The role of widows in the heterosexual transmission of HIV in Manicaland, Zimbabwe, 1998/2003

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Abstract

Background: AIDS is the main driver of young widowhood in Southern Africa. In Zimbabwe, HIV prevalence amongst adults is approximately 25%. Family structures in rural Zimbabwe have historically been maintained by traditional intra- and intergenerational mechanisms whereby widows are remarried, often to members of the deceased husband's family. In this paper, we describe the demographic patterns of widowhood and the behaviour of widows. The results from statistical analyses were used to inform the construction of a mathematical model with the aim of estimating the importance of widow behaviour in the heterosexual transmission of HIV.

Methods: We analysed a longitudinal population based cohort of men and women aged 15 to 54 yrs in Manicaland, eastern Zimbabwe. The baseline survey was conducted in 1998 to 2000 with the follow-up survey performed in 2001 to 2003. Statistical analyses of male and female widow HIV prevalence and sexual behaviour were performed on the baseline (n = 9580) and follow-up (n = 8437) cross-sectional data as well as on individuals followed-up in the closed cohort (n = 5507). The heterosexual transmission of HIV was simulated using a dynamic mathematical model with a population stratified by age, sexual activity and marital status.

Results: At follow-up, 11.4% (n = 413) of sexually-experienced women and 1.2% (n = 31) of sexually-experienced men reported to be widowed. HIV prevalence was high amongst both female widows (61%) and male widows (54%). In terms of sexual behaviour, female widows were more likely to have had 10 or more partners in 3 years (odds ratio (OR) = 7.1 compared with married women), more frequently engaged in commercial sex work (n = 24, 50% of sexually-active widowed women) and often took partners who were married to someone else (69%). Male widows took partners who were a median of 10 years younger than themselves. Mathematical model simulations of different scenarios of widow sexual behaviour suggested that between 6% and 17% of HIV cases over a 20 yr period would be averted if widows were celibate.

Conclusions: This combined statistical analysis and dynamic simulation model suggest that widowhood may play an important role in the transmission of HIV in this rural Zimbabwean population. Highly risky partnerships may be formed when widowed men and women reconnect to the sexual network.

Background

AIDS, as the leading cause of death amongst adults in Southern Africa,[1] is the major driver of early widowhood, even in areas of low prevalence.[2-4] The percentage of females widowed in the 25 to 29 age group from the last country censuses for African settings of lower prevalence was between 0.1% in Mali (1995/6) and 0.8% in Senegal (1999). For higher prevalence settings the figures were between 0.8% in South Africa and 2.9% in Zimbabwe (1999).[5] As early as 1992/93, prior to the major impacts of AIDS mortality, HIV was estimated to cause 49% of spousal deaths in Uganda.[6] In 1997, males cited AIDS as the second main cause of death of a spouse whilst females cited this as the leading cause in 3 different Ugandan districts.

In Zimbabwe an estimated 25% of men and women aged between 15 and 49 are infected with HIV[7] and the resulting mortality in these age groups means that children are orphaned and spouses are widowed, thus eroding family structures.[8 9] Due to the relatively high levels of adult mortality even before the HIV epidemic, family structures were maintained by traditional intra- and intergenerational coping mechanisms such as the levirate, whereby a widow is remarried, often to a member of the deceased husband's family.[10-12] As the epidemic progresses and populations become aware of the impact of AIDS mortality, such practices may diminish.[13 14] Remarriage of widows involves people with a sexual history and therefore may account for some of the serodiscordant couples (where one person is HIV positive) observed in cohorts in sub-Saharan Africa.[3 15] Serodiscordant couples have high risk of widowing compared to seroconcordant-negative couple and seroconcordant-positive couples have the highest risk of widowhood, in which case an HIV positive widow(er) is always produced.[16]

Previous findings from this cohort and others in the Southern African region, as well as modelling estimates, suggest that men mostly acquire HIV infection from pre- and extramarital relations while, for married women, the strongest determinants of infection are their partner's behaviour.[9 17 18] Marriage is a potentially risky form of partnership since sex occurs more frequently and condom use would be low.[19] In Kisumu, Kenya and Ndola, Zambia, Clark found that although married females reported fewer partners than single females, husbands were 2 to 3 times more likely to be infected than boyfriends, thus cancelling out the protective effect of their own behaviour. Clearly, marriage is only protective against STDs if it monogamous and coincides with initiation of sexual activity [20 21] Declines in HIV prevalence have been associated with a reduction in the number of sexual partners as a result of health campaigns strongly promoting 'zero-grazing' or fidelity to one partner.[14 22]

Because the HIV epidemic first spread widely in men, because male mortality is naturally higher and because husbands are generally older than wives, 78% of widows in Zimbabwe in 1999 were women.[23] Importantly in terms of the further spread of HIV, the prevalence of HIV amongst widows is extraordinarily high. In the baseline round of the Manicaland HIV/STD Prevention Study cohort (1998 to 2000), males and females who were widowed less than two years before the study had the highest HIV prevalence of all marital status groups (64% and 58%, respectively).[9] Studies in other Zimbabwean populations have also observed similar risk of HIV in widows.[24 25]

The demographic structure of a population may affect the prevalence of HIV on a number of levels.[26 27] In the case of marital dissolution, one can conceptualise overall prevalence of widowhood as an underlying demographic determinant of sex partner acquisition, concurrency, abstinence, and sexual mixing patterns.[28] These are proximate determinants that result in the exposure of susceptible individuals to infected sexual partners. The probability of forming a sexual partnership with an infected individual depends on the prevalence of HIV. We hypothesize that widowhood and other forms of marriage dissolution may impact transmission by supplying a source of infected individuals in the sexual network. In this paper, we describe the demographic patterns of widowhood and the behaviour of widows as they 'reconnect' to the sexual network in a setting of high HIV prevalence. The results from these statistical analyses were used to inform the construction of a mathematical model with the aim of estimating the importance of widow behaviour in the heterosexual transmission of HIV.

Methods:

Study area, population and survey design

The Manicaland HIV/STD Prevention Project is a population-based open cohort, full details of which can be found elsewhere.[29] The study population are resident of 4 subsistence farming areas, 2 roadside trading centres, 4 forestry, tea and coffee estates, and 2 small towns in the rural province of Manicaland in eastern Zimbabwe. Male and female local residents identified in an initial household census were considered eligible for the study. The baseline round of the study was conducted between July 1998 and January 2000 with the follow-up conducted 3 yrs later in each site. Males aged 17 to 54 and females aged 15 to 54 were included in the present analysis. Written informed consent was obtained from all participants, who were offered free HIV counselling and testing. A maximum of one member of each marital group was selected to participate in order to maximise the power of an embedded randomised controlled trial. HIV serological testing was performed on dried blood spots using a highly sensitive and specific antibody dipstick assay.[30] Information on marital status and marital history in addition to demographic, socioeconomic and sexual behaviour data were collected from each individual through an interviewer-led questionnaire. Responses to sensitive questions about sexual behaviour were collected using an informal confidential system of voting, which has been shown to improve the discrepancy between male and female reports of sexually activity.[31] Ethical approval for the study was granted by the Research Council of Zimbabwe (Number 02187) and the Applied and Qualitative Research Ethics Committee in Oxford, United Kingdom (N97.039).

Statistical methods

Prevalence and incidence calculations

For the purposes of prevalence calculations, the baseline and follow-up survey populations were treated as separate cross-sectional studies. Thus, all subjects interviewed in a given study round were included in the denominator of prevalence calculations. Men and women who had not yet started sex were included, but percentages are also presented based only the sexually-experienced population (i.e. those who had begun sex at the time of interview).

Individuals who were part of a marital union at the time of the baseline survey were considered the population at risk of becoming widowed. Widowhood incidence was calculated as the number married people at baseline who reporting to be widowed at the time of follow-up divided by the time at risk. The year of the widowing event was available from questionnaire data, but was sometimes missing or inconsistent (a person's marital status changed to widow in the previous 3 years, but they reported that their last partner died > 3 yrs ago). In either situation, we assumed that the person was widowed halfway (1.5 yrs) through follow-up. Widowing events where a husband and wife in a martial pair both died in the 3 yr follow up period would not have been observed, and therefore may have resulted in underestimation of widowing incidence rates. Rates were stratified by gender, age and HIV status at baseline. For the purposes of calculating HIV incidence, time-at-risk from all individuals negative at baseline who were found at follow-up were included in the denominator.

Poisson regression models were fitted to the widowing incidence data and HIV incidence data and are presented with respect to age, gender and HIV status at baseline (widowing incidence only). Multiple logistic regression was used to model widowhood on HIV status at follow-up. Because age, martial status and HIV prevalence are correlated, we controlled for age in order to describe the independent association of martial status with HIV. Cox proportional-hazards models were fitted to remarriage events and are presented with respect of gender, controlling for age. The combination of questions "how many years is it since your last marital partner passed away?" and "how many years later did you remarry" were used to construct a Kaplan-Meier curve of remarriage. Data on individuals who had been widowed, but not yet remarried, were included as censored observations.

Mathematical model of widowhood

Based on the findings from the statistical analysis, a mathematical model was constructed to examine the relative importance of male and female widow behaviour in the transmission of HIV. Based on previously described models,[32] we simulate the heterosexual transmission of HIV in an age (five year categories), sexual-activity (three categories with different rates of sexual partnership formation) and marital-status (married or not-married) stratified population. Individuals are at risk of becoming widowed if they are currently married, or of getting re-married if they are currently a widow. The risk that a susceptible individual is infected with HIV is dependent on with whom they are currently in a sexual partnership, and the pattern of sexual partnership formation is defined with respect to age (older men with young women) sexual-activity (biased to one's own sexual activity group), and marital-status. We investigate the effect of reducing the number of sexual partnerships made by widows under a range of assumptions about the baseline sexual behaviour of widows and non-widows; the rate of partnership formation by widows exceeding that of non-widows, different preferences of male widows and non-widows to form partnerships with younger women, and the extent to which male widows chose female widows as sexual partners. A full description of the model is presented in the appendix.

Results:

At baseline there were 4261 men and 5319 women whose marital status was known and at follow-up there were 3341 men and 5096 women. Amongst the men and women interviewed and tested for HIV at baseline whose marital status was known, 2242 men and 3265 women were followed-up (follow-up rates: males = 54%; women = 66%). Thirteen males and 292 females who were widowed at baseline were found at follow-up (follow-up rate; male widows: 39%; female widows = 80%). An additional 180 men and 219 women with full data from the baseline study were known to have died.

Incidence and prevalence of widowhood

The proportion of sexually-experienced men who reported to be widowed was 1.2% at baseline (n = 44) and follow-up (n = 33)(Table 1). The proportion of sexually-experienced women who were widowed increased from 9.4% (n = 410) to 11.4% (n = 420) between baseline and follow-up. Figures 1A and 1B highlight that prevalence of widowhood was higher in men under 35 years of age at follow-up,. The same trend was observed in women – where widowhood prevalence at follow-up was higher up to the age of 45.

Table 2 describes the incidence of widowhood amongst those who were married at the baseline interview. Nineteen men and 148 women were married at baseline reported to be widowed at follow-up. The incidence rate ratio (RR) with respect to gender (female:male) was 4.1 (95% CI: 2.5 – 6.6, z-test $p < 0.001$, controlling for age). Being infected with HIV at baseline was significantly associated with increased rate of becoming widowed for women (RR = 5.8; 95% CI = 4.1 – 8.1; z-test $p < 0.001$) and non-significantly for men (HR = 2.3; 95% CI = 0.9 – 5.7; z-test $p = 0.07$), after controlling for age.

HIV risk and widowhood

At follow-up, HIV prevalence was high amongst ever-widowed men (54%) and women (63%). HIV prevalence was higher in widows compared to those still married in both genders (Table 3).

For females, incidence of HIV was not significantly higher in widows (n = 6 seroconversions, 14.7 cases/1000 person years (pyrs), 95% CI = 2.2 – 10.9) than married women (n = 65 seroconversions, 12.5 cases/1000 pyrs, 95% CI = 5.7 – 9.3). Of the 14 men who were widowed and HIV-negative at baseline, 2 had died and 7 were lost to follow-up. Of the remaining five, none seroconverted (incidence = 0) thus precluding a full analysis of HIV incidence in widowed men.

Mortality

Mortality rates for both male and female widows (95 per 1000 pyrs and 39 per 1000 pyrs) were substantially higher than other marital status categories (Table 4). Mortality rates were higher for female widows (RR = 3.1; 95% CI: 2.1 – 4.4; z-test $p < 0.0001$) and male widows (RR = 3.7, 95% CI = 2.8 – 6.8; z-test $p < 0.0001$) compared to individuals married at baseline after controlling for unequal age distribution between marital states.

Mortality rates were higher in HIV positive compared to HIV negative male widows (62 per 1000 pyrs compared with 17 per 1000 pyrs) as well as female widows (117 per 1000 pyrs compared with 51 per 1000 pyrs). Even after controlling for HIV status at baseline, there were still increased mortality in female widows (RR = 2.2; 95% CI: 1.2 – 4.1; z-test $p = 0.014$) and male widows (RR = 1.5; 95% CI: 1.1 – 2.2; z-test $p = 0.03$) compared to individuals married at baseline. This suggests that mortality clustering, where one spouse's death follows their partner's death, is not completely attributable to HIV in this population.

Remarriage and sexual behaviour of widows

77% of male widows (73/94) reported sexual activity in the previous year compared with 35% (104/297) of females. Traditional practices in Manicaland discourage widows from taking another partner for 1 year after the death of their spouse. Thus, the high levels of reported sexual activity in the first year after widowhood (77% for males, 52% for women) are surprising, but this figure may be influenced by relations with partners who died less than one year ago, as well as recall bias.

Females widows (at baseline) had a median of 0 total partners in the 3 yrs of follow-up compared to 1 among women who were separated, divorced, married or unmarried sexually experienced. However, widows were more likely to have high sexual activity (≥10 partners in 3 yrs) compared to those married at baseline (OR = 7.1; 95% CI = 2.4 to 20.8, p < 0.001, adjusted for age). Only 13 men who were widowed at baseline were found at follow-up, so no comparison could be made. However, separated and divorced men were much more likely to have high sexual activity (≥10 partners in 3 yrs) compared to those married at baseline (OR = 4.1; 95% CI = 1.4 to 11.6, p = 0.009, adjusted for age). A summary of the partnership history in the follow-up period can be seen in Figure 2.

Fifty percent of all sexually active widowed women at follow-up (24/48) reported that they had received money or gifts in exchange for sex with their last partner compared with 3% of married women (83/2794)(chi-squared p-value <0.0001).

The hazard ratio of male remarriage to female remarriage was 3.4 (95% CI = 2.4 to 4.9; z-test p < 0.001, controlling for age; Figure 3).

It has previously been shown that the age difference of sexual relations (men being older than their female partners) influences the age-patterns of HIV in this population.[29] There was a greater age difference between male widows and their last partner (median: 10.5 older than partner; IQR: 4.5 to 15.5) compared with non-widows (median = 6; IQR: 3 to 8)(Spearman's rank test; rho = 0.106; p = 0.0001). The median age difference between females and their last partner was 6 years (females being younger; IQR: 3 to 10) which was similar between widows and non-widows (Spearman's rank test; rho = -0.0176; p = 0.4).

69% of female widows, (31/45) reported that their last partner was married to someone else compared with 14% (320/2281) of married women (chi-squared p-value < 0.0001).

Condom use (either consistent or inconsistent) was more commonly reported by widowed women (53%, 21/40) than married women (8%, 151/1921)(chi-squared p-value <0.0001), though, HIV-positive widows reported condom use less frequently (42%, 10/24) than HIV-negative widows (64%, 8/11)(chi-squared p-value = 0.11)

Model: Dynamic population impacts of widowhood

Two parameters were estimated directly from the longitudinal data from the present study. The rates of being widowed stratified by gender and HIV status were based on the widowhood incidence presented in Table 2 and the rate of widow remarriage, stratified by gender, was estimated on the basis of the Kaplan-Meier survivor function (1/8 for male widows, 1/15 for female widows). Other parameters were selected as described previously.[32]

For the purposes of our baseline model, we assume that the rate of partner change amongst widows is equal to that of the non-widowed population, with widowed males from older age groups (≥ 30 yrs) having a preference for females 5 to 10 yrs younger and widows preferentially selecting non-widows as their partners. The impact of cessation of widow sexual activity at year 20 of the epidemic is illustrated in figure 4a. Stopping male widow sexual activity has a minor impact whereas stopping female sexual activity results in a 2% to 3% decrease in adult prevalence within 10 years.

Figure 4b shows the predicted cases averted (i.e. the percentage of fewer cases in the intervention as compared with the baseline) over a 20 yr period in the baseline scenario. These estimates were sensitive to assumptions about levels of activity of widows and their relationships in the sexual network (Figure 4b). If we assume that widows form partnerships at a rate 4 times that of non-widows in each activity class the impact of stopping male and female sexual activity entirely would result in > 15% of cases averted (black bars). Removing widowed males preference for female partners much younger than themselves has only a very minor effect (light brown bars). Cancelling the assumption that widows preferentially form partnerships with non-widows results in a reduction in cases averted because partnerships would more often be formed amongst seroconcordant couples (lightest brown bars).

Discussion and conclusion

This combined statistical analysis and dynamic simulation model suggest that widowhood may play an important role in the transmission of HIV in this rural Zimbabwean population. The prevalence of young widowhood, particularly amongst women, is high (11.4%) in Manicaland. And, HIV prevalence amongst female widows (63%) and male widows (at 54%) is exceptionally high and is consistent with the finding that incidence of becoming widowed is strongly associated with HIV status. However, we found no evidence that widowed men or women had greater risk of becoming infected with HIV compared to married individuals, supporting the idea that the high prevalence of HIV amongst widows is a result of infections acquired while in marital unions, rather than as widows. However, widows may be a source of infection as they resume sexual activity, since the sexual relations they form may be very risky for their partners. Men are likely to take on partners much younger than themselves and women are likely to have relations with already married men and are disproportionately involved in high levels of sexual partner acquisition (≥ 10 partners in 3 yrs) and commercial sex work. These relationships may be important means by which HIV is transmitted in a sexual network to widow's partners and their partner's partners.

The mathematical model simulations presented here serve to quantify the relative importance of particular behaviours amongst widows in the transmission of HIV in this population. This model suggests that at the population level, the impact of heterosexual transmission of HIV from widows is non-trivial. The cessation of males and female widow sexual activity would result in the aversion of between 6 to 17% of cases. Female widow sexual activity is much more important than male widow sexual activity according to the models but, this prediction results from the parameterisation of the model which fixed widowing rates in order to reflect the observed widow prevalence in the study population. As female mortality rises as a result of AIDS deaths,[8] male widows may become more common and therefore their sexual activity may exert a stronger influence on the HIV prevalence. The current model fails to capture this possible future trend. Also not apparent from the model output is the high risk widowers pose to their partners. They have very high HIV prevalence and a preference for women much younger than themselves, meaning the chances for a susceptible female coming into contact with an infected widower is high.

The strong sex difference, with male widow prevalence at 1.2%, is notable and is likely to be a result of male mortality being 'naturally' higher combined with the impact of the early stages of the HIV epidemic which disproportionately affected men and the pattern of husbands being older than wives.[33] Similarly, polygamy also affects the sex difference; one male death has the potential to create multiple widows. The 1999 Demographic and Health Survey found 8.4% of men in Manicaland involved in a polygamous union.[23] In traditional patrilineal family structures, widowed women would be remarried to the brother of their deceased spouse. However, for the inheriting brother, this union would not typically be his first marriage. More often the inheriting male would be presently married, widowed, separated or divorced. Marriage of widows may become less desirable, particularly in settings where HIV status is known. In rural Malawi, HIV-positive widows and widowers are already less likely to remarry compared to HIV-negative widows and widowers.[34] Remarriage rates for divorcees are higher than for that of widows who are more likely to be perceived as 'high-risk'.[35] In Uganda less healthy widows were found to frequently leave their deceased husband's home and return to their natal village, while healthier widows were more likely to remarry or form new sexual partnerships.[6]

The most common reasons for loss in our study were migration out of the study area and households not being found at follow-up, respectively.[36] It is possible that widows may be especially difficult to study since they may move to the town or village of their new spouse or their own extended family. Overall, follow-up of widows was similar to that of the married population. But it remains possible that people married at baseline who were widowed in the course of follow-up were lost more frequently than those who remained married. In addition, newly widowed men and women may have died before follow-up causing our underestimation in our estimated of widowhood and widow morality.

A limitation of this analysis is that we could only consider patterns of widowhood during a three year follow-up. In order to see if re-marriage patterns are changing, a longer study period will need to be analysed, which will be possible as data become available from further rounds. In this analysis, we have focused on quantifying contributors to transmission probability and contact patterns with respect to widowhood. However, these individual characteristics and behaviours will depend on local social networks and the cultural milieu, which are predicated on demographic change (as discussed above), legal frameworks and other structural factors.[28] Although the legal standing of Zimbabwean widows and their rights to inheritance changed in 1997 with the passing of several Acts affording them greater protection, widows married under customary law do not have complete security. [37]

In the immediate term, counselling and testing services should reinforce efforts to provide widows with support and knowledge needed to make safe choices after the death of a spouse, and encourage participation in church or women's organisation support groups where legal advice and support might be sought. In the longer term, if the levirate is declining, increasing financial independence through employment opportunities for widows will reduce their need for support from a new partner. Given the success of the ABC approach in Uganda in helping to lower HIV prevalence,[36] church and community leaders as well as faith-based organisations should continue to promote safer sexual behaviours such as 'zero grazing' as well as respect within the marital union. In the future, as more longitudinal data become available from this population, these behavioural measures should be re-visited to determine whether widow practices are changing. The impact of demographic changes on behavioural trends may be hard to predict. One interpretation of higher levels of widowhood is that the prospect of remarriage is falling over time[13] although this would be part of the natural course of the epidemic. Qualitative research is therefore also needed to provide a more nuanced understanding of changing cultural rules and norms regarding sexual behaviour and marriage patterns in Zimbabwe and whether these substantiate quantitative results.

Table 1. Distribution of marital status at baseline (1998/2000) and follow-up survey (2001/2003)

	Baseline			Follow-up		
	n	% of total	% of ever had sex	n	% of total	% of ever had sex
Men						
Presently widowed	44	1%	1%	31	1%	1%
Presently divorced	135	3%	4%	71	2%	3%
Presently separated	36	1%	1%	33	1%	1%
Presently in union	1,734	41%	49%	1,533	47%	60%
Never married, ever had sex	1,602	38%	45%	874	27%	34%
Never married, never had sex	710	17%		705	22%	
Total, ever had sex	3,551	83%		2,542	78%	
Total	4261			3247		
Women						
Presently widowed	410	8%	9%	420	9%	11%
Presently divorced	424	8%	10%	290	6%	8%
Presently separated	194	4%	4%	139	3%	4%
Presently in union	2,968	56%	68%	2,615	54%	71%
Never married, ever had sex	343	6%	8%	221	5%	6%
Never married, never had sex	980	18%		1,114	23%	
Total, ever had sex	4,339	82%		3,685	77%	
Total	5319			4799		

Table 2. Incidence of widowhood amongst men (17 to 49) and women (19 to 49) who were married at the time of baseline interview (1998/2000) until follow-up interview (2001/03)

	Married at baseline*	Widowed at follow-up	Years of observation	Incidence per 1000 person-years at risk (95% CI)
Men				
All	1033	19	3070	6.2 (3.9 – 9.7)
HIV negative	736	10	2192	4.6 (2.5 – 8.7)
HIV positive	297	9	878	10.2 (5.3 – 19.7)
Women				
All	2149	148	6228	23.7 (20.2 – 27.9)
HIV negative	1738	71	5190	13.9 (11.0 – 17.5)
HIV positive	411	77	1118s	68.9 (55.1– 86.1)

*and found at follow-up

Table 3. Prevalence of HIV by widowhood status at follow-up (2001/03)

	HIV positive/ total	Prevalence	OR (95%CI)*
Men			
Presently married, formerly widowed	15/46	54%	5.2 (2.7 – 10.0)
Presently widowed	19/31	54%	3.9 (1.9 – 8.1)
Presently married, never widowed	403/1465	19%	1
Never married, ever had sex	72/868	21%	0.7 (0.5 – 0.9)
Never married, never had sex	8/702	1%	0.2 (0.1 – 0.5)
Women			
Presently married, formerly widowed	70/129	67%	5.7 (3.9 – 8.4)
Presently widowed	223/413	61%	6.2 (4.9 – 7.9)
Presently married, never widowed	484/2512	28%	1
Never married, ever had sex	46/218	8%	1.6 (1.1 – 2.3)
Never married, never had sex	16/1105	1%	0.2 (0.1 – 0.4)

* adjusted for age

Does not include divorced or separated persons

OR = odds ratio

Table 4. Mortality rates by marital status at baseline, controlling for age and HIV status

Marital status at baseline	N	Deaths	Rate (per 1000 PYARS)	RR: adjusted for age	RR: adjusted for age and HIV status
Men					
Presently widowed	30	11	95.2 (52.7 - 172)	3.1 (1.6 - 5.7)	1.8 (1.0 - 3.3)
Presently divorced	105	17	44.8 (27.8 - 72.1)	2 (1.2 - 3.4)	1.8 (1.1 - 3)
Presently separated	28	1	9.4 (1.3 - 66.7)	0.5 (0.1 - 3.8)	0.5 (0.1 - 3.7)
Presently in union	1,374	114	22.7 (18.9 - 27.2)	1	1
Never married, ever had sex	1,200	30	6.3 (4.4 – 9.0)	0.8 (0.5 - 1.3)	0.9 (0.6 - 1.5)
Never married, never had sex	587	7	3.3 (1.6 - 6.9)	0.5 (0.2 - 1.4)	0.8 (0.3 - 2.1)
Women					
Presently widowed	371	45	38.7 (28.9 - 51.8)	3.1 (2.1 - 4.4)	1.6 (1.1 - 2.3)
Presently divorced	363	35	28.7 (20.6 - 40)	2.6 (1.7 - 3.8)	1.4 (0.9 - 2)
Presently separated	168	12	21.3 (12.1 - 37.5)	2 (1.1 - 3.6)	1.3 (0.7 - 2.4)
Presently in union	2,611	96	11 (9.0 - 13.4)	1	1
Never married, ever had sex	289	19	19 (12.1 - 29.8)	2.2 (1.3 - 3.8)	1.8 (1.1 - 2.9)
Never married, never had sex	867	12	4.1 (2.3 - 7.2)	0.8 (0.4 - 1.7)	1.3 (0.6 - 2.9)

RR = rate ratio

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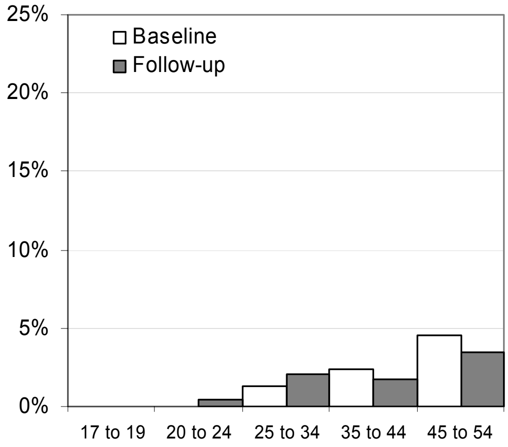
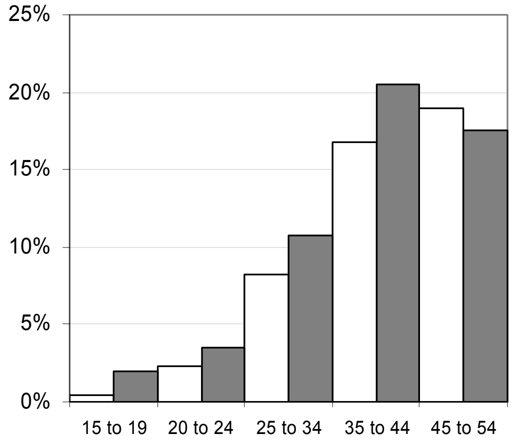
Figure 1. Prevalence of widowhood by age and sex, Manicaland, Zimbabwe, 2001/03

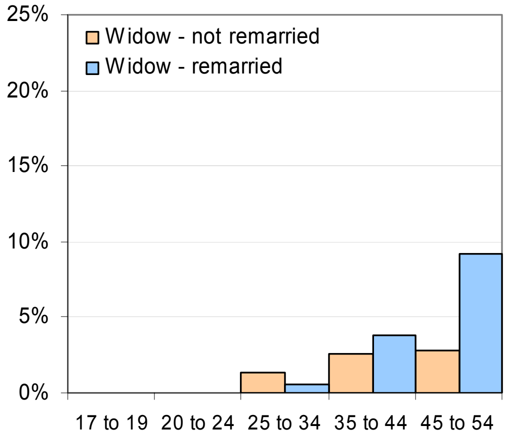
A)Males: Comparison between baseline and follow-up



B) Females: Comparison between baseline and follow-up



C) Males: Remarried and unmarried widowhood prevalence at follow-up



D) Females: Males: Remarried and unmarried widowhood prevalence at follow-up

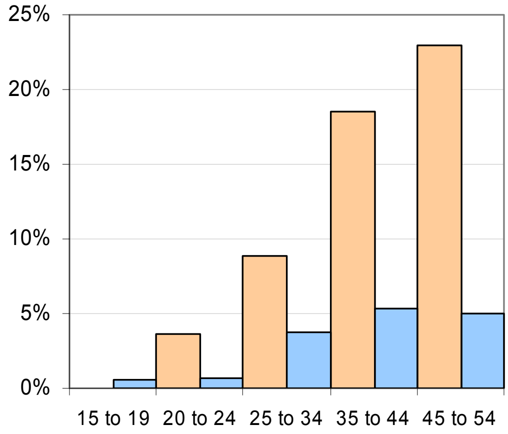
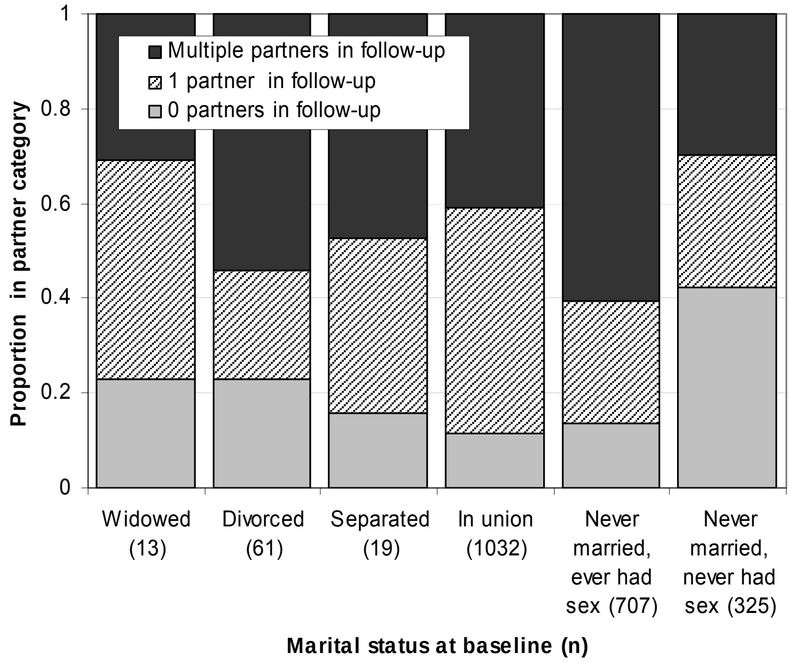


Figure 2. Total number of partnerships in follow-up period (3y) based on martial status at baseline.

A)Males



B) Females

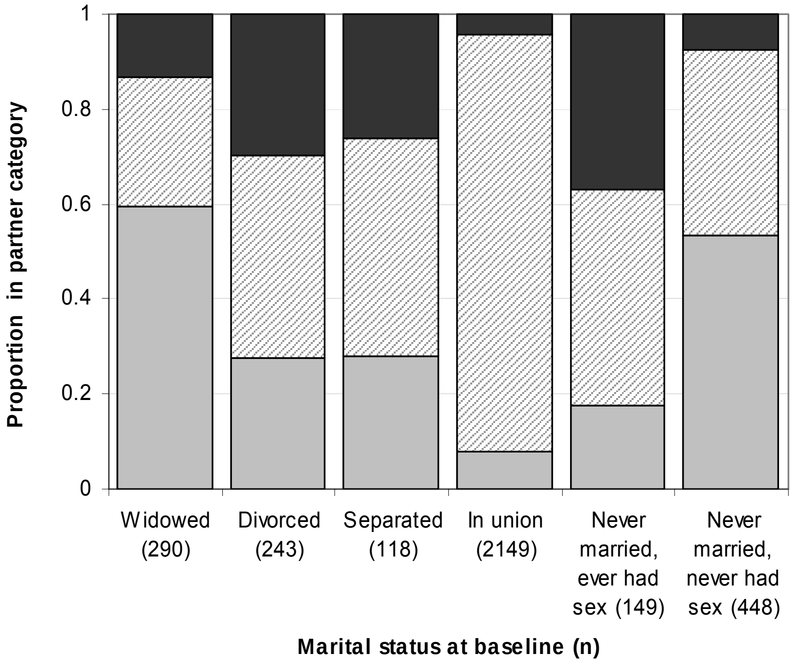


Figure 3. Remarriage after widowhood, Kaplan-Meier survival plot (n = 99 males; 644 females)

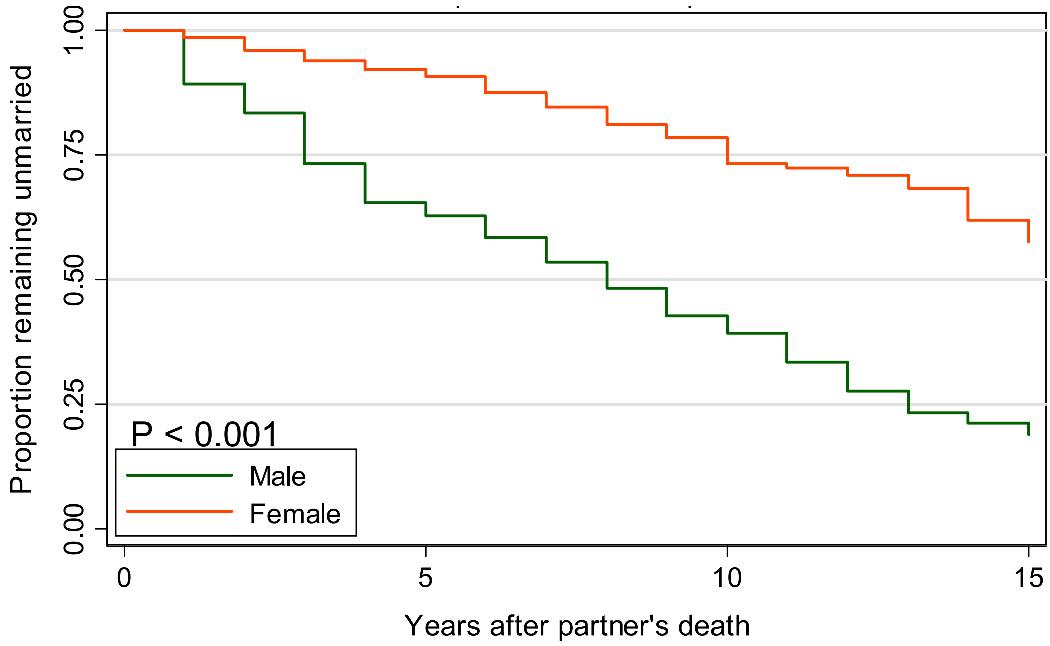
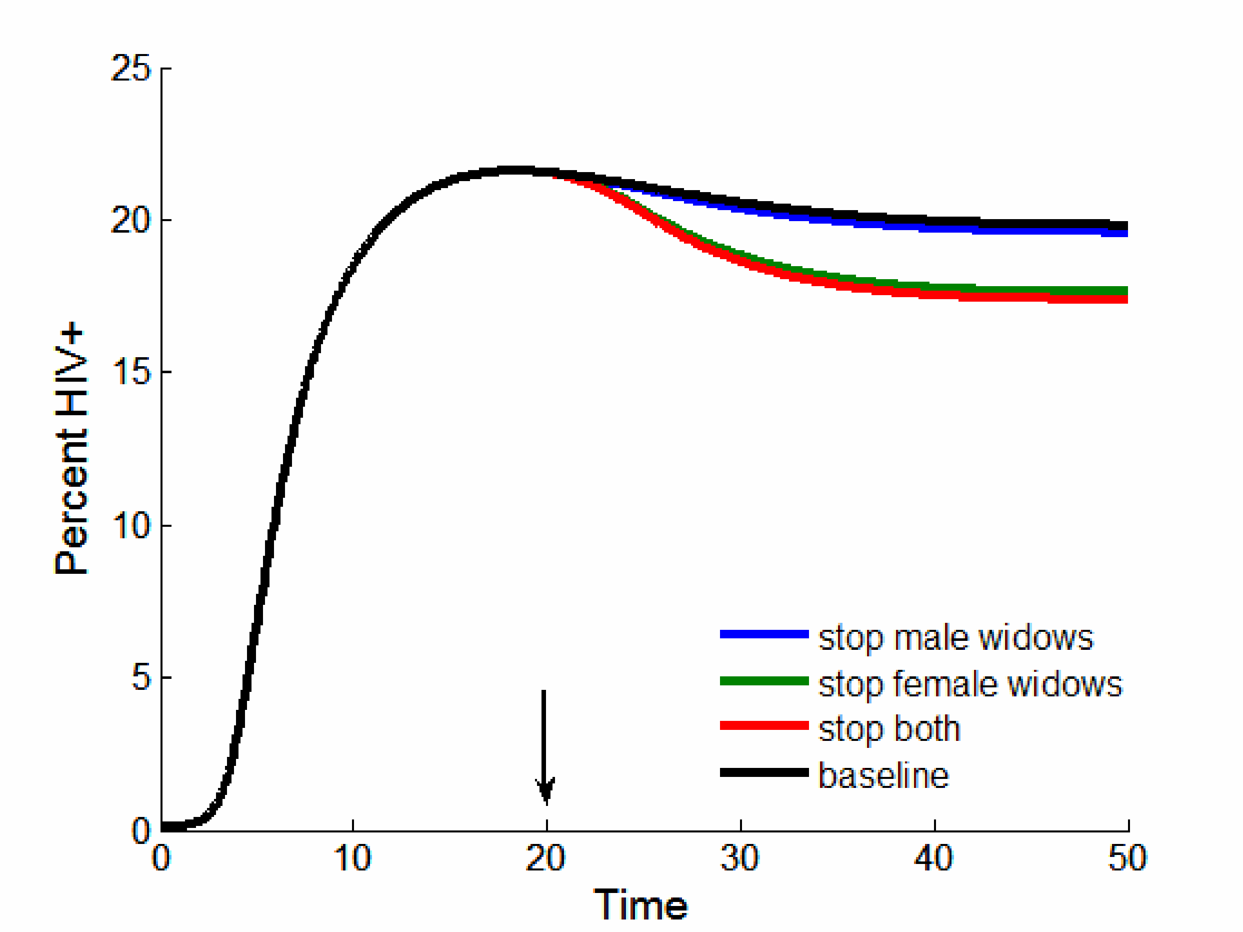
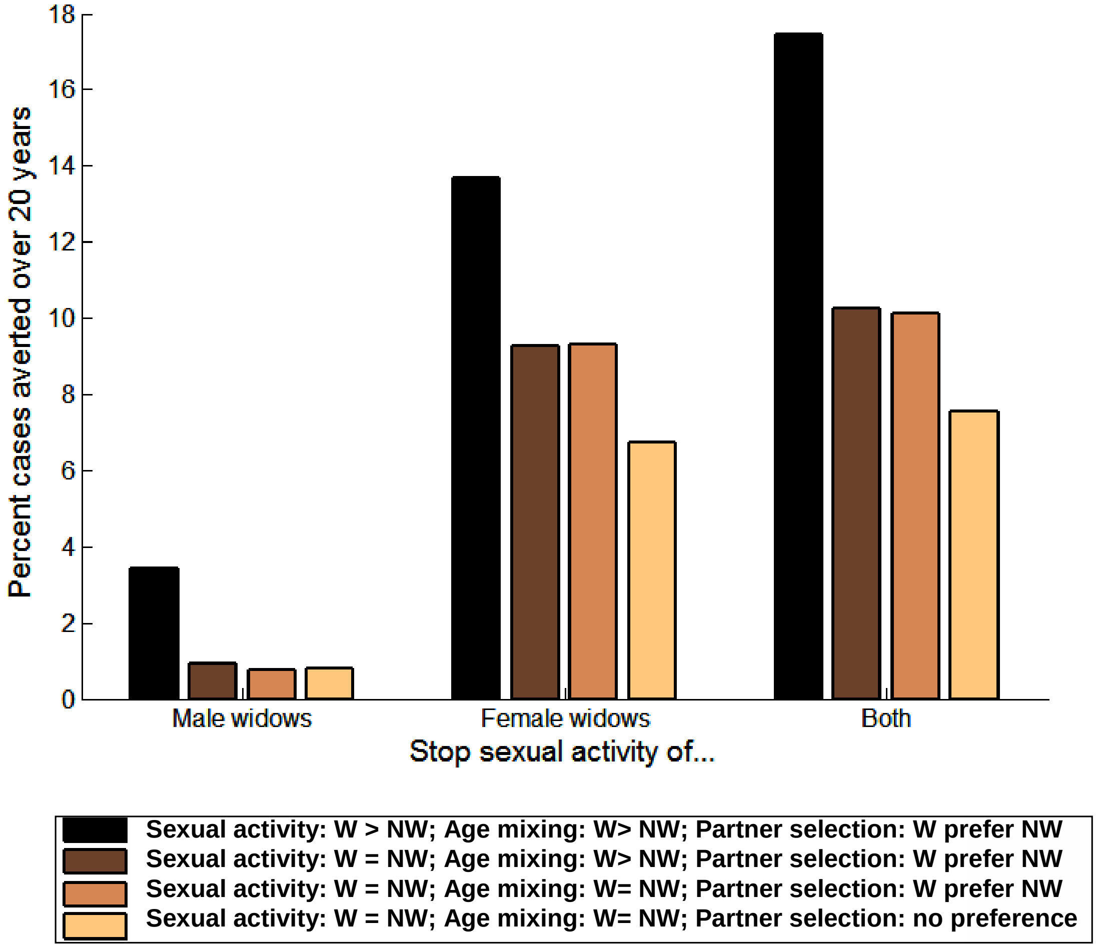


Figure 4.

A) Simulation of the impact of cessation of male and female widow sexual activity on adult prevalence of HIV.



B) Model prediction: Percentage of cases averted over twenty years after cessation in sexual behaviour of male, female and all widows. Four scenarios of the pre-intervention mixing and sexual activity patterns of widows (W) and non-widows (NW) are presented.



Appendix

Model definition

The model is based on a system of ordinary differential equations which are solved numerically by simulation. The state variables are given by: $X_{k,l}^{s,v,a}$, where *k* refers to sex (*k=1* men; *k=2* women), *l* refers to sexual activity (*l=1* sex work group; *l=2* casual sex group; *l=3* spousal sex group), *s* refers to status with respect to HIV (*s=0* susceptible; *s=1* primary HIV; *s=2* incubating; *s=3* 'pre-AIDS'; *s=4* AIDS), *v* refers to marital-status (0=married 1=not-married) and *a* is the five-year age group (1,2,..6).

$$\frac{dX_{k,l}^{0,0,1}}{dt} = \kappa_k \phi_{kl} b(t) - \left(\mu + \lambda_{k,l}^{,0} + \pi_k^{0,} + \upsilon\right) X_{k,l}^{0,0,1} + \tau X_{k,l}^{0,1,1}$$

$$\frac{dX_{k,l}^{0,1}}{dt} = \pi_k^{0,} X_{k,l}^{0,0,1} - (\mu + \lambda_{k,l}^{,1,1} + \tau_k + \upsilon) X_{k,l}^{0,1,1}$$

$$\frac{dX_{k,l}^{0,1,a}}{dt} = \tau X_{k,l}^{0,1,a} + \upsilon X_{k,l}^{0,0,a-1} - \left(\mu + \lambda_{k,l}^{,0} + \pi_k^{0,} + \upsilon\right) X_{k,l}^{0,0,a} + \tau X_{k,l}^{0,1,a}$$

for a=2 to 6.

$$\frac{dX_{k,l}^{0,1,a}}{dt} = \pi_k^{0,} X_{k,l}^{0,0,1} + \upsilon X_{k,l}^{0,0,a-1} - (\mu + \lambda_{k,l}^{,1,a} + \tau_k + \upsilon) X_{k,l}^{0,1,a}$$

In the equations κ_k is the fraction of the population in that sex at entry; μ is the per capita death rate; α is the population growth rate; π_k^s is the risk of being widowed for that sex and that infection status; τ_k is the rate at which widows of that sex remarry; υ is the rate of progression to the next age-category; *b(t)* is the birth rate:

$$b(t) = \sum_{a=1}^{A} \psi_a X_{2,\bullet}^{\bullet,\bullet,a}$$

$$\frac{dX_{k,l}^{1,0,1}}{dt} = \lambda_{k,l}^{0,1} X_{k,l}^{0,0,1} + \tau_k X_{k,l}^{1,1,1} - \left(\mu + \sigma^1 + \pi_k^{1,} + \upsilon\right) X_{k,l}^{1,0,1}$$

$$\frac{dX_{k,l}^{1,1,1}}{dt} = \lambda_{k,l}^{1,1} X_{k,l}^{0,1,1} + \pi_k^{1,} X_{k,l}^{1,0,1} - \left(\mu + \sigma^1 + \tau_k + \upsilon\right) X_{k,l}^{1,1,1}$$

$$\frac{dX_{k,l}^{1,0,a}}{dt} = \lambda_{k,l}^{0,1} X_{k,l}^{0,0,a} + \upsilon X_{k,l}^{1,0,a-1} + \tau_k X_{k,l}^{1,1,a} - \left(\mu + \sigma^1 + \pi_k^1 + \upsilon\right) X_{k,l}^{1,0,a}$$

$$\frac{dX_{k,l}^{1,1,a}}{dt} = \lambda_{k,l}^{1,1} X_{k,l}^{0,1,a} + \upsilon X_{k,l}^{1,1,a-1} + \pi_k^{1,} X_{k,l}^{1,0,a} - \left(\mu + \sigma^1 + \tau_k + \upsilon\right) X_{k,l}^{1,1,a}$$

for a=2 to 6.

$$\frac{dX_{k,l}^{s,0,1}}{dt} = \sigma^{s-1,} X_{k,l}^{s-1,0,1} + \tau_k X_{k,l}^{s,1,1} - \left(\mu + \sigma^s + \pi_k^{1,} + \upsilon\right) X_{k,l}^{s,0,1}$$

$$\frac{dX_{k,l}^{s,1,1}}{dt} = \sigma^{s-1,} X_{k,l}^{s-1,1,1} + \pi_k^{1,} X_{k,l}^{s,0,1} - \left(\mu + \sigma^s + \tau_k + \upsilon\right) X_{k,l}^{s,1,1}$$

for *s=2 to 4.*

$$\frac{dX_{k,l}^{s,0,a}}{dt} = \sigma^{s-1,} X_{k,l}^{s-1,0,a} + \upsilon X_{k,l}^{s,0,a-1} + \tau_k X_{k,l}^{s,1,a} - \left(\mu + \sigma^s + \pi_k^{1,} + \upsilon\right) X_{k,l}^{s,0,a}$$

$$\frac{dX_{k,l}^{s,1,a}}{dt} = \sigma^{s-1,} X_{k,l}^{s-1,1,a} + \upsilon X_{k,l}^{s,1,a-1} + \pi_k^{1,} X_{k,l}^{s,0,a} - \left(\mu + \sigma^s + \tau_k + \upsilon\right) X_{k,l}^{s,1,a}$$

for *s=2 to 4, a=2 to 6.*

Here σ_s is the rate of progress from stage of HIV infection *s* to the next stage *s+1*. In the case of σ_4 it is the time spent with AIDS before dying.

The per capita force of infection is defined:

$$\lambda_{k,l}^{,v,a} = c_{k,l}^{,v,a} \left\{ \sum_{v'=0}^{1} \sum_{l'=1}^{3} \sum_{a'=1}^{6} \rho_{k,v,l,a,v',l',a'} . \sum_{s'=1}^{4} \left(\beta_{k'}^{s'} \frac{X_{k',m}^{s,v,a}}{X_{k',m}^{\bullet,v,a}} \right) \right\}$$

Here $\beta_{k'}^{s'}$ is the transmission probability per partnership from that gender and that stage of infection; $c_{k,l}^{,v,a}$ is the number of sexual partnerships formed per year by individuals of that marital status, age, gender and sexual-activity; $\rho_{k,v,l,a,v',l',a'}$ is the fraction of partnerships formed between individuals with respect to the marital status, age and sexual-activity of each (prime denotes the characteristic of the partner; subscripts in strict order: own gender, own marital status, own activity-group, own age group, partner's marital-status, partner's activity-group, partner's age-group).

The value $\rho_{k,v,l,a,v',l',a'}$ is the probability that when someone of sex *k,* marital status *v*, activity group *l* and age-group *a* forms a sexual partnership it is with someone of the opposite sex of marital status *v'*, in activity group *l'* and in age-group *a'*. The proportion of each male's partnerships that are reserved for individuals in the same activity-class is ε_l, and the proportion of partnerships reserved for widows is ε_v. The fraction of partnerships formed by a male in age-group *a* and marital-status *v*, with females in age-group *a'* is $\Delta_{v,a,a'}$.

$$W_{k,l}^{v,a} = \sum_{s=1}^{4} c_{k,l} X_{2,1}^{s,v',a'}$$

$$\rho_{1,v,l,a,v',l',a'} = \left[(1-\varepsilon_v) \left\{ (1-\varepsilon_L) \frac{W_{2,1}^{v',a'}}{W_{2,\bullet}^{\bullet,a'}} + \varepsilon_L \delta_{l,l'} \frac{W_{2,1}^{v',a'}}{W_{2,l'}^{\bullet,a'}} \right\} + \varepsilon_v v' \left\{ (1-\varepsilon_L) \frac{W_{2,1}^{1,a'}}{W_{2,\bullet}^{1,a'}} + \varepsilon_L \delta_{l,l'} \right\} \right] \Delta_{v,a,a'}$$

Where $\delta_{i,j}$ is the identity matrix.

$\Delta_{0,1,1} = 1$

$\Delta_{0,a,a'} = \delta_{a-1,a'}$ for a>1

The pattern of females' partnership formation is then determined (male characteristic primed):

$$\rho_{2,v,l,a,v',l',a'} = \rho_{1,v',l',a',v,l,a} \frac{c_{1,l} X_{1,l}^{\bullet,v',a'}}{c_{2,l} X_{2,l}^{\bullet,v,a}}$$

The initial rate of sexual partner change rates for men are $c_{1,v,l}$ and are based upon a mean rate of partner change $\bar{c}_v$, and the relative activity of the highest and next-highest groups to the lowest: ω_1 and ω_2, respectively.

$$c_{1,0,3} = \frac{\bar{c}_v}{\left(\phi_{1,1}\omega_1 + \phi_{1,2}\omega_2 + \phi_{1,3}\right)}$$

$$c_{1,0,1} = c_{1,0,3}\omega_1 ; c_{1,0,2} = c_{1,0,3}\omega_2$$

$$c_{1,1,l} = \gamma c_{1,0,l}$$

$$c_{2,v,l} = c_{1,v,l} \frac{X_{1,l}^{\bullet,v}}{X_{2,l}^{\bullet,v}}$$

Parameter Values

μ = 0.005

κ_k =0.5

ν =1/5

α =0.04

σ_1 =1

σ_2 =1/8

σ_3 =1/2

σ_4 =1

τ_0 =1/8

τ_1 =1/15

π_0^0 = 12.1/1000

π_0^s = 60.1/1000 for s>0

π_1^0 = 2/1000

π_1^s =8.6/1000 for s>0

$\beta_1^1 = \beta_1^2 = \beta_1^4$ =0.1

β_1^2 =0.02

$\beta_0^s = 2\beta_1^s$

$\phi_{k,1}$ =0.1

$\phi_{k,2}$ =0.3

$\phi_{k,3}$ =0.6

ω_1 =50

ω_2 =10

$\bar{c}$ =3

Intervention Scenarios

γ =4 or 1

ε_w = 0.3 or 0

$\Delta_{1,a,a'} = \Delta_{0,a,a'}$ or:

$\Delta_{1,a,a'} = \delta_{a-k,a'} \frac{1}{3}$ for k=2 to 4 and a>4

$\Delta_{1,a,a'} = \Delta_{0,a,a'}$ otherwise