1%	955	30.2%
2	309	36.5%	191	54.5%
3	50	36.0%	39	61.5%
4	9	33.3%	10	20.0%
5	3	33.3%	3	100.0%
Characteristics of formerly married episodes				
Observed duration formerly married				
<=1 year	371	59.0%	382	74.4%
2-5 years	1,732	34.9%	903	42.0%
6-10 years	414	23.7%	180	24.4%
11-14 years	157	8.3%	44	9.1%
HIV status (at last observation)				
Negative	2,095	37.4%	1,222	49.2%
Positive	579	26.1%	287	38.3%
Sex in last 12 months (at last observation)				
Yes	971	70.7%	810	74.4%
No	1,703	14.6%	699	15.5%
Age (at last observation)				
15-24	325	47.4%	88	40.9%
25-34	719	46.9%	503	59.6%
35-44	678	38.8%	454	49.1%
45-59	952	18.2%	464	32.8%
Observed prior marriages				
1	2,070	20.1%	922	19.9%
2-3	574	86.1%	555	90.1%
4+	30	83.3%	32	87.5%
Marital status				
Ever divorced/ separated	1,551	35.7%	1,060	40.8%
Ever widowed	453	16.3%	91	44.0%
Both divorced and widowed	503	27.8%	176	32.4%
Dissolution cause unknown	167	100.0%	182	100.0%
Ethnicity				
Muganda	1,765	36.6%	844	52.5%
Munyanrwanda	419	34.6%	258	41.1%
Other	490	29.2%	407	39.8%
Education				
No education	243	28.0%	77	31.2%
Some primary	1,792	37.1%	1,082	47.3%
Some secondary	460	39.6%	296	55.1%
Unknown	179	11.2%	54	22.2%

Note: The percent remarrying is influenced by the duration a man or woman has remained single. However, since duration single is only observed from the 1999 onwards, we do not know the exact length people have been exposed to the risk of remarriage. Percentages of those experiencing remarriage presented in this table do not take into account exposure.

A discrete-time logistic regression model is used to estimate the odds of remarriage among the formerly married, with separate models for men and women. Time (t) is the observed duration unmarried, not reported duration. We compare the full sample in this paper with the sample of only those with known duration unmarried, and find similar substantive conclusions. Similar to the models for marital dissolution, a series of three models examine how remarriage changes with ART. Model 1 includes a dummy variable for lagged HIV-positive status, and model 2 a dummy variable for the post-ART period (2005-2011). Model 3 (shown in Eq. 2) includes the dummy variable for lagged HIV-positive status, and two interaction terms between lagged HIV-status and the post-ART dummy variable. We estimate three parameters of interest: β_1 estimates the odds of remarriage for HIV-positive individuals in the pre-ART period, compared to HIV-negative individuals in the pre-ART period. β_2 estimates the odds of remarriage among HIV-negative men and women in the post-ART period, compared to HIV-negative men and women in the pre-ART periods. Likewise, β_3 estimates the odds of remarriage among HIV-positive men and women after ART, compared to HIV-positive men and women before ART.

All three models include a series of time-invariant controls, including education, ethnicity, and number of previous marriages, represented by the vector γ in Eq. 2. Time-varying covariates, including a linear and quadratic term for age, are included in vector $\eta(t)$. $\delta(t)$ is a vector of discrete-time variables controlling for the duration unmarried. Since men and women can contribute multiple unmarried episodes, we include the individual-level random effect u_j, which is assumed to be normally distributed with a mean of 0 and variance σ_u^2. In Eq. 2, t denotes the duration unmarried, *j* the individual, and *i* the unmarried-episode for that individual.

$$logit\left[h_{ij}(t)\right] = \alpha + \beta_1 HIV(+)_{ij}(t-1) + \beta_2 PostART \times HIV(-)_{ij}(t-1) + \beta_3 PostART \times HIV(+)_{ij}(t-1) + \gamma + \eta(t) + \delta(t) + u_j \quad (2)$$

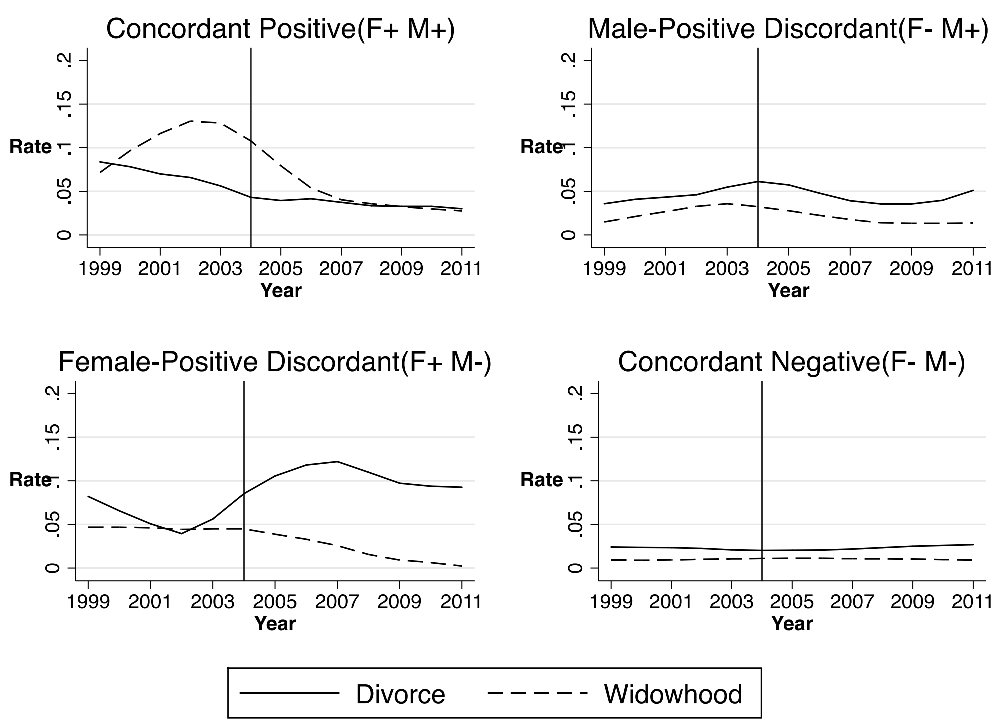
$$u_j \sim N(0, \sigma_u^2)$$

We also use the model in Eq. 2 to analyze the HIV status of new spouses among those who remarry. The sample is restricted to formerly married men and women who have remarried and can be linked to a partner with a known HIV status at the time of marriage (N=918, 56% of remarriages). The outcome variable is the HIV status of their spouse at remarriage, represented by a binary variable equal to one when their spouse is HIV-positive. The primary predictor continues to be the individual's own HIV status at remarriage, and an interaction between HIV status and the post-ART period. We again control for age (a linear and quadratic term), education, ethnicity and the number of previous marriages, and a series of discrete-time variables to control for duration unmarried. Men and women are included in the same model. We test for differences between men and women, but find that the odds of marrying an HIV-positive partner by the individual's own HIV status do not vary by gender. For this reason the gender controls are excluded from the models shown here.

4 RESULTS: MARITAL DISSOLUTION

The rates of divorce and widowhood in Figure 2 support our hypothesis that marital dissolution is higher in HIV-infected marriages, and that since the introduction of ART there have been important changes in the rates of divorce and widowhood. Figure 2 shows the Lowess smoothed (Cleveland 1981) rates of divorce and widowhood for each combination of husbands' and wives' HIV status. The vertical line at 2004 denotes the introduction of ART. The upper left quadrant shows that seroconcordant positive couples experience a reduction in both widowhood and divorce over time. While seroconcordant positive couples experience a convergence in their rates of divorce and widowhood, female-positive serodiscordant marriages experience an increasing persistently high rate of divorce after ART but a declining rate of widowhood. Male-positive serodiscordant couples do not see a large reduction in divorce, though they experience a decline in widowhood since the introduction of ART.

Figure 2 Lowess smoothed rates of divorce and widowhood by couples' HIV status from 1999-2011 in rural Uganda



Note: Lowess graph constructed in Stata. The smoothed value is calculated using the weighted surrounding observations with a bandwidth of 0.8 (StataCorp 2013). The vertical line indicates the time at which ART became freely accessible in the study site.

Examining how couples' HIV status predicts marital dissolution in the subsequent year, we find that couples in which at least one partner is HIV-positive are more likely to experience dissolution than have their marriage remain intact (Table 3, Model 1). Overall, the relative risk for widowhood is higher than the relative risk of divorce. The relative risk of widowhood is highest in marriages where both partners are HIV-positive, while the relative risk of divorce is highest in marriages in which only the female is HIV-positive, compared to the risk of widowhood and divorce, respectively, for seroconcordant negative marriages. Marriages in which the woman is older than the man by five or more years have over three times the relative risk of divorce rather than the marriage not dissolving, compared to women and men who are within five years of each other's age. Marriages in which the wife is younger than the husband by more than 10 years have the highest relative risk of widowhood rather than the marriage not dissolving, compared to the risk of widowhood for couples within five years of age of each other.

Model 2, which adds an indicator variable for the post-ART period, shows that the relative risk of widowhood compared to staying married decreases by 35.2% after the introduction of ART, and that the relative risk of divorce compared to staying married increases by 54.4% after ART. Once the interaction terms are added (Model 3), we see that the relative risk of divorce and widowhood in the post-ART varies greatly by the HIV status of the couple. Seroconcordant negative couples have no change in their relative risk of widowhood between the pre- and post ART periods. The relative risk of divorce, on the other hand, increases in the post-ART period for seroconcordant negative marriages compared to the pre-ART period (RRR = 1.680). Seroconcordant positive marriages seem to benefit from the availability of treatment, as the relative risk of widowhood compared to no dissolution decreases by 70.3% compared to seroconcordant positive couples before ART.

Table 3: Multinomial logistic regression of lagged couples sero-status on the risk of divorce and widowhood compared to no dissolution (relative risk ratios)

	Model 1		Model 2		Model 3	
	Divorce	Widowhood	Divorce	Widowhood	Divorce	Widowhood
Couples HIV Status (lagged)						
Concordant Negative (F- M-)	1	1	1	1	1	1
Concordant Positive (F+ M+)	1.950**	6.843***	1.854**	7.142***	2.908***	11.20***
	(1.277 - 2.979)	(4.396 - 10.65)	(1.202 - 2.860)	(4.552 - 11.21)	(1.672 - 5.058)	(6.586 - 19.06)
Female-Positive Discordant (F+ M-)	3.020***	3.437***	2.854***	3.548***	2.906***	5.532***
	(2.059 - 4.430)	(1.738 - 6.797)	(1.939 - 4.200)	(1.793 - 7.024)	(1.564 - 5.402)	(2.487 - 12.31)
Male-Positive Discordant (F- M+)	1.877**	2.646**	1.862**	2.684**	2.228**	3.905***
	(1.212 - 2.905)	(1.437 - 4.871)	(1.200 - 2.888)	(1.458 - 4.938)	(1.244 - 3.992)	(1.875 - 8.134)
Post-ART			1.544***	0.648*		
			(1.226 - 1.945)	(0.434 - 0.967)		
Post-ART X HIV						
(F-M-) x ART					1.680***	0.902
					(1.304 - 2.165)	(0.584 - 1.393)
(F+ M+) x ART					0.681	0.297**
					(0.288 - 1.613)	(0.131 - 0.673)
(F+ M-) x ART					1.608	0.233+
					(0.734 - 3.521)	(0.0430 - 1.259)
(F- M+) x ART					1.155	0.319
					(0.480 - 2.779)	(0.0793 - 1.280)
Wife's Education						
No Education (ref)	1	1	1	1	1	1
Some Primary	1.257	0.438***	1.136	0.472***	1.127	0.467***
	(0.883 - 1.790)	(0.297 - 0.646)	(0.792 - 1.630)	(0.320 - 0.697)	(0.786 - 1.615)	(0.316 - 0.691)
Some Secondary	1.240	0.195***	1.051	0.221***	1.033	0.212***
	(0.805 - 1.909)	(0.0979 - 0.387)	(0.673 - 1.641)	(0.111 - 0.442)	(0.662 - 1.612)	(0.106 - 0.424)
Unknown	2.973***	0.201*	2.553***	0.223*	2.529***	0.215*
	(1.752 - 5.043)	(0.0451 - 0.899)	(1.481 - 4.399)	(0.0496 - 0.999)	(1.466 - 4.362)	(0.0479 - 0.966)
Husband's Education						
No Education (ref)	1	1	1	1	1	1
Some Primary	0.878	0.454***	0.805	0.476**	0.798	0.459***
	(0.585 - 1.317)	(0.289 - 0.712)	(0.534 - 1.215)	(0.304 - 0.744)	(0.530 - 1.203)	(0.292 - 0.724)
Some Secondary	0.608*	0.418**	0.560*	0.437**	0.556*	0.435**
	(0.385 - 0.960)	(0.239 - 0.732)	(0.353 - 0.888)	(0.250 - 0.764)	(0.351 - 0.881)	(0.248 - 0.763)
Unknown	0.828	1.650	0.805	1.725	0.781	1.653
	(0.393 - 1.744)	(0.724 - 3.757)	(0.388 - 1.673)	(0.760 - 3.916)	(0.375 - 1.630)	(0.720 - 3.798)
Wife's Ethnicity						
Muganda (ref)	1	1	1	1	1	1
Munyanrwanda	1.011	0.900	0.995	0.919	0.987	0.911
	(0.724 - 1.411)	(0.542 - 1.496)	(0.716 - 1.385)	(0.551 - 1.534)	(0.710 - 1.371)	(0.547 - 1.517)
Other	0.723	1.150	0.717	1.152	0.716	1.173
	(0.483 - 1.084)	(0.704 - 1.878)	(0.481 - 1.070)	(0.701 - 1.893)	(0.480 - 1.068)	(0.714 - 1.927)
Husbands's Ethnicity						
Muganda (ref)	1	1	1	1	1	1
Munyanrwanda	1.016	0.361**	0.990	0.368**	0.987	0.368**
	(0.711 - 1.452)	(0.186 - 0.699)	(0.696 - 1.409)	(0.189 - 0.717)	(0.694 - 1.404)	(0.189 - 0.717)
Other	1.106	0.528*	1.071	0.539*	1.075	0.540*
	(0.773 - 1.584)	(0.298 - 0.935)	(0.750 - 1.529)	(0.303 - 0.960)	(0.753 - 1.536)	(0.303 - 0.960)
Age Difference with Spouse						
Wife >= 10 years younger	1.131	1.725**	1.120	1.731**	1.122	1.722**
	(0.880 - 1.453)	(1.205 - 2.470)	(0.871 - 1.440)	(1.210 - 2.476)	(0.873 - 1.443)	(1.205 - 2.461)
Wife 5-9 years younger	0.934	0.971	0.927	0.982	0.935	0.996
	(0.720 - 1.211)	(0.649 - 1.453)	(0.714 - 1.202)	(0.657 - 1.466)	(0.721 - 1.214)	(0.669 - 1.483)
Wife < 5 years younger or older	1	1	1	1	1	1
Wife >= 5 years older	3.368***	1.025	3.214***	1.057	3.184***	1.032
	(2.201 - 5.155)	(0.340 - 3.094)	(2.098 - 4.924)	(0.351 - 3.183)	(2.085 - 4.862)	(0.345 - 3.083)
Observed Marital Duration						
Duration	0.821***	1.146	0.824**	1.156+	0.827**	1.167+
	(0.731 - 0.922)	(0.964 - 1.362)	(0.732 - 0.928)	(0.973 - 1.374)	(0.734 - 0.931)	(0.979 - 1.390)
Duration Squared	1.009*	0.994	1.006	0.996	1.006	0.995
	(1.000 - 1.018)	(0.983 - 1.006)	(0.997 - 1.016)	(0.985 - 1.008)	(0.997 - 1.016)	(0.984 - 1.007)
Model Fit						
AIC	5559.649		5545.289		5542.032	
BIC	5850.432		5851.377		5894.033	
Number of couples	2,627	2,627	2,627	2,627	2,627	2,627
Number of events	400	197	400	197	400	197
Marriage-years of observation	15,556	15,556	15,556	15,556	15,556	15,556

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

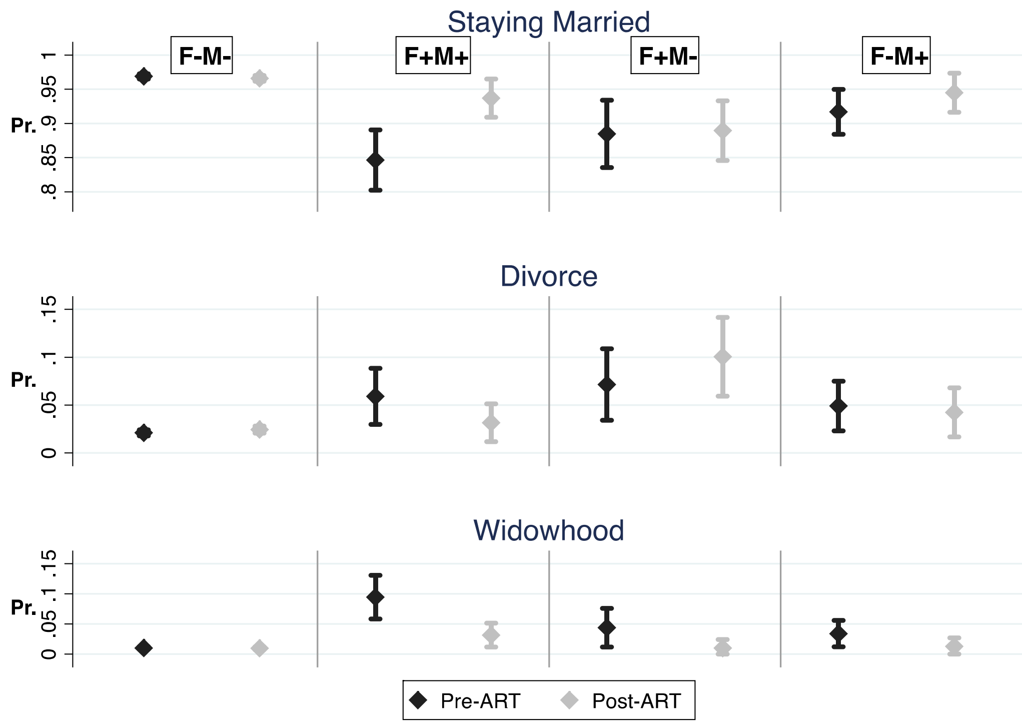
Note: The reference category for all relative risk ratios is no dissolution. Age, marital order, age at first marriage and age at first sex were also tested as controls, but were not included as they were insignificant and did not improve the model fit. Further information on the AIC and BIC measures of model fit can be found in Akaike (1981) and Gelfand and Dey (1994).

These relative risks are difficult to interpret because the risk of divorce or widowhood is in relation to the base outcome of the couple staying married. The risks of each outcome – becoming divorced, becoming widowed, or remaining remarried – change over time. To obtain insight into the absolute risks, rather then just relative risks, we estimate the average predicted probability of divorce and widowhood among seroconcordant and serodiscordant marriages in the pre- and post-ART period using the margins command in Stata (StataCorp 2013). This calculation uses the average of the predicted probabilities for each marriage, rather than the predicted probability for the average marriage.

Serodiscordant couples experience a decline in their probability of widowhood, from .044 in the pre-ART period to .010 in the post-ART period for female-positive serodiscordant couples, and from .034 to .013 for male-positive serodiscordant couples (Fig. 3). However, the decline in widowhood between the pre- and post-ART period is not significant for either type of marriage. We see no statistically significant changes in the average predicted probability of divorce in the post-ART period for serodiscordant marriages. Although the average predicted probability of divorce among female-positive serodiscordant marriages increases from .071 to .100 between the pre- and post-ART periods, this change is not statistically significant. We observe no change in the predicted probability of divorce for male-positive serodiscordant couples.

The average predicted probability of both widowhood and divorce decrease between the pre- and post-ART periods for seroconcordant positive couples. Together, these reductions in widowhood and divorce lead to a stabilization of seroconcordant positive marriages; seroconcordant positive couples are the only group to have a significantly higher predicted probability of staying married in the post-ART period than in the pre-ART period, an increase from .846 to .937.

Figure 3 Average predicted probability of staying married, divorce and widowhood by couples' HIV status in the pre- and post-ART periods (calculated from Table 3, Model 3)

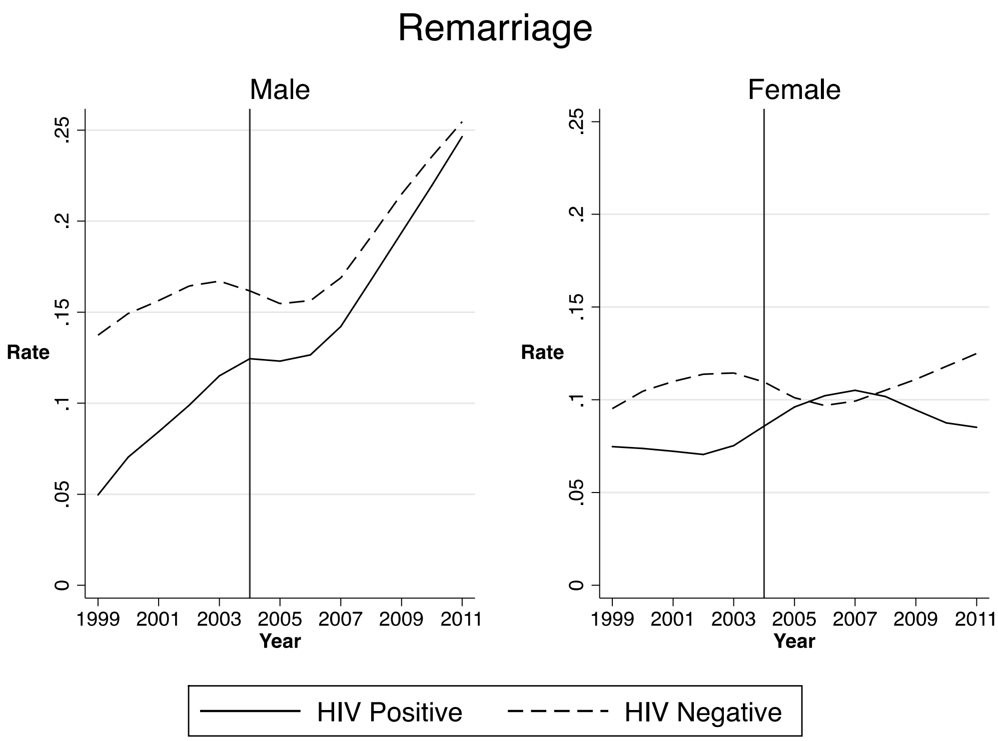


Note: Average predicted probabilities calculated using the Margins command in Stata (StataCorp 2013). The predicted probability of staying married is plotted in a different scale from the predicted probability of divorce and widowhood. The sum of all three predicted probabilities for each HIV-status group equals one.

5 RESULTS: REMARRIAGE

The hypothesis that PLHIV are being excluded from marriage would suggest that both HIV-positive men and HIV-positive women are less likely to remarry. We find, however, that Lowess smoothed remarriage rates (unadjusted for covariates) increase for HIV-positive and HIV-negative men over time, whilst remaining relatively stable for women (Fig. 4). In the pre-ART period, HIV-positive men have much lower remarriage rates than HIV-negative men, but after the introduction of ART there is a convergence of remarriage rates by HIV status. Remarriage rates for HIV-positive and HIV-negative women remain below those of men, except in the earliest years. For the majority of years, HIV-negative women have higher rates of remarriage than HIV-positive women.

Figure 4 Lowess smoothed remarriage rates by individual HIV status from 1999-2011 in rural Uganda



Note: Lowess graph constructed in Stata. The smoothed value is calculated using the weighted surrounding observations with a bandwidth of 0.8 (StataCorp 2013). The vertical line indicates the time at which ART became freely accessible in the study site.

The lower likelihood of remarriage among HIV-positive men and women holds even after controlling for factors that may affect remarriage prospects, and are correlated with HIV status (e.g., age, education, ethnicity, the previous number of marriages, and the duration of non-married life) (Table 4). Without any controls for pre- and post-ART differences (Model 1), we find that women have a 42.7% lower odds of remarrying when they are HIV-positive, and HIV-positive men have a 31.5% lower odds of remarriage, compared to HIV-negative women and men, respectively. In the post-ART period, remarriage rates increase for men (OR 1.332), but are unchanged for women (post-ART indicator, Model 2). We see no significant interaction between HIV status and the post-ART period for women (Model 3). Men, however, experience a change in their odds of remarriage between the pre- and post-ART period: HIV-negative men have a 24.2% higher odds of remarriage in the post-ART period than in the pre-ART period, while HIV-positive men have over two times the odds of remarriage in the post-ART period than HIV-positive men in the pre-ART period. In the post-ART period, HIV-positive and HIV-negative men have a similar average predicted probability of remarriage (.167 for HIV-positive men and .190 for HIV-negative men, results not shown).

Conditional on remarriage, HIV-positive men and women have, on average, over 24 times the odds of remarrying someone who is also HIV-positive, compared to the odds of someone who is HIV-negative marrying someone who is HIV-positive (Table 5, Model 1). In Model 3 we see no change in the odds of remarrying an HIV-positive spouse among both HIV-positive or HIV-negative men and women.

Table 4: Logistic regression of lagged HIV status on remarriage among formerly married respondents (odds ratios)

	Females			Males		
	Remarriage Model 1	Remarriage Model 2	Remarriage Model 3	Remarriage Model 1	Remarriage Model 2	Remarriage Model 3
HIV Status (lagged)						
HIV Negative (ref)	1	1	1	1	1	1
HIV Positive	0.573***	0.565***	0.490***	0.685**	0.671**	0.498**
	(0.449 - 0.733)	(0.441 - 0.726)	(0.345 - 0.696)	(0.526 - 0.894)	(0.511 - 0.882)	(0.325 - 0.764)
Post-ART		1.134			1.332**	
		(0.953 - 1.349)			(1.095 - 1.621)	
Post-ART X HIV						
HIV Negative X ART			1.086			1.242*
			(0.902 - 1.309)			(1.010 - 1.527)
HIV Positive X ART			1.405+			2.048**
			(0.943 - 2.092)			(1.251 - 3.352)
Age (Centered)						
Age	0.927***	0.925***	0.926***	0.973***	0.972***	0.972***
	(0.913 - 0.940)	(0.912 - 0.939)	(0.912 - 0.939)	(0.963 - 0.983)	(0.962 - 0.983)	(0.962 - 0.983)
Age Squared	0.998***	0.998***	0.998***	0.999*	0.999*	0.999*
	(0.997 - 0.999)	(0.997 - 0.999)	(0.997 - 0.999)	(0.998 - 1.000)	(0.998 - 1.000)	(0.998 - 1.000)
Education						
No Education (ref)	1	1	1	1	1	1
Some Primary	1.248	1.200	1.206	2.088**	1.954**	1.960**
	(0.907 - 1.717)	(0.865 - 1.664)	(0.870 - 1.671)	(1.301 - 3.350)	(1.204 - 3.169)	(1.209 - 3.177)
Some Secondary	1.468*	1.401+	1.407+	2.947***	2.715***	2.710***
	(1.014 - 2.125)	(0.959 - 2.047)	(0.964 - 2.052)	(1.775 - 4.893)	(1.614 - 4.565)	(1.613 - 4.551)
Unknown	0.469*	0.451**	0.455**	1.386	1.255	1.262
	(0.260 - 0.847)	(0.248 - 0.822)	(0.251 - 0.828)	(0.635 - 3.027)	(0.564 - 2.792)	(0.568 - 2.803)
Ethnicity						
Muganda (ref)	1	1	1	1	1	1
Munyanrwanda	1.116	1.112	1.110	0.922	0.931	0.936
	(0.873 - 1.426)	(0.867 - 1.425)	(0.867 - 1.421)	(0.713 - 1.192)	(0.715 - 1.213)	(0.719 - 1.218)
Other	1.015	1.007	1.007	0.993	0.999	0.999
	(0.734 - 1.405)	(0.724 - 1.400)	(0.725 - 1.397)	(0.758 - 1.300)	(0.757 - 1.319)	(0.757 - 1.317)
Number of previous marriages	2.012***	1.929***	1.940***	2.186***	2.000***	1.981***
	(1.593 - 2.542)	(1.507 - 2.468)	(1.518 - 2.479)	(1.784 - 2.680)	(1.603 - 2.497)	(1.589 - 2.469)
Observed duration controls	Yes	Yes	Yes	Yes	Yes	Yes
ρ	0.189	0.203	0.197	0.0646	0.0870	0.0839
σ	0.875	0.914	0.899	0.477	0.560	0.549
AIC	5597.857	5597.803	5598.409	3649.343	3642.647	3640.993
BIC	5769.269	5776.357	5784.105	3789.984	3789.681	3794.419
Number of respondents	2,226	2,226	2,226	1,198	1,198	1,198
Person-years formerly married	9,341	9,341	9,341	4,459	4,459	4,459
Number of remarriages	934	934	934	711	711	711

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Note: All respondents aged 15-59 who were unmarried but formerly married were included in the model. Sigma is the square root of the variance of the individual-level random effect, and Rho is intra-class correlation, or the fraction of the variance that is explained by the individual-level random effect.

Table 5: Logistic regression of lagged HIV status on remarrying an HIV-positive spouse among formerly married respondents who experienced a remarriage (odds ratios)

	All men and women who remarried (with a linked spouse)		
	HIV-Positive Spouse Model 1	HIV-Positive Spouse Model 2	HIV-Positive Spouse Model 3
HIV Status (lagged)			
HIV Negative (ref)	1	1	1
HIV Positive	24.81***	23.40***	27.85***
	(8.708 - 70.66)	(8.454 - 64.78)	(7.067 - 109.7)
Post-ART		1.699+	
		(0.932 - 3.099)	
Post-ART X HIV			
HIV Negative X ART			1.827+
			(0.900 - 3.713)
HIV Positive X ART			1.418
			(0.478 - 4.208)
Age (Centered)			
Age	1.014	1.009	1.009
	(0.980 - 1.049)	(0.975 - 1.045)	(0.975 - 1.045)
Age Squared	0.998	0.998	0.998
	(0.995 - 1.001)	(0.995 - 1.001)	(0.995 - 1.001)
Education			
No Education (ref)	1	1	1
Some Primary	0.617	0.511	0.497
	(0.198 - 1.925)	(0.160 - 1.632)	(0.153 - 1.614)
Some Secondary	0.642	0.524	0.509
	(0.178 - 2.316)	(0.142 - 1.937)	(0.136 - 1.913)
Unknown	10.21*	7.208+	7.064+
	(1.027 - 101.5)	(0.726 - 71.54)	(0.704 - 70.91)
Ethnicity			
Muganda (ref)	1	1	
Munyanrwanda	0.843	0.851	0.846
	(0.356 - 1.995)	(0.360 - 2.013)	(0.356 - 2.013)
Other	1.418	1.421	1.436
	(0.594 - 3.382)	(0.598 - 3.377)	(0.600 - 3.433)
Number of previous marriages	1.292	1.166	1.172
	(0.765 - 2.182)	(0.687 - 1.979)	(0.690 - 1.992)
Observed duration controls	Yes	Yes	Yes
ρ	0.485	0.481	0.488
σ	1.759	1.747	1.769
AIC	693.2951	692.2765	693.942
BIC	746.3392	750.1428	756.631
Number of respondents	740	740	740
Person-years formerly married	918	918	918
Number of remarriages	918	918	918

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Note: All respondents aged 15-59 who were unmarried but formerly married were included in the model. We tested for gender differences, including an interaction between HIV status and gender, but the results were insignificant. Gender controls were no included in the final model. Sigma is the square root of the variance of the individual-level random effect, and Rho is intra-class correlation, or the fraction of the variance that is explained by the individual-level random effect.

Our analysis focuses on the changes in marital partnership mixing, but it is also possible that ART changes non-marital partnership dissolution and formation. Unfortunately, we are unable to conduct the same analysis on non-marital partnerships as we only have linked partnership data for marital partners. However, we explore whether there are any broad changes in non-marital sexual behavior among HIV-positive men and women before and after the introduction of ART. Table 6 presents the odds of any reported sexual partnership in the previous 12 months among formerly married men and women. This analysis uses the same model and set of controls presented in Eq. 2. We find that, similar to remarriage, HIV-positive women and men have lower odds of having any sexual partner in the previous 12 months, compared to HIV-negative women and men (Table 6, Model 1). In the post-ART period (Model 3), HIV-negative women have a 39.4% lower odds of having any sexual partner, compared to HIV-negative women before ART. Despite finding that remarriage among HIV-positive men increases in the post-ART period, we find no corresponding changes for any reported sexual partner for HIV-positive men or women. ART does not seem to change non-marital partnership mixing patterns in the same way as marital partnership mixing.

Table 6: Logistic regression of lagged HIV status on any sexual partner in the previous 12 months among formerly married respondents (odds ratios)

	Females			Males		
	Sexual Partner Model 1	Sexual Partner Model 2	Sexual Partner Model 3	Sexual Partner Model 1	Sexual Partner Model 2	Sexual Partner Model 3
HIV Status (lagged)						
HIV Negative (ref)	1	1	1	1	1	1
HIV Positive	0.624***	0.643***	0.571***	0.669**	0.668**	0.715+
	(0.506 - 0.770)	(0.521 - 0.792)	(0.436 - 0.748)	(0.516 - 0.868)	(0.515 - 0.866)	(0.508 - 1.005)
Post-ART		0.633***			1.205*	
		(0.548 - 0.732)			(1.010 - 1.438)	
Post-ART X HIV						
HIV Negative X ART			0.606***			1.092
			(0.517 - 0.710)			(0.898 - 1.329)
HIV Positive X ART			0.760+			0.959
			(0.564 - 1.023)			(0.647 - 1.421)
Age (Centered)						
Age	0.910***	0.911***	0.911***	0.958***	0.958***	0.958***
	(0.901 - 0.919)	(0.902 - 0.920)	(0.902 - 0.920)	(0.948 - 0.968)	(0.948 - 0.968)	(0.948 - 0.968)
Age Squared	0.997***	0.997***	0.997***	0.999*	0.999*	0.999*
	(0.996 - 0.998)	(0.996 - 0.998)	(0.996 - 0.998)	(0.998 - 1.000)	(0.998 - 1.000)	(0.998 - 1.000)
Education						
No Education (ref)	1	1	1	1	1	1
Some Primary	1.238	1.443*	1.450**	2.169***	2.131***	2.130***
	(0.938 - 1.632)	(1.092 - 1.909)	(1.097 - 1.918)	(1.463 - 3.216)	(1.433 - 3.170)	(1.431 - 3.168)
Some Secondary	1.031	1.240	1.246	3.270***	3.196***	3.200***
	(0.738 - 1.438)	(0.886 - 1.737)	(0.890 - 1.745)	(2.089 - 5.116)	(2.033 - 5.024)	(2.035 - 5.031)
Unknown	0.352***	0.398***	0.400***	1.045	1.023	1.021
	(0.218 - 0.568)	(0.247 - 0.641)	(0.248 - 0.645)	(0.525 - 2.081)	(0.512 - 2.044)	(0.511 - 2.040)
Ethnicity						
Muganda (ref)	1	1	1	1	1	1
Munyanrwanda	1.394**	1.437**	1.437**	0.953	0.955	0.955
	(1.099 - 1.769)	(1.134 - 1.821)	(1.134 - 1.821)	(0.721 - 1.258)	(0.723 - 1.262)	(0.722 - 1.262)
Other	0.710*	0.739+	0.739+	1.106	1.107	1.108
	(0.515 - 0.980)	(0.537 - 1.018)	(0.537 - 1.018)	(0.816 - 1.498)	(0.817 - 1.500)	(0.818 - 1.502)
Number of previous marriages	1.338**	1.551***	1.552***	1.925***	1.881***	1.888***
	(1.076 - 1.664)	(1.241 - 1.939)	(1.242 - 1.940)	(1.503 - 2.466)	(1.458 - 2.428)	(1.462 - 2.438)
Observed duration controls	Yes	Yes	Yes	Yes	Yes	Yes
ρ	0.350	0.345	0.345	0.281	0.281	0.282
σ	1.331	1.317	1.315	1.133	1.135	1.136
AIC	9253.240	9222.796	9222.427	5366.496	5367.303	5369.000
BIC	9346.088	9322.786	9329.560	5449.731	5456.941	5465.040
Number of respondents	2,226	2,226	2,226	1,198	1,198	1,198
Person-years formerly married	9,341	9,341	9,341	4,459	4,459	4,459
Number of remarriages	934	934	934	711	711	711

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Note: All respondents aged 15-59 who were previously married but currently not married were included in the model. Sigma is the square root of the variance of the individual-level random effect, and Rho is intra-class correlation, or the fraction of the variance that is explained by the individual-level random effect.

6 DISCUSSION

This paper finds strong evidence that ART may be having an impact on marriage. While HIV-positive men and women have historically faced a higher likelihood of marital dissolution, and lower rates of a subsequent remarriage, we find three important changes occurring after the introduction of ART: a lower risk of widowhood in unions with HIV-positive women, an overall stabilization of seroconcordant positive couples, and a higher likelihood of HIV-positive men remarrying.

While marriage has never been particularly stable among the Baganda (Nahemow 1979), the predominant ethnic group in the study site, we do find clear differences in the level of marital instability by HIV status. We see three possible reasons for the higher stability of seroconcordant positive compared to serodiscordant marriages following the roll out of ART. First, ART may reconfigure couples' fertility intentions as viral suppression brings childbearing within reach of seroconcordant positive couples. Infertility has historically been a primary reason for marital discord and divorce in rural Uganda (Nabaitu, Bachengana, and Seeley 1994b), so we would anticipate that changes in childbearing feasibility in marriage may have a stabilizing effect on marriage. Childbearing behaviors may be less likely to change among serodiscordant couples if they are not on ART, or if they are unaware of the lower transmission risk associated with ART. Second, couples may bond over the shared experience of being on ART, thus strengthening relationships. Third, it could be that seroconcordant positive unions are now being purposefully formed, as HIV-positive partners seek out partners of the same HIV status as themselves (Gombachika 2012; Rhine 2009; Seeley et al. 2009). The observed change over time in the stability of seroconcordant positive marriages may not only be about how ART is changing the dynamics within marriage, but also about how ART is changing the types of marriages that are being formed.

The continued higher risk of divorce in serodiscordant marriages suggests that ART may not be impacting marriage dynamics as much as predicted. If one's partner is not on ART, there remains a very real risk of HIV transmission, which could make an HIV-negative partner more likely to leave. Moreover, even if one's spouse is on ART, the knowledge that ART can prevent the transmission of HIV may not be widely held, or believed. The perception of HIV risk may therefore be high, even if the real risk of transmission is low, and we know that risk perception is an important determinant of divorce (Grant & Soler-Hampejsek 2014). ART could also be impacting marriage dynamics, but not in the way we hypothesized. ART drugs create physical evidence of HIV infection, making it harder for PLHIV to hide their HIV status from their partner. Forced disclosure among serodiscordant couples could increase the risk of divorce, offsetting any reductions in the risk of divorce resulting form the lower transmission risk following ART. Future research should explore the risk of marital dissolution by HIV status, taking into account perceived risk of HIV and knowledge of the preventative effects of ART on HIV transmission, as well as changes in disclosure between the pre- and post-ART periods.

The persisting instability of serodiscordant marriages also suggests that HIV infection may not be the primary driver of divorce, but rather that divorce may be driven by the extra-marital partnerships that HIV infection signifies. Previous research found that infidelity or suspected infidelity were associated with divorce (Nabaitu et al. 1994; Reniers 2008). We would not necessarily expect to see a change between the pre- and post-ART period if extra-marital partnerships were the primary driver of divorce.

We find that widowhood rates are lower in the post-ART period for couples in which the wife is HIV-positive, including seroconcordant positive couples and female-positive serodiscordant couples (though the latter was only significant at $p<.10$). This is consistent with the literature on services uptake: Compared to men, HIV positive women are more likely to enroll in treatment and have better treatment outcomes (Cornell et al. 2012; Druyts et al. 2013; Hawkins et al. 2011; May et al. 2010; Mills et al. 2011; Muula et al. 2007). Male-positive serodiscordant marriages do not see a similar reduction in widowhood, highlighting the disproportionate gains in health for women as a result of their different treatment-seeking behaviors.

The dynamics of marital change in the pre- and post-ART period in rural Uganda also reveal important gender differences. While female-positive serodiscordant couples see a reduction in widowhood over time, they continue to experience a relatively high risk of divorce. Women are also less likely to remarry in both the pre- and post-ART periods than men. Together, these dynamics lead to an exclusion of HIV-positive women from the marriage market. More research is needed to explore whether the exclusion from marriage is coupled with other forms of social and economic disadvantage.

This paper presents an analysis of the HIV status among spouses who remarry, finding that PLHIV who remarry are much more likely to have a partner who is also HIV-positive. The formation of seroconcordant positive marriages among those formerly married may limit the onward transmission of HIV, as long as formerly married HIV-positive men and women who remarry have not infected their partners prior to marriage and do not engage in extra-marital sex. That said, the greater inclusion of PLHIV in marriage might create new opportunities for HIV transmission: HIV-negative men and women remarrying in the post-ART period see a marginally significant increase in their likelihood of marrying someone who is HIV-positive. The increased survivorship of PLHIV in the post-ART period may be one explanation for the increased odds of HIV-negative men and women marrying an HIV-positive spouse after the introduction of ART: Reductions in AIDS-related mortality imply that HIV-positive men and women live longer, increasing the number of HIV infected men and women in the marriage market.

Beyond HIV transmission, HIV-related marital change also has important implications for the social and economic wellbeing of families and children. A growing body of literature documents the effects of marital instability on children in sub-Saharan Africa, including earlier age of sexual debut and marriage (Beegle & Krutikova 2008; Birdthistle et al. 2008; Palermo & Peterman 2009), a higher risk of child mortality among younger children (Clark & Hamplová 2013; Thiombiano, LeGrand, & Kobiané 2013), and a higher risk of adolescent childbearing, early school drop out or grade repetition, and underemployment (Goldberg 2013). As a result, children of HIV-infected parents may experience greater social disadvantage through HIV-related marital instability. However, the growing stabilization of marriage in the post-ART period may also improve conditions for children and families. The effect of ART on family wellbeing is an important area for further study.

The pre- and post-ART differences in marital change may have important public health implications for the future transmission of the virus. The exclusion of HIV-positive men and women from marriage offers fewer opportunities for the transmission of HIV within marriage. While this is changing with the introduction of ART, the suppressed viral loads resulting from ART are reducing the risk of HIV transmission. The stabilization of seroconcordant positive marriages is promising, as more HIV-positive individuals form sustaining and strong partnerships without the risk of HIV transmission (assuming that ART is not also impacting extra-marital partnership formation). More research is needed to determine whether the increasing rate of remarriage since ART is increasing HIV transmission, or whether ART is offsetting the risk associated with new partnerships being formed.

While the immediate implications for HIV transmission are unclear, the historic exclusion of HIV-positive individuals from marriage, and the ways in which ART is altering this association, have important implications for the wellbeing of families and children. We need to move beyond seeing ART as only a medical intervention, and begin to document its social impacts.

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