**Supplemental digital content**

**Exploring the Potential Impact of a Reduction in Concurrency on HIV Incidence in Rural Uganda: a Modelling Study**

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**Supplemental methods**

**Data sources and analysis**

**Demography**

The total size of the empirical 15-54 year old population in 2008 was 3318 men and 3749 women, giving a sex ratio of 0.885 males per female. After age standardising and adjusting for under 15 mortality (individuals were recruited into the model at age 15) the average adjusted ‘birth’ rate for 15-54 year old women in 1990-91 was 206 per 1000 woman years. The Brass lifetable model fitted[[1](#_ENREF_1)] mortality rate for 15-54 year olds in 1989-95 was 2.76 per 1000 person years at risk for men and 2.48 per 1000 person years for women.

**Concurrency and number of partners**

Concurrency is defined as ‘overlapping sexual partnerships where sexual intercourse with one partner occurs between two acts of intercourse with another partner’[[2](#_ENREF_2)]. Concurrency can be measured either as a point prevalence - the proportion of the population with more than one ongoing partnership at a single point in time – or as a period prevalence – the proportion who have had overlapping sexual partnerships at any point during a period of time. Compared to period prevalences, point prevalences are less affected by short-duration overlaps (e.g. an individual starting a second partnership shortly before ending the first, or having a single encounter with a sex worker while in a long-term relationship) and are therefore more strongly influenced by the prevalence of sustained overlaps of long term partnerships. As sustained overlaps are believed to contribute more to increasing the spread of HIV than short overlaps,[[3](#_ENREF_3)]a point prevalence was used when measuring concurrency and fitting the model to the concurrency levels found in the cohort.

In line with the recommendations made by the UNAIDS Reference Group on Estimates, Modelling, and Projections[[2](#_ENREF_2)], individuals’ concurrency status six months before their interview were used to calculate the prevalence of concurrency. This was used in preference to their concurrency status at the time of the interview because it does not depend on participants’ guesses about whether they will have sex with specific partners again.

Data on concurrency and number of current partners were available from round 21 of the General Population Cohort, collected in 2009-2010, from 1214 15-54 year old men and 1470 15-54 year old women. Participants were asked a series of questions about their most recent sexual partners within the last 12 months, up to a maximum of three partners. Information was obtained on when the participant first and last had sex with each partner to the nearest month (Using the questions “*When did you first have sex with this partner? How many months ago?*” and “*When did you last have sex with this partner? How many months ago?*”), and the partnership type in each case (“*How would you best describe your relationship with this person?*”). Partnerships were classified by the survey team as spouse, ex-spouse, non-spousal regular partner, casual partner, commercial, or other. Spouses were defined by the survey team as ‘partners who are in a consistent sexual relationship and are living together or perceive themselves as married’ (Alex Karabarinde, Head of GPC Survey Team, personal correspondence). These six responses were categorised into two groups for the data analysis and modelling: long-duration partners (partners described as spouses or ex-spouses) and short-duration partners (all other partners).

The proportions of individuals with zero ongoing partnerships, one ongoing partnership, and two or more ongoing partnerships (concurrency) by gender and by partnership type were calculated.

Following the UNAIDS Reference Group on Estimates, Modelling, and Projections’ recommendations[[2](#_ENREF_2)], individuals reporting two or more partnerships for which first sex occurred at least six months before the interview, and most recent sex was no more than six months before the interview, were classified to have concurrent partnerships. Partnerships were not considered to be concurrent if one was reported to have started and the other ended exactly six months before the interview. Individuals were excluded from the calculation if data were missing on the start or end date of any partnership and it was not possible to determine conclusively whether they had had overlapping partnerships six months before the interview.

Possible sources of bias in the measurement of concurrency and partnership prevalences were explored by comparing data on partnerships reported to have been ongoing six months before the interview with data on partnerships reported to be ongoing at the time of the interview, and by calculating the proportion of men and women reporting more than three sexual partners in the past year.

To allow comparisons to be made between the prevalence of concurrency in Uganda and the prevalence in other sub-Saharan African countries two further measures of concurrency were calculated: the proportion of 15-24 year old men reporting more than one ongoing partnership at the time of the interview and the proportion of 15-34 year old men who reported ever having had sex who reported that they were still having sex with more than one of their last three sexual partners at the time of the interview.

**Other sexual behaviour**

Data on annual partnership incidence were available from a subset of the cohort of 1446-1471 men for 2004-2008. The average incidence (standardised to the 2008 cohort population by sex and HIV status) was 0.44 partners per year.

The proportion of men who reported using a condom the last time they had sex was calculated for men who reported having one ongoing partnership, and for men who reported having more than one ongoing partnership.

**Epidemiology**

The age-standardised prevalence of HIV in 15-54 year olds in the cohort in 1992 was 9.7% in men (95% CI: 8.4-11.2%) and 10.9% in women (95% CI: 9.6-12.4%). In 2001 it was 7.8% in men (95% CI: 6.7-9.0%) and 9.4% in women (95% CI: 8.3%-10.7%). In 2007 it was 7.1% in men (95% CI: 6.1-8.3%) and 10.5% in women (95% CI: 9.4-11.7%). These years were chosen as the fitting years as they were local maximum or minimum years for the prevalence of HIV in the cohort, and therefore fitting to them meant that the overall trend in HIV prevalence by gender in the model would be similar to the overall trend in the cohort.

Antiretroviral therapy (ART) was introduced into the cohort in 2004. 51% of all adults in the cohort who were eligible to receive ART received it that year. This increased to 88% in 2005, 90% in 2006, 91% in 2007, and 92% in 2008 onwards.

**Model description**

The Mukwano model is an event-driven stochastic network model incorporating individual level behaviour, written in C++. The model runs for a user-defined time period. Using graph theory terminology, individuals are represented by nodes in the network and partnerships between individuals are represented by edges between the nodes. We will use ‘individuals’ and ‘partnerships’ rather than ‘nodes’ and ‘edges’ from now on. The initial population is set up using input parameters; the size *N* of the population, the population distribution between genders and the age distribution of the initial population. Events such as births, deaths, formation and dissolution of partnerships and transmission of disease occur when the model is running. In order to model sexual behaviour in the population, we calculate the rate of partnership formation that is expected between subgroups in the population and use these rates to schedule partnership formation events. When a scheduled partnership formation event between two subgroups occurs, one individual is chosen at random from each of the two subgroups and a partnership is formed. All events are scheduled sequentially by an event manager.

Each simulated human has certain characteristics attached to it at birth. These include gender, time of birth, a sexual activity index, and a concurrency index.

The sexual activity index is a random number between 0 and 1, where closer to 0 means a lower desired sexual partnership formation rate. This index is used in the allocation of individuals to sexual activity groups.

The concurrency index is a random number between 0 and 1 and is used in the allocation of simulated humans to groups with different behaviour with respect to the formation of concurrent partnerships.

**Demography**

The initial population was exponentially distributed and restricted so that everyone was aged between 15 and 54 years old. People were recruited into the model population at age 15, at a rate which is a function of the empirically found birth rate and empirically found under-15 mortality. At age 55, people were removed from the model and all partnerships with that person were dissolved.

Births: Let there be females in the population. Let each female have an annual birth rate of *b*. Then the total expected number of births per year is.

Deaths: Let there be females and males in the population and let the annual death rates for females and males be and respectively. The total expected number of deaths per year is

**Sexual Behaviour**

We define sexual activity groups in the model by associating a desired annual contact rate (desired sexual partnership formation rate) with each group and specifying the proportion of males and females assigned to each of these groups. A gender, , specific contact rate is denoted by . In this study we assumed two sexual activity groups.

Let be the maximum number of sexual activity groups (identical in both genders), be the maximum number of concurrency groups (identical in both genders), and be the maximum number of current partner groups (identical in both genders). Individuals are assigned to a concurrency group based on their concurrency index and sexual activity group. The proportion from each sexual activity group in each concurrency group is specified. These proportions are permitted to vary by gender. In this study, we assumed two concurrency groups; the first group contained individuals who were constrained to behave monogamously, and the second group contained individuals who were permitted to have concurrent relationships.

Each gender, , and concurrency group, , has a parameter associated with it.The parameter is permitted take values between 0 and 1. In this study, as we had two concurrency groups, there were four inputted values for for a scenario, one for each gender and one for each concurrency group. The fitted values of these parameters are given in Table S2. determines how likely it is that a person with current partners can take another partner, where is a non-negative integer. We defined to be equal to one. When is equal to one, the value of is one regardless of the value of, so how likely a simulated individual can take another partner is unchanged for any number of current partners. If is less than one, it becomes less likely that a simulated individual will take another partner. Finally, if is zero then simulated individuals are constrained to only have one current partner and therefore behave monogamously.

In the model, only heterosexual relationships are modelled. Partnership formation is a dynamic process, depending on the desired contact rate, ,per year, the number of current partners, , of each individual, the concurrency parameter, , the size of each population subgroup, a parameter, , used to control mixing between sexual activity groups, and a parameter, , that controls the balancing of partnerships between the two genders.

**Partnership Formation**

Let be the size of the population subgroup consisting of individuals of gender in sexual activity group , with the desired contact rate for this population subgroup denoted by The mean number of contacts desired by this group is .

The subgroup, of individuals of gender and in sexual activity group may be further partitioned into subgroups according to concurrency group and number of current partners . Let be the size of the population subgroup consisting of individuals of gender , in sexual activity group , concurrency group and with current partners.

In this study, we want to maintain the overall desired contact rate in the sexual activity groups (and hence overall partnership incidence) whilst allowing the propensity for concurrent partnerships () to change over time. This is achieved as follows.

Let be the desired per-person contact rate for the subgroup. Then is the desired total contact rate for this group. Let

(S1)

where and are dummy variables summing over the concurrency groups and current number of partner groups respectively. Thus, we apportion a proportion of the desired total contact rate to each subgroup. This proportion is determined by the size of the subgroup, weighted by concurrency parameter in that subgroup.

Equation S1 may be rearranged as

(S2)

and so is the desired per-person contact rate for the subgroup. Since , for any value of , it can be seen that this method maintains the desired total contact rate for each sexual activity group.

**Distribution of contacts**

The desired contacts of each subgroup are distributed between individuals of the opposite gender (opposite gender indicated by a ).

We define as the desired number of contacts the subgroup assigns to the subgroup. Then

(S3)

Where is a dummy variable summing over the opposite gender’s sexual activity groups and is a parameter used to control mixing between sexual activity groups such that it takes values between 0 and 1. indicates that mixing is completely assortative and indicates that mixing is proportionate-random. The parameter takes the value 1 if sexual activity groups of both genders are the same (i.e. ) and otherwise.

Now we extend equation S3 to consider the subgroups of. The desired total contact rate that the subgroup allocates to the subgroup is

(S4)

Where , and and are dummy variables summing over the opposite gender’s concurrency groups, current number of partner groups, and sexual activity groups, respectively. The contacts that are allocated to sexual activity group via the assortativity parameter are further distributed to the concurrency group and partner group according to the weighted proportion .

As the total number of partnerships desired by males and females may not be the same, we balance these potentially different partnership demands using a compromise parameter*,* which takes a weighted mean of what both groups desire. In the case where ,the formation rate is simply the arithmetic mean of the desired female and male rates. Thus the partnership formation rate between the and groups is

|  |  |
| --- | --- |
|  | (S5) |

We assume that the occurrence of partnership formation events between the and groups in a given time period forms a non-homogeneous Poisson process with rate given in equation S5.

**Partnership duration**

When a partnership forms, it is assigned a duration of user defined length of time - in this paper, there were either short or long partnerships. If two low-sexual activity individuals formed the partnership then the duration of the partnership was long. If two high-activity individuals formed a partnership, then the duration of the partnership was short. If low and high activity individuals form the partnership, there was a 50% probability of either partnership type being formed.

We also introduced a constraint on the parameters related to partnership formation to ensure that we did not choose combinations of these parameters that would be impossible to simulate. We ensured that the inequality was satisfied when , where is the proportion of people of gender in sexual activity groupand is the partnership duration associated with sexual activity group

**Epidemiology**

Mukwano contains a very flexible STI module allowing unlimited (subject to memory constraints) different STIs to be simulated. This is accomplished by instantiating multiple instances of a 'generic' STI definition objects based on the user-defined characteristics for specific STIs. Here we outline the characteristics for HIV in the model.

**HIV natural history**

Currently, the user-defined characteristics for the natural history of HIV are the number and order of HIV/AIDS stages and gender-specific attributes of each stage, such as duration (mean and distribution), per contact infectivity and sub-stage characteristics. HIV stage transitions are implemented using a state machine. At the end of each HIV stage, individuals will either move to another HIV stage, or die. During a simulation, each individual contains a reference to his/her HIV status. The initial HIV stage is defined as stage 0, defined as 'susceptible'.

**HIV introduction**

HIV is seeded into a population by infecting a certain proportion of individuals at random with the disease at a user specified time. HIV is distributed randomly by stage.

**HIV transmission**

In each relationship, sex acts are scheduled to occur according to a user-defined probability distribution. At each unprotected sexual contact between a susceptible and infectious partner, we draw a random number from the uniform distribution between 0 and 1 and compare it with the transmission probability for the corresponding stage of the infectious individual. The infection is transmitted if the random number is less than the transmission probability.

**ART**

ART is implemented by moving a proportion of individuals in the AIDS/pre-AIDS stage onto the ART sub-stage where they have longer survival and lower transmission probabilities than untreated individuals. Full details are shown below.

**Scheduling of Events**

An event in the Mukwano model is any occurrence which could change the state of the network, e.g. birth, death, aging, relationship forming, relationship dissolving, transmission of disease and moving from one disease state to another. Events occur sequentially in the model and are scheduled to occur using a calendar queue with a priority queue for each bucket [[4](#_ENREF_4)]­­­. Certain events that occur in the model can force other events to occur before their scheduled time. For example, if a person dies and she/he is in a relationship with one or more people, then those relationships must end immediately - not at their original appointed time.

We describe how births are scheduled in the model; the scheduling of other events may be inferred from this. We assume that the occurrence of birth events forms a non-homogeneous Poisson process with rate where it is implicitly assumed that the number of females may change over time. The time to a birth event is determined by Monte-Carlo sampling from an exponential distribution.

Assume we are at time *t0* and births occur with rate . A time is sampled to schedule the next birth; this time is drawn from an exponential distribution with mean . Let that time be . The next birth event thus occurs at scheduled-time. If there is any change in the original rate before time then we must adjust for that. Say that at time there is a change to the rate, and we have a new rate *new*. We adjust the scheduled time as follows:

We may choose to adjust the scheduled time every time a change (e.g. death/age-updating) occurs or at regular intervals if we want to speed up the model.

**Interventions**

To reflect changes in behaviour over time, some parameters in the model can be changed at regular or once-off time points. We can alter sexual behaviour (contact rates, concurrency parameters and partnership durations) and transmission probabilities due to the introduction of anti-retroviral therapy.

In particular, we set up our model so that the concurrency parameters change at a specified time in the model to reflect an intervention to reduce concurrency. The way the model is set up, a reduction in the value of will not affect partnership incidence as the overall contact rate for sexual activity groups is maintained, but the distribution of the partnerships is altered, i.e. using graph theory terminology, there is a change in the way edges are distributed in the network.

**Baseline scenario creation**

In the lower- and higher-concurrency scenarios, the ratio of the prevalence of male long-duration partnership concurrency to the prevalence of male short-duration partnership concurrency, and the ratio of the proportion of males with exactly one long-duration partnerships (and any number of short-duration partnerships) to the proportion of males with exactly one short-duration partnerships (and any number of long-duration partnerships), were the same as the ratios of reported partnerships. The ratios of the prevalence of female long-duration partnership concurrency to the prevalence of female short-duration partnership concurrency in the estimated- and higher-concurrency scenarios were the same as the ratios of reported partnerships in men.

In all scenarios the proportions of men with one partner of either type were the same as the proportions reported. In the scenarios modelling the reported level of male concurrency (estimated- and reported-concurrency scenarios), the proportions with zero partners by type and in total were fitted to be the same as the proportions reported. In the lower- and higher-concurrency scenarios, the proportion of men with zero partners varied according to the prevalence of male concurrency.

As a closed population was modelled, it was necessary that the total number of partnerships by type was identical for men and women. For this reason, the model could only be fitted exactly to the data for one sex. As it is likely that there is a stronger social desirability bias on women to mis-report partnerships (e.g. to report a lower number of partners or to report non-spousal partners as spouses) than on men, we preferentially fitted to the sexual behaviour reported by males. The proportion of females with one or zero partners was therefore allowed to vary so that the number of partnerships of each type females were in at any point would balance the number that men were in.

**Summary of plausible ranges for model inputs and outputs**

**Demography: Inputs:** The modelled birth rate and death rates by gender were based on the rates in the cohort in 1990-91 and 1989-95 respectively.

**Outputs:** The size of the model population in 2008 was fitted to the size of the cohort population aged 15-54 in 2008 by gender. The fits were considered acceptable if they were within ±10% of the target size. An approximately stable population size was desired between the introduction of HIV in 1979 and the fitting year, 2008. An average growth rate between these years of between -0.1% and 0.1% per year was considered acceptable.

**Sexual behaviour: Inputs:** Details of the sexual behaviour input parameters and constraints upon them are given in Supplemental Table S2. **Outputs:** The model was fitted to the target partnership distributions for each scenario. Fits were considered acceptable if all proportions and ratios were within ±10%(relative) of the desired values. In the lower-concurrency scenario, a fit was only considered acceptable if there was no female concurrency. The target male partnership incidence in the best-estimate scenario was the reported partnership incidence in the cohort in 2004-08. A range of ±10% was considered acceptable. There was no target male partnership incidence in the lower- and higher-concurrency scenarios.

**Epidemiology: Inputs:** Untreated HIV infection was crudely categorised into four sequential stages, primary HIV infection, post primary CD4+ count >200 cells/µl, pre AIDS CD4+ count <200 cells/µl and an AIDS stage(Supplemental Figure S1). Starting in 2004, ART was implemented by simulating treatment of a proportion of individuals with CD4 count <200 cells/µl. Details of assumed stage durations, transmission probabilities, the effect of ART on transmission probabilities and survival, and ART coverage were based on literature review and shown in Supplemental Content. **Outputs:** The model was fitted to the male and female prevalences of HIV in the cohort in 1992, 2001 and 2007. Fits were considered acceptable if they were within the 95% confidence intervals for the data.

**Longer description of plausible ranges for model inputs**

**Demography**

The upper bound on the birth rate was taken to be 110% of the birth rate in the cohort in 1990-91, adjusted for under-15 mortality (individuals were recruited into the model at age 15). The lower bounds for the male and female mortality rates were taken to be 90% of the mortality rates in 1989-95. There was no lower bound on the birth rate or upper bound on the mortality as migration was not modelled and there is a net out-migration from these rural areas of Uganda[[5](#_ENREF_5)]. The demographic input parameters were kept the same in all scenarios.

The sex ratio in the initial population in 1950 was assumed to be the same as the sex ratio of the cohort in 2008 to ease fitting the population composition in 2008. A mortality rate of 1000 per person per year was modelled for over 54 year olds to remove them from the model population.

**Sexual behaviour**

All individuals were simulated to be able to form partnerships from their recruitment into the model population at the age of 15. A coital frequency of ten times a month was modelled, in line with findings from neighbouring Rakai district[[6](#_ENREF_6)]. The partnership formation rate was taken to be the male desired formation rate (). The proportion of men and women in the high activity group was allowed to vary between 10 and 50%. Mixing by activity level was allowed to vary between a moderate level of assortative mixing () and random mixing (). The proportion of men and women in each activity group and the value of the mixing parameter were held constant across all scenarios. The durations of long-duration partnerships was fixed at 10 years. The duration of short-duration partnerships was varied in the best-estimate scenario. The fitted value was then used in all other scenarios. For each gender, 100% of one activity group were simulated to be in the high concurrency group. The proportion of the other activity group who were also in the high concurrency group was allowed to vary between 0 and 1.

Three different sets of risk behaviour with different contact rates and concurrency parameters were modelled over time. The first lasted between the start of the model and year X, the second between year X and year Y, and the third between year Y and the end of the model. Year X was allowed to vary between1986 and 1992 and year Y between 1998 and 2002. Simulated contacts rates and concurrency parameters in the third risk set were greater than or equal to those in the second risk set and less than or equal to those in the first risk set. The male and female concurrency parameters, for the high concurrency group were allowed to vary between 0 and 1 in each set. Males and females in the low concurrency group were not allowed to form concurrent partnerships (i.e. for males and females in the low activity group). The contact rates for high and low activity males were allowed to take any value provided that the contact rate for high activity males was higher than the contact rate for low activity males. Female contact rates were set equal to the male contact rates in the same activity group and risk behaviour set. The ratio of the high activity contact rate to the low activity contact rate was kept constant across all risk sets.

Female behaviour parameters were allowed to vary across all scenarios unless stated otherwise. Male behaviour parameters were held constant across the estimated- and reported-concurrency scenarios.

**Epidemiology**

A schematic of the simulated natural history of HIV is shown in Figure S1. Untreated HIV infection was crudely categorised into four sequential stages, primary HIV infection (*Pri*), post primary CD4+ count more than 200 cells/µl (*CD4>200*), pre AIDS CD4+ count less than 200 cells /µl (*CD4<200PreAIDS*), and an AIDS (*AIDS*) stage. ART was implemented by simulating the removal from the *CD4<200PreAIDS* into the *ARTFromPreAIDS* stage and the removal from the AIDS stage into the *ARTFromAIDS* stage. Stage durations were drawn from a Weibull distribution with a mean of 0.25 years for the primary stage, 7.9 years for the *CD4>200* stage, 2.1 years for the *CD4<200PreAIDS* stage, 0.75 years for the *AIDS* and *AIDSFromART* stages, 6.4 years for the *ARTFromPreAIDS* stage, and 2.25 years for the *ARTFromAIDS* stage. Transmission probabilities were assumed to follow a bathtub distribution based on analysis by *Hollingsworth et al* [[7](#_ENREF_7)] and data from *Wawer et al* [[6](#_ENREF_6)]. The assumed ratio of transmission probabilities by stage are shown in Table S2. ART was assumed to reduce transmission probabilities in the *ARTFromPreAIDS* and the *ARTFromAIDS* stage by 92% [[8-10](#_ENREF_8)] and increase survival by a multiple of 3 [[11](#_ENREF_11)] (Table S2). In line with data from the MRC cohort, ART coverage was simulated to increase from 0% before 2004, to 51%, 88%, 90%, 91% and 92% in 2004, 2005, 2006, and 2007 and 2008 onwards.

**Baseline fitting strategy**

Model outputs were fitted by manually varying model inputs within the ranges specified *a priori*. Demographic outcomes were fitted first, followed by sexual behaviour then HIV prevalence. Simulated demography and sexual behaviour were re-fitted slightly after HIV was introduced. The model was run between 1950 and 2020 and the results of 2000 runs with identical input parameters were averaged to produce the results.

**Supplemental Results**

**Empirical prevalence of concurrency and partnership distribution, and reported condom use**

Six men (0.5%) and no women were excluded from the concurrency calculations due to incomplete partnership data. 9.0% (109/1208, 9.6% when age-standardised to the model population) of men reported having had concurrent partners at six months prior to the interview (95% CI: 7.9-11.4%) (Table S1). 3.6% (43, 3.8%) reported having had concurrent long-duration partnerships (95% CI: 2.7-4.9) and 1.8% (22, 1.9%) reported having had concurrent short-duration partnerships (95% CI: 1.1-2.7%). Only 0.20% (3/1470, 0.20%) of women reported having had concurrent partners at six months prior to the interview (95% CI: 0.00-0.44 %). 0.07% (1, 0.07%) reported concurrent long-duration partnerships (95% CI: 0.00-0.20%). No women reported concurrent short-duration partnerships.

Only one person reported one partnership ending and another starting exactly six months before the interview. He reported a duration of only day for both partnerships and therefore they were highly unlikely to have been concurrent.

The proportions of men and women reporting zero, one, and more than one ongoing partnership at the time of the survey are shown in Table S8. There was very little difference in the proportions of men and women reporting concurrent partners six months before the interview and the proportion reporting concurrent ongoing partnerships at the time of the survey (men: 9.6% six months before and 9.9% at the time of the survey, p=0.47; women: 0.20% and 0.14%, p=0.48). There was also little difference in the proportions reporting one partner (men: 39.4% and 39.6%, p=0.47.; women: 57.9% and 60.0%, p=0.13). This suggests that the estimates of concurrency and partnership prevalences are unlikely to have been greatly affected by either recall bias or by the fact that the prevalences used were, strictly speaking, one-month period prevalences and not point prevalences.

Only 2.3% (27) of men (95% CI: 1.4-3.2%) and 0.12% (2) of women (95% CI: 0.00-0.30) reported having had more than three sexual partners in the preceding 12 months. This shows that the fact that concurrent partnerships may not have been detected in individuals who had had more than three partners in the six months prior to the interview (as full information was collected on the last three sexual partners only) is unlikely to have had much effect on the estimates of concurrency.

1.8% of 15-24 year old men reported having more than one ongoing partnership at the time of the interview. Using the same measure of concurrency, 23% of 15-24 year old men reported concurrency in KwaZulu-Natal in South Africa in 2002[[12](#_ENREF_12)]. 8.5% of 15-34 year old men in the cohort who had ever had sex reported that they were still having sex with more than one of their last three sexual partners, compared to 21% in Botswana in 2007[[13](#_ENREF_13)].

15.9% of men with more than one ongoing partnership at the time of the interview reported using a condom the last time they had sex, compared to 9.9% (59/594) of men with only one ongoing partnership (p=0.04).

**Baseline simulated scenarios**

The values of the input parameters used in each scenario are given in Table S2. The fitted values for partnership prevalences are given in Table S4 and the fitted values for demographic, epidemiological and all other behavioural outputs are given in Table S5.The fit to the male and female population sizes in 2008 is shown in Figure S3. The target and simulated partnership prevalences and HIV prevalences for the reported-concurrency scenario are shown in Figure S4.

**Simulated interventions**

**Impact on sexual behaviour**

The 20% reduction in concurrency was achieved by reducing the magnitude of *θm* in the high concurrency group by between 34.0% and 54.0% and the magnitude of *θf* in the high concurrency group by between 24.9% and 31.5% (Table S3). The 50% reduction in concurrency was achieved by reducing by between 68.0% and 87.0% and by between 58.0% and 66.0%.

In the 20% reduction in concurrency intervention scenarios the prevalence of long-duration partnership concurrency in 2020 was between 25.3% and 33.9% lower in men and between 18.7% and 18.9% lower in women (where relevant) compared to the baseline scenarios. (Table S6), and the prevalence of short-duration partnership concurrency was between 20.2% and 23.6% lower in men and between 20.9% and 24.0% lower in women.

In the 50% reduction in concurrency intervention scenarios, the prevalence of long-duration partnership concurrency in 2020 was between 56.1% and 67.4% lower in men and between 45.9% and 47.7% lower in women (where relevant) compared to the baseline scenarios, and the prevalence of short-duration partnership concurrency was between 47.8% and 50.0% lower in men and between 52.1% and 55.9% lower in women.

There was a sharp decrease in the prevalence of total concurrency between 2010 and 2011 following the start of the intervention (Table S6). With a 20% reduction in concurrency by 2020, this ranged between a 9.6% and 13.7% reduction in men and between an 11.8% and 13.5% reduction in women. With a 50% reduction in concurrency by 2020, this ranged between a 27.4% and 33.0% reduction in men and between a 32.7% and 34.2% reduction in women. This was due to all ‘excess’ short-duration partnership concurrent partnerships started before the intervention ending between 2010 and 2011. Following this, there was a gradual decline in the prevalence of concurrency as ‘excess’ long-duration partnership concurrent partnerships started before the intervention ended. This is illustrated for the best-estimate scenario in Figure S5*.* The full impact of the intervention on concurrency was reached by 2020, 10 years after the introduction of the intervention, when all partnerships started before the intervention had ended.

There was very little difference in partnership incidence (Figure S6) or average number of sex acts per male per year (Figure S7) between the baseline scenarios and the corresponding intervention scenarios. Average annual partnership incidence between 2011 and 2020 was between 0.04% lower and 0.08% higher in the intervention versions compared to the baseline versions. For any single year average partnership incidence was between 0.23% lower and 0.33% higher. The average annual number of sex acts per person between 2011 and 2020 was between 0.01% lower and 0.18% higher in the intervention versions compared to the baseline versions. For any single year it varied between 0.06% lower and 0.44% higher. All differences are presented as relative differences.

**Impact on HIV**

The incidences of HIV in 2020 with and without the fitted interventions and the percentage reductions in incidence caused by the interventions are given in 9. The trend in HIV over time in the baseline and intervention (50% reduction in concurrency) scenarios are shown for the best-estimate scenario in Figure S2.

The reductions in HIV incidence cause by differing reductions in male and female concurrency are shown in Table S10.

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|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **Men** | | **Women** | |
|  |  | **Number (%)** | **Age standardised proportion\* (%) (95% CI)** | **Number (%)** | **Age standardised proportion\* (%) (95% CI)** |
| **Long-duration partnerships** | **0** | 733 (60.7) | 57.8 (55.0-60.6) | 722 (49.1) | 49.3 (46.7-51.8) |
| **1** | 432 (35.8) | 38.5 (35.7-41.3) | 747 (50.8) | 50.7 (48.1-53.2) |
| **2+** | 43 (3.6) | 3.8 (2.7-4.9) | 1 (0.1) | 0.07 (0.00-0.20) |
| **Short-duration partnerships** | **0** | 1045 (86.5) | 86.1 (84.1-88.1) | 1365 (92.9) | 92.9 (91.6-94.2) |
| **1** | 141 (11.7) | 12.1 (10.2-13.9) | 105 (7.1) | 7.1 (5.8-8.1) |
| **2+** | 22 (1.8) | 1.9 (1.1-2.7) | 0 (0.0) | - |
| **All partnerships** | **0** | 620 (51.3) | 48.3 (45.5-51.2) | 619 (42.1) | 42.3 (39.8-44.8) |
| **1** | 479 (39.7) | 42.0 (39.2-44.9) | 848 (57.7) | 57.5 (55.0-60.0) |
| **2+** | 109 (9.0) | 9.6 (7.9-11.4) | 3 (0.2) | 0.20 (0.00-0.44) |
| **Total** | | 1208 |  |  | 1470 |  |

Table S1. Prevalence of concurrency and number of partners in 15-54 year olds in the Masaka cohort in 2008

\* age standardised to the empirical 2008 population

| Inputs | | | Fitting constraint | Held constant across scenarios: | Modelled value | | | | | Reference/explanation for fitting constraint/notes | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | |  |  | Best-estimate scenario | Lower-concurrency scenario | Higher-concurrency scenario | *Reported-concurrency scenario* |  | | |
| Demography | | |  |  |  |  |  |  |  | | |
| Initial population size (male) | | | n/a | All | 2874 | 2874 | 2874 | *2874* | n/a | | |
| Initial population size (female) | | | n/a | All | 3247 | 3247 | 3247 | *3247* | n/a | | |
| Ratio of men to women in initial population | | | 0.885 | All | 0.885 | 0.885 | 0.885 | *0.885* | Same as the ratio in the cohort in 2008 | | |
| Birth rate (per 1000 women years) | | | 195 (no lower bound-215) | All | 57.00 | 57.00 | 57.00 | *57.00* | Average birth rate in cohort in 1990-91. No lower bound to +10% | | |
| Male mortality rate (per 1000 years at risk) | | | 2.76 (2.48-no upper bound) | All | 10.00 | 10.00 | 10.00 | *10.00* | Male mortality rate in cohort in 1989-95. -10% to no upper bound | | |
| Female mortality rate (per 1000 years at risk) | | | 2.48 (2.23- no upper bound) | All | 2.48 | 2.48 | 2.48 | *2.48* | Female mortality rate in cohort in 1989-95. -10% to no upper bound | | |
| Sexual behaviour | | |  |  |  |  |  |  |  | | |
| Age at debut | | | 15 | All | 15 | 15 | 15 | *15* |  | | |
| Coital frequency (per month) | | | 10 | All | 10 | 10 | 10 | *10* | Wawer (2005)[[6](#_ENREF_6)] | | |
| Duration of long-duration partnerships (years) | | | 10 | All | 10 | 10 | 10 | *10* |  | | |
| Duration of short-duration partnerships (years) | | | <10 | All | 0.43 | 0.43 | 0.43 | *0.43* | Varied to fit empirical partnership incidence in best-estimate scenario and then fitted value used in all other scenarios | | |
| Proportion of men in high activity group | | | 0.1-0.5 | All | 0.35 | 0.35 | 0.35 | *0.35* |  | | |
| Proportion of women in high activity group | | | 0.1-0.5 | All | 0.35 | 0.35 | 0.35 | *0.35* |  | | |
| Mixing by activity group (ε) | | | 0.5-1 | All | 0.67 | 0.67 | 0.67 | *0.67* | A moderate level of assortative mixing to random mixing | | |
| Proportion of high activity men in high concurrency group | | | 0-1 | Estimated and Reported | 1 | 1 | 1 | *1* | Either the proportion in the high activity group or the proportion in the low activity group was set equal to one to minimise the modelled value of theta | | |
| Proportion of low activity men in high concurrency group | | | 0-1 | Estimated and Reported | 0.275 | 0.4 | 0.35 | *0.275* |
| Proportion of high activity women in high concurrency group | | | 0-1 | No | 1 | 1 | 0.85 | *1* | Either the proportion in the high activity group or the proportion in the low activity group was set equal to one to minimise the modelled value of theta | | |
| Proportion of low activity women in high concurrency group | | | 0-1 | No | 0.7 | 0.6 | 1 | *0.1* |
| Risk behaviour 1 | **High activity contact rate** | | > Low activity contact rate | No | 2.071 | 2.045 | 2.406 | *2.156* | Ratio of high activity rate to low activity rate the same in all risk behaviour sets | | |
| **Low activity contact rate** | | < High activity contact rate | No | 0.179 | 0.167 | 0.190 | *0.186* |
| **Male concurrency parameter in high concurrency group** | | 0-1 | No | 0.65 | 0.5 | 0.85 | *0.65* |  | | |
| **Female concurrency parameter in high concurrency group** | | 0-1 | No | 0.5 | 0.12 | 0.6 | *0.5* |  | | |
| Start year for risk behaviour 2 | | | 1986-1992 | All | 1986 | 1986 | 1986 | *1986* |  | | |
| Risk behaviour 2 | **High activity contact rate** | | > Low activity contact rate | No | 0.925 | 0.828 | 1.283 | *0.925* | Ratio of high activity rate to low activity rate the same in all risk behaviour sets | | |
| **Low activity contact rate** | | < Low activity contact rate | No | 0.080 | 0.068 | 0.101 | *0.080* |
| **Male concurrency parameter in high concurrency group** | | 0-1 | No | 0.65 | 0.2 | 0.4 | *0.65* |  | | |
| **Female concurrency parameter in high concurrency group** | | 0-1 | No | 0 | 0 | 0.05 | *0* |  | | |
| Start year for risk behaviour 3 | | | 1998-2002 | All | 1998 | 1998 | 1998 | *1998* |  | | |
| Risk behaviour 3 | **High activity contact rate** | | > Low activity contact rate | Estimated and Reported | 1.100 | 0.964 | 1.361 | *1.100* | Ratio of high activity rate to low activity rate the same in all risk behaviour sets | | |
| **Low activity contact rate** | | < Low activity contact rate | Estimated and Reported | 0.095 | 0.079 | 0.107 | *0.095* |
| **Male concurrency parameter in high concurrency group** | | 0-1 | Estimated and Reported | 0.65 | 0.34 | 0.85 | *0.65* |  | | |
| **Female concurrency parameter in high concurrency group** | | 0-1 | No | 0.065 | 0 | 0.055 | *0* |  | | |
| Epidemiology | | |  |  |  |  |  |  |  | | |
| Female to male transmission probability during the Pri stage | | |  | None | 0.0338 | 0.0420 | 0.0220 | *0.0338* |  | | |
| Ratio of male to female/male to female transmission probabilities | | | 1-3 | None | 1.73 | 1.90 | 1.98 | *1.73* |  | | |
| Ratio of transmission probability in CD4>200 stage to transmission probability in Pri stage | | | 0.038 | All | 0.038 | 0.038 | 0.038 | *0.038* |  | | |
| Ratio of transmission probability in CD$<200PreAIDS stage to transmission probability in Pri stage | | | 0.038 | All | 0.038 | 0.038 | 0.038 | *0.038* |  | | |
| Ratio of transmission probability in AIDS stage to transmission probability in Pri stage | | | 0.275 | All | 0.275 | 0.275 | 0.275 | *0.275* |  | | |
| Ratio of transmission probability in ARTFromPreAIDS transmission probability in Pri stage | | | 0.003 | All | 0.003 | 0.003 | 0.003 | *0.003* |  | | |
| Ratio of transmission probability in AIDSFromART stage to transmission probability in Pri stage | | | 0.275 | All | 0.275 | 0.275 | 0.275 | *0.275* |  | |  |
| Ratio of transmission probability in ARTFromAIDS stage to transmission probability in Pri stage | | | 0.022 | All | 0.022 | 0.022 | 0.022 | *0.022* |  | |  |
| Mean Pri stage duration (years) | | | 0.25 | All | 0.25 | 0.25 | 0.25 | *0.25* |  | | All stage durations were drawn from a weibull distribution |
| Mean CD4>200 stage duration (years) | | | 7.9 | All | 7.9 | 7.9 | 7.9 | *7.9* |  | |
| Mean CD4<200PreAIDS stage duration (years) | | | 2.1 | All | 2.1 | 2.1 | 2.1 | *2.1* |  | |
| Mean AIDS stage duration (years) | | | 0.75 | All | 0.75 | 0.75 | 0.75 | *0.75* |  | |
| Mean AIDSFromART stage duration (years) | | | 0.75 | All | 0.75 | 0.75 | 0.75 | *0.75* |  | |
| Mean ARTFromPreAIDS stage duration (years) | | | 6.4 | All | 6.4 | 6.4 | 6.4 | *6.4* |  | |
| Mean ARTFromAIDS stage duration (years) | | | 2.25 | All | 2.25 | 2.25 | 2.25 | *2.25* |  | |
| Proportion of eligible individuals receiving ART | | **Pre-2004** | 0 | All | 0 | 0 | 0 | *0* |  | |  |
| **2004** | 0.51 | All | 0.51 | 0.51 | 0.51 | *0.51* |  | |  |
| **2005** | 0.88 | All | 0.88 | 0.88 | 0.88 | *0.88* |  | |  |
| **2006** | 0.90 | All | 0.90 | 0.90 | 0.90 | *0.90* |  | |  |
| **2007** | 0.91 | All | 0.91 | 0.91 | 0.91 | *0.91* |  | |  |
| **2008 onwards** | 0.92 | All | 0.92 | 0.92 | 0.92 | *0.92* |  | |  |

Table S2. The plausible ranges for the input parameters and the values used in each scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scenario** | **Percent decrease in the high concurrency group concurrency parameter** | | | |
| **20% reduction in concurrency** | | **50% reduction in concurrency** | |
| **Male** | **Female** | **Male** | **Female** |
| **Best-estimate** | 43.0% | 24.9% | 78.0% | 58.0% |
| **Lower-concurrency** | 34.0% | n/a | 68.0% | n/a |
| **Higher-concurrency** | 54.0% | 31.5% | 87.0% | 66.0% |
| ***Reported-concurrency\**** | *43.0%* | *n/a* | *78.0%* | *n/a* |

Table S3. The fitted reduction in the concurrency parameters in the high concurrency group in the intervention scenarios after the start of the intervention

Note: n/a: not applicable as there is no female concurrency in these scenarios

\*The reported concurrency scenario simulated the reported prevalence of both male and female concurrency (ie 9.6% and 0%)

|  |  |  | Long-duration | | Short-duration | | Total | | Ratio of prevalence of men with one long-duration partnership to prevalence of men with one short-duration partnership | | Ratio of prevalence of long-duration partnership concurrency to prevalence of short-duration partnership concurrency | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Number of partners | Target (%)  (bounds) | Model output (%) | Target (%)  (bounds) | Model output (%) | Target (%)  (bounds) | Model output (%) | Target  (bounds) | Model output | Target  (bounds) | Model output |
| Best-estimate scenario | **Men** | **0** | 57.78  (52-63.56) | 57.16% | 86.05  (77.45-94.66) | 86.65% | 48.34  (43.5-53.17) | 47.34% | - | 3.42 | - | 2.01 |
| **1** | 38.46  (34.62-42.31) | 38.73% | 12.07  (10.86-13.27) | 11.31% | 42.03  (37.83-46.24) | 43.84% |
| **2+** | 3.76  (3.38-4.13) | 4.11% | 1.88  (1.69-2.07) | 2.04% | 9.63  (8.66-10.59) | 8.82% |
| **Women** | **0** | - | 58.93% | - | 86.66% | - | 46.42% | - | 3.11 | - | 2.07 |
| **1** | - | 40.13% | - | 12.89% | - | 51.37% |
| **2+** | 0.94  (0.85-1.03) | 0.93% | 0.47  (0.42-0.52) | 0.45% | 2.41  (2.17-2.65) | 2.21% |
| Lower-concurrency scenario | **Men** | **0** | - | 62.60 | - | 87.69 | 53.15  (47.84-58.47) | 52.29 | 3.19  (2.87-3.51) | 3.15 | 2.00  (1.80-2.20) | 1.95 |
| **1** | - | 35.21 | - | 11.19 | 42.03  (37.83-46.24) | 42.56 |
| **2+** | - | 2.19 | - | 1.12 | 4.81  (4.33-5.29) | 5.15 |
| **Women** | **0** | - | 64.94 | - | 88.11 | - | 53.07 | - | 2.95 | - | - |
| **1** | - | 35.04 | - | 11.89 | - | 46.93 |
| **2+** | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 |
| Higher-concurrency scenario | **Men** | **0** | - | 54.90% | - | 84.57% | 43.53  (39.18-47.88) | 44.69% | 3.19  (2.87-3.51) | 3.17 | 2.00  (1.80-2.20) | 2.05 |
| **1** | - | 38.18% | - | 12.05% | 42.03  (37.83-46.23) | 41.93% |
| **2+** | - | 6.92% | - | 3.38% | 14.44  (13-15.88) | 13.38% |
| **Women** | **0** | - | 53.98% | - | 83.61% | - | 38.89% | - | 2.85 | 2.00  (1.80-2.20) | 1.87 |
| **1** | - | 44.56% | - | 15.61% | - | 57.57% |
| **2+** | - | 1.46% | - | 0.78% | 3.61  (3.25-3.97) | 3.53% |
| *Reported-concurrency scenario* | ***Men*** | ***0*** | *57.78*  *(52-63.56)* | *57.20* | *86.05*  *(77.45-94.66)* | *86.68* | *48.34*  *(43.5-53.17)* | *47.40* | *-* | *3.43* | *-* | *2.02* |
| ***1*** | *38.46*  *(34.62-42.31)* | *38.70* | *12.07*  *(10.86-13.27)* | *11.30* | *42.03*  *(37.83-46.24)* | *43.81* |
| ***2+*** | *3.76*  *(3.38-4.13)* | *4.10* | *1.88*  *(1.69-2.07)* | *2.03* | *9.63*  *(8.66-10.59)* | *8.79* |
| ***Women*** | ***0*** | *-* | *57.87* | *-* | *86.19* | *-* | *44.07* | *-* | *3.05* | *-* | *-* |
| ***1*** | *-* | *42.13* | *-* | *13.81* | *-* | *55.93* |
| ***2+*** | *0* | *0.00* | *0* | *0.00* | *0* | *0.00* |

Table S4. The plausible ranges and model outputs for the prevalence of concurrency and number of partners

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Outputs** | **Target (Fitting constraint)** | **Modelled value** | | | | **Reference/explanation for fitting constraint** |
|  |  | **Lower-concurrency scenario** | **Best-estimate scenario** | **Higher-concurrency scenario** | ***Reported-concurrency scenario*** |  |
| **Demography** |  |  |  |  |  |  |
| Population size in 2008 (male) | 3318 (2986-3650) | 3321 | 3317 | 3332 | *3310* | Population size of cohort in 2008 ±10% |
| Population size in 2008 (female) | 3749 (3374-4124) | 3758 | 3745 | 3759 | *3722* | Population size of cohort in 2008 ±10% |
| Average population growth rate 1979-2008 (% increase per year) | -0.1-0.1 | -0.01 | -0.02 | 0.00 | *-0.03* | Approximately stable population size |
| **Sexual behaviour** |  |  |  |  |  |  |
| Average male partnership incidence in 2008 | 0.444 (0.400-0.489) estimated and reported scenarios only | 0.370 | 0.429 | 0.528 | *0.429* | Average partnership incidence in cohort between 2004-2008 ±10% |
| **Epidemiology** |  |  |  |  |  |  |
| HIV prevalence in 1992 (male) | 0.097 (0.084-0.112) | 0.090 | 0.094 | 0.089 | *0.092* | Within the 95% confidence intervals for the data |
| HIV prevalence in 1992 (female) | 0.109 (0.096-0.124) | 0.110 | 0.115 | 0.112 | *0.119* | Within the 95% confidence intervals for the data |
| HIV prevalence in 2001 (male) | 0.078 (0.07-0.090) | 0.077 | 0.075 | 0.074 | *0.076* | Within the 95% confidence intervals for the data |
| HIV prevalence in 2001 (female) | 0.094 (0.083-0.107) | 0.093 | 0.095 | 0.096 | *0.096* | Within the 95% confidence intervals for the data |
| HIV prevalence in 2007 (male) | 0.071 (0.060-0.084) | 0.079 | 0.078 | 0.073 | *0.076* | Within the 95% confidence intervals for the data |
| HIV prevalence in 2007 (female) | 0.105 (0.093-0.119) | 0.098 | 0.097 | 0.099 | *0.098* | Within the 95% confidence intervals for the data |

Table S5. The plausible ranges and simulated values for model outputs

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Reduction in concurrency in 2020 (%)** | | | | | | **Reduction in concurrency in 2011 (%)** | | | | | |
| **Scenario** | | **Target: 20% reduction in total concurrency** | | | **Target: 50% reduction in total concurrency** | | | **Target: 20% reduction in total concurrency** | | | **Target: 50% reduction in total concurrency** | | |
|  |  | **Long-duration** | **Short-duration** | **Total** | **Long-duration** | **Short-duration** | **Total** | **Long-duration** | **Short-duration** | **Total** | **Long-duration** | **Short-duration** | **Total** |
| **Lower-concurrency** | **Men** | 25.3 | 20.2 | 20.8 | 56.1 | 47.8 | 49.5 | 6.1 | 19.6 | 13.7 | 13.2 | 48.0 | 33.0 |
| **Women** | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| **Best-estimate** | **Men** | 29.8 | 22.3 | 20.7 | 57.6 | 60.2 | 49.2 | 6.7 | 22.2 | 12.0 | 13.7 | 51.0 | 30.8 |
| **Women** | 18.7 | 20.9 | 19.3 | 51.7 | 49.5 | 50.2 | 4.7 | 18.3 | 12.7 | 11.8 | 48.1 | 32.7 |
| **Higher-concurrency** | **Men** | 33.9 | 23.6 | 20.1 | 67.4 | 49.5 | 49.4 | 7.4 | 23.4 | 9.6 | 14.1 | 50.8 | 27.4 |
| **Women** | 18.9 | 24.0 | 20.6 | 45.9 | 55.9 | 49.8 | 5.9 | 19.0 | 14.2 | 13.5 | 48.0 | 34.2 |
| ***Reported-concurrency*** | ***Men*** | *29.7* | *22.4* | *20.7* | *58.0* | *61.0* | *50.0* | *6.8* | *22.4* | *12.0* | *13.7* | *50.8* | *30.8* |
| ***Women*** | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* | *n/a* |

Table S6. Reduction in the prevalence of concurrency in 2020 and 2011

Calculated as the difference in prevalence in the intervention scenario compared to the baseline scenario over the prevalence in the baseline scenario. Note: n/a: not applicable as there is no female concurrency in these scenarios.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Number of partnerships** | **Total** | | | **Long-duration** | | | **Short-duration** | | |
|  |  | **Baseline** | **20% reduction in concurrency** | **50% reduction in concurrency** | **Baseline** | **20% reduction in concurrency** | **50% reduction in concurrency** | **Baseline** | **20% reduction in concurrency** | **50% reduction in concurrency** |
| **Best-estimate (Men)** | **0** | 47.34% | 44.35% | 41.22% | 57.09% | 55.33% | 53.77% | 86.68% | 86.15% | 85.54% |
| **1** | 43.68% | 48.52% | 54.27% | 38.64% | 41.68% | 44.60% | 11.29% | 12.28% | 13.45% |
| **2+** | 8.98% | 7.12% | 4.51% | 4.26% | 2.99% | 1.63% | 2.03% | 1.58% | 1.01% |
| **Best-estimate (Women)** | **0** | 46.33% | 45.85% | 45.12% | 58.77% | 58.49% | 58.13% | 86.72% | 86.67% | 86.55% |
| **1** | 51.40% | 52.32% | 53.74% | 40.25% | 40.74% | 41.41% | 12.83% | 12.96% | 13.21% |
| **2+** | 2.27% | 1.83% | 1.15% | 0.97% | 0.77% | 0.47% | 0.46% | 0.37% | 0.24% |
| **Lower-concurrency (Men)** | **0** | 52.20% | 50.93% | 49.29% | 62.44% | 61.80% | 61.03% | 87.74% | 87.48% | 87.18% |
| **1** | 42.57% | 44.93% | 48.07% | 35.31% | 36.51% | 37.98% | 11.14% | 11.62% | 12.24% |
| **2+** | 5.23% | 4.15% | 2.64% | 2.25% | 1.68% | 0.99% | 1.12% | 0.89% | 0.58% |
| **Lower-concurrency (Women)** | **0** | 52.92% | 52.88% | 52.85% | 64.77% | 64.74% | 64.69% | 88.16% | 88.14% | 88.16% |
| **1** | 47.08% | 47.12% | 47.15% | 35.23% | 35.26% | 35.31% | 11.84% | 11.86% | 11.84% |
| **2+** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Higher-concurrency (Men)** | **0** | 44.58% | 38.51% | 33.43% | 54.72% | 50.84% | 48.12% | 84.60% | 83.41% | 82.40% |
| **1** | 41.98% | 50.74% | 59.78% | 38.31% | 44.55% | 49.61% | 12.03% | 14.02% | 15.90% |
| **2+** | 13.44% | 10.74% | 6.80% | 6.97% | 4.61% | 2.27% | 3.37% | 2.57% | 1.70% |
| **Higher-concurrency (Women)** | **0** | 38.73% | 37.80% | 36.65% | 53.75% | 53.19% | 52.62% | 83.64% | 83.50% | 83.30% |
| **1** | 57.62% | 59.31% | 61.52% | 44.72% | 45.64% | 46.71% | 15.56% | 15.85% | 16.27% |
| **2+** | 3.65% | 2.90% | 1.83% | 1.53% | 1.16% | 0.67% | 0.79% | 0.64% | 0.43% |

**Table S7. The distribution of partnerships in 2020 in the baseline and intervention scenarios (20% and 50% reduction in concurrency)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Six months before** | | **Time of interview** | |  |
|  |  | **Number** | **Proportion (%)**  **(95% CI)** | **Number** | **Proportion (%)**  **(95% CI)** | **p-value** |
| **Men** | **0** | 620 | 48.3 (45.5-51.2) | 611 | 47.5 (44.7-50.4) |  |
|  | **1** | 479 | 42.0 (39.2-44.9) | 479 | 41.91 (39.1-44.7) | 0.47 |
|  | **2+** | 109 | 9.6 (7.9-11.4) | 120 | 10.5 (8.8-12.3) | 0.47 |
|  | **Total** | 1208 |  | 1210 |  |  |
| **Women** | **0** | 619 | 42.3 (39.8-44.8) | 585 | 40.0 (37.4-42.5) | 0.28 |
|  | **1** | 848 | 57.5 (55.0-60.0) | 880 | 59.9 (57.4-62.4) | 0.13 |
|  | **2+** | 3 | 0.2 (0.0-0.4) | 2 | 0.2 (0.0-0.4) | 0.48 |
|  | **Total** | 1470 |  | 1467 |  |  |

Table S8. Comparison of the empirical partnership distribution six months prior to the interview and the empirical partnership distribution at the time of the interview

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **HIV incidence in 2020** | | | | |
|  |  |  | **20% reduction in concurrency** | | **50% reduction in concurrency** | |
|  |  | **No intervention**  **(per year)** | **Intervention**  **(per year)** | **Percent reduction** | **Intervention**  **(per year)** | **Percent reduction** |
|  |  |  |  |  |  |  |
| **Lower-concurrency** | **Male** | 0.66% | 0.66% | 0.29% | 0.65% | 1.42% |
| **Female** | 0.80% | 0.78% | 2.09% | 0.75% | 6.25% |
| **Total** | 0.73% | 0.72% | **1.32%** | 0.70% | **4.18%** |
|  |  |  |  |  |  |  |
| **Best-estimate** | **Male** | 0.65% | 0.62% | 4.08% | 0.61% | 6.03% |
| **Female** | 0.81% | 0.74% | 9.24% | 0.68% | 16.19% |
| **Total** | 0.73% | 0.68% | **7.06%** | 0.65% | **11.91%** |
|  |  |  |  |  |  |  |
| **Higher-concurrency** | **Male** | 0.56% | 0.52% | 5.74% | 0.50% | 10.79% |
| **Female** | 0.77% | 0.64% | 16.79% | 0.59% | 23.37% |
| **Total** | 0.67% | 0.58% | **12.37%** | 0.55% | **18.34%** |
|  |  |  |  |  |  |  |
| ***Reported-concurrency*** | ***Male*** | *0.62%* | *0.60%* | *2.51%* | *0.59%* | *3.91%* |
| ***Female*** | *0.80%* | *0.73%* | *8.66%* | *0.67%* | *15.13%* |
| ***Total*** | *0.71%* | *0.67%* | ***6.10%*** | *0.64%* | ***10.47%*** |

Table S9. The reduction in HIV incidence in 2020 caused by the intervention

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | **Reduction in concurrency parameter** | | | | | | | | |
| **Scenario** | | |  | **10%** | **20%** | **30%** | **40%** | **50%** | **60%** | **70%** | **80%** | **90%** |
| **Best-estimate** | **Reduction in male concurrency** | | **Reduction in concurrency** | 3.89% | 8.56% | 13.37% | 18.76% | 24.97% | 32.36% | 41.31% | 52.23% | 67.79% |
| **Male** | 0.86% | 0.53% | 1.74% | 2.68% | 2.40% | 3.67% | 4.53% | 4.38% | 5.53% |
| **Female** | 2.20% | 4.86% | 8.00% | 9.07% | 11.24% | 13.04% | 14.56% | 16.17% | 18.31% |
| **Overall** | 1.63% | 3.03% | 5.36% | 6.37% | 7.51% | 9.09% | 10.33% | 11.20% | 12.93% |
| **Reduction in female concurrency** | | **Reduction in concurrency** | 7.63% | 15.85% | 24.04% | 32.63% | 41.62% | 51.51% | 62.10% | 73.46% | 85.97% |
| **Male** | 0.21% | 1.00% | 1.23% | 1.65% | 2.27% | 2.46% | 3.40% | 3.52% | 4.59% |
| **Female** | 0.07% | 0.66% | 0.56% | 0.87% | 0.86% | 1.20% | 1.65% | 1.67% | 1.66% |
| **Overall** | 0.13% | 0.81% | 0.85% | 1.20% | 1.46% | 1.74% | 2.39% | 2.46% | 2.91% |
| **Lower-concurrency** | **Reduction in male concurrency** | | **Reduction in concurrency** | 5.39% | 11.61% | 17.94% | 24.97% | 33.02% | 41.77% | 51.96% | 63.71% | 78.76% |
| **Male** | 0.29% | 0.70% | 0.76% | 1.12% | 1.95% | 1.49% | 2.12% | 2.11% | 2.00% |
| **Female** | 0.63% | 1.49% | 2.74% | 3.46% | 4.57% | 4.98% | 6.54% | 7.66% | 8.04% |
| **Overall** | 0.43% | 1.15% | 1.89% | 2.45% | 3.44% | 3.48% | 4.64% | 5.28% | 5.45% |
| **Higher-concurrency** | **Reduction in male concurrency** | | **Reduction in concurrency** | 2.47% | 5.60% | 9.15% | 13.11% | 18.18% | 23.90% | 31.37% | 40.72% | 54.37% |
| **Male** | 1.28% | 1.63% | 2.91% | 4.98% | 5.22% | 5.93% | 8.00% | 8.46% | 8.59% |
| **Female** | 2.96% | 6.71% | 10.00% | 12.79% | 14.70% | 17.71% | 19.34% | 22.52% | 23.46% |
| **Overall** | 2.27% | 4.67% | 7.16% | 9.65% | 10.90% | 13.00% | 14.80% | 16.90% | 17.52% |
| **Reduction in female concurrency** | | **Reduction in concurrency** | 6.48% | 13.16% | 19.98% | 27.09% | 35.37% | 44.47% | 54.48% | 65.60% | 79.37% |
| **Male** | 0.30% | 1.66% | 1.21% | 1.45% | 1.87% | 2.35% | 3.55% | 4.08% | 3.94% |
| **Female** | 0.28% | 0.59% | 0.60% | 0.64% | 1.36% | 0.97% | 0.83% | 1.67% | 1.42% |
| **Overall** | 0.29% | 1.01% | 0.84% | 0.96% | 1.57% | 1.52% | 1.91% | 2.63% | 2.43% |

Table S10. The impact of differing reductions in male and female concurrency on HIV incidence in 2020



Figure S1. Schematic of simulated HIV natural history

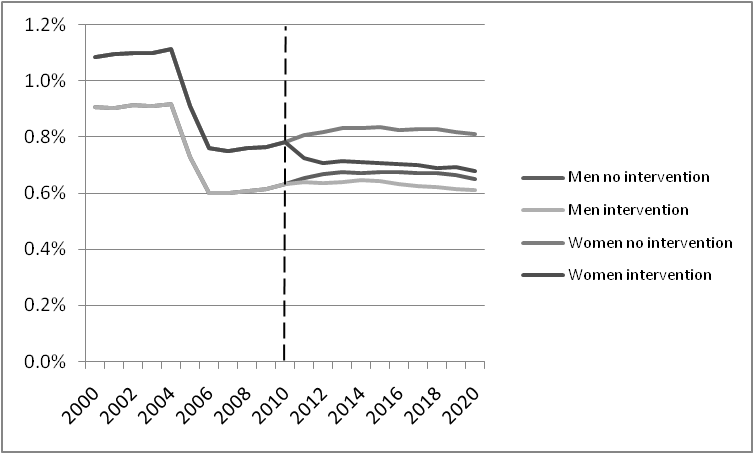
****

Figure S2. The change in HIV incidence over time in the best-estimate scenario following a 50% reduction in concurrency commencing in 2010.

The dashed vertical line indicates the start of the intervention. The drop in HIV incidence starting in 2004 is due to the introduction of ART. Trends in other scenarios are similar (not shown)

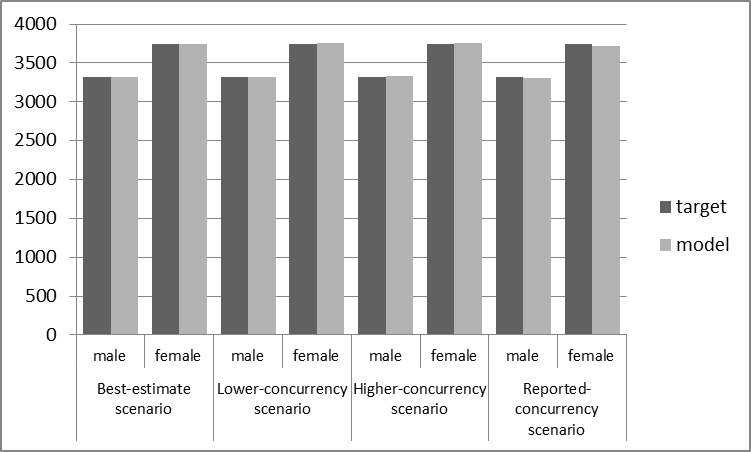


Figure S3. The target and simulated male and female population sizes in 2008



Figure S4. ‘Reported’-concurrency scenario: a) The target and simulated male partnership distribution, b) the simulated female partnership distribution, and c) the model fit to the empirical HIV prevalences in 1992, 1997 and 2007 and the trend in HIV prevalence

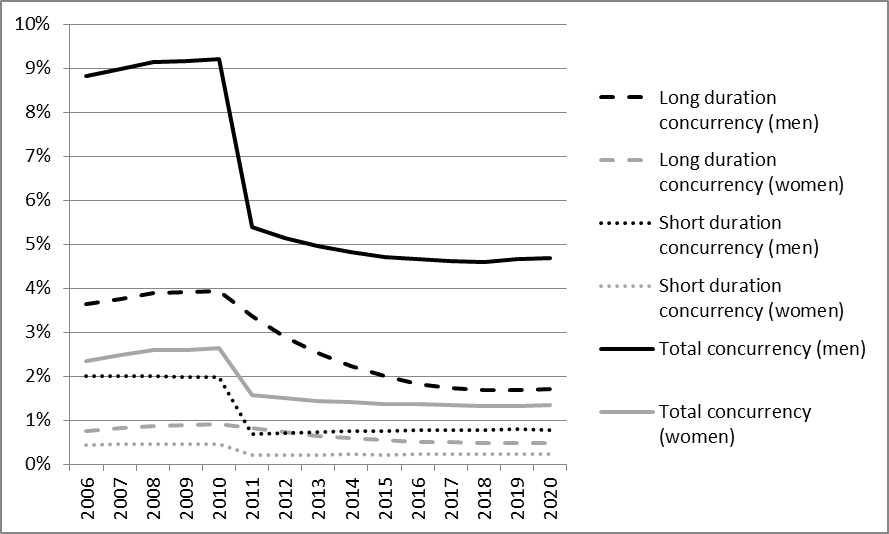
****

Figure S5. The effect of the intervention (50% reduction in concurrency) on the prevalence of concurrency over time in the best-estimate scenario. Intervention starts in 2010.

Trends in other scenarios were very similar (not shown).

Figure S6. The effect of the intervention on partnership incidence. Intervention starts in 2010.

\*the average number of new partners per male per year

Figure S7. The effect of the intervention on the amount of sex. Intervention starts in 2010.