### Sexual behaviour and risk of HIV acquisition

Here we describe the approach to modelling sexual behaviour and HIV acquisition. The basic approach is summarized Figure S3. The parameter values related to sexual behaviour were chosen such that they lead to a modelled HIV prevalence level over time as observed. Sexual behaviour is characterized by two variables representing, respectively, the number of short term condomless sex partners and whether the person has a current long term condomless *sex* partners in the 3 month period. The status of long term partners is tracked over time (i.e. if they are infected, diagnosed, on ART). Short term partners are not tracked over time, in that if a person has a short term partner in time period t who is infected with HIV, this is independent of the probability that any short term partner in time t+1 is infected with HIV.

**Diagram

Description automatically generated**

Figure S3 Summary of modelling of sexual behaviour and HIV acquisition

### Determination of number of short term (condomless sex) partners at period t

#### Men

For men, the number of short term partners in a given period was generated at random, according to which of four sexual behaviour groups the man was in for this period. Changes in the sexual behaviour group from t-1 to t were determined by transition probabilities between 4 groups: (i) no short term condomless partners in 3 month period, (ii) low number of short term partners (*n*=1-3), (iii) medium number of short term partners (*n*=4-9), and (iv) high number of short term partners (*n*=10-35; Tables S9 and S10).

#### Women (who are not sex workers)

For women who are not sex workers, the number of short term partners in a given period was generated at random, according to which of two sexual behaviour groups the woman was in for this period. Changes in the sexual behaviour group from t-1 to t were determined by transition probabilities between 2 groups: (i) no short term condomless partners in 3 month period, (ii) one or more short term condomless partners in 3 month period (*n*=1-9; Tables S11 and S12). Younger women (age 15-24) can have up to nine short-term condomless partners in a three month period and women aged 25 and older can have up to three.

#### Sex workers

<<<<<<FILL IN SW DETAILS HERE>>>>>

Transition probabilities of moving from partner group i at t-1 to partner group j at t are given by

for j=1

otherwise

where g = 0,1 for males, females, respectively, and a = 1-10 for age groups 15-, 20-, 25-, 30-, 35-, 40-, 45-, 50-, 55-, 60-, respectively. Values of and are given in Tables S9 and S10, respectively, and if j=1 then =1.

We considered 15 sets of values of each for males and females as shown in Tables S10 and S12, characterized by substantially different intra-person variability over time in sexual behaviour subgroups, and sampled a matrix at random independently for each gender for each model run.

Values of can be modified at time t by several factors, described in Table S3.

Table S3. Factors modifying transition probabilities between categories of short-term condomless partners

|  |  |  |
| --- | --- | --- |
| Factor | Description | Value |
| *newp\_factor* | Underlying propensity of whole population to form short-term partnership with condomless sex | 0.5, 1 or 2, in equal probabilities |
| *rred\_a* | Factor to balance the number of short-term partnerships with condomless sex between different age groups within the population. | Calculated every time step within model. Equals 1 if partnerships balance across the sexes, <1 if the number of age-specific partnerships formed by one sex outweighs that reported by the other and vice versa. |
| *rred\_p* | Person-specific factor reflecting a person’s propensity to be in a higher or lower risk category for short-term condomless partners | For each person, there is a 0.3, 0.5 or 0.7 (termed *p\_rred\_p*) chance of *rred\_p*=0.00001, in equal probabilities. Otherwise *rred\_p*=1. |
| *rred\_adc* | Factor reducing the chance of transitioning to higher risk category for short-term partnerships with condomless sex for people with a AIDS-defining condition | 0.2 |
| *rred\_adhav* | Possible reduction in risk category for people who are generally adherent to ART (??? – is this right?) | In 20% of runs, people with an adherence score of less than 0.8 will have *rred\_adhav*=0.5. NOT SURE I HAVE UNDERSTOOD THIS? BUT NOT USED IN RRED |
| *rred\_d* | Possible reduction in condomless sex following a positive HIV test | 0.7, 0.8, 0.9 or 1.0 (termed *ch\_risk\_diag\_newp*), in equal probabilities, within six months of diagnosis and the square root of the above values thereafter. Informed by Fonner et al 2012 [4]. |
| *rred\_balance* | Factor to balance the absolute number of short-term condomless partners between men and women across the population. | Calculated every time step within model. Equals 1 if total partnerships balance across the sexes, <1 if the number of partnerships formed by one sex outweighs that reported by the other and vice versa. |
| *rred\_rc* | Factor representing population-level behaviour change through time with respect to the number of condomless sex partners. In addition, for sex workers, the existence and effectiveness of a sex worker program can affect sexual risk behaviour. | From 1995-2000, there is a general reduction in condomless sex among the whole population, determined by *ych\_risk\_beh\_newp* according to the distribution:   |  |  |  |  | | --- | --- | --- | --- | | Probability | 20% | 60% | 20% | | Factor change | 0.6 | 0.7 | 0.8 |   From 2010-2015, there is the possibility of a further behavioural change, determined by *ych2\_risk\_beh\_newp* according to the distribution:   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Probability | 5% | 5% | 80% | 5% | 5% | | Factor change | 0.95 | 0.99 | 1 | 1 / 0.99 | 1 / 0.95 |   For sex workers, the impact of any sex worker program (established in 20% of all model runs) can also modify risk, with the factor distributed equally between 0.3, 0.5, 0.6 (a ‘strong’ effect, termed *effect\_strong\_sw\_prog\_newp*), 0.7, 0.8, 0.9 (a ‘weak’ effect termed *effect\_weak\_sw\_prog\_newp*).  Is this time-dependent? – assuming not? |
| *rred\_ep* | Population-level factor modifying chance of transitioning to higher risk category for short-term condomless partnership for those in a long-term partnership. | 0.33, 1.0 or 3.0 (termed *conc\_ep*), in equal probabilities |

Actual transitions between groups were determined by random sampling. For the first risk group, the number of partners in the period is set to zero. When a man is in a particular risk category, the number of short-term condomless partners was determined by sampling from the probability distributions given in Table S9. The value of these parameters is also sampled from a distribution at the start of each model run (see below).

Table S9. Distribution of number of short-term condomless partners in each risk category for men

|  |  |  |
| --- | --- | --- |
| Risk category | Probability | Number of short-term condomless partners |
| Zero | 100% | 0 |
| Low | 50%  30%  20% | 1  2  3 |
| Medium | 35%  21%  17%  13%  9%  5% | 4  5  6  7  8  9 |
| High | 60%  20%  10%  5%  4%  1% | 10  15  20  25  30  35 |

Table S10. Values of (values determining probability of transitioning between short term partner risk behaviour groups) for men.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Short term partners group in period t** | | | |
| **Short term partners group in period t-1** | Zero (*n* = 0) | Low (*n* = 1-3) | Medium (*n* = 4-9): | High (*n* = 10-35) |
| **Sexual behaviour transition matrix 1** | | | | |
|  |  |  |  |  |
| Zero | 0.995 | 0.005 | 0.005 | 0.00005 |
| Low | 0.95 | 0.03 | 0.02 | 0.00005 |
| Medium | 0.03 | 0.07 | 0.90 | 0.00025 |
| High | 0 | 0 | 0.05 | 0.95 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 2** | | | | |
|  |  |  |  |  |
| Zero | 0.98 | 0.01 | 0.01 | 0.00025 |
| Low | 0.98 | 0.01 | 0.01 | 0.00025 |
| Medium | 0.05 | 0.15 | 0.80 | 0.00125 |
| High | 0 | 0 | 0.20 | 0.80 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 3** | | | | |
|  |  |  |  |  |
| Zero | 0.95 | 0.03 | 0.02 | 0.0005 |
| Low | 0.93 | 0.05 | 0.02 | 0.0005 |
| Medium | 0.20 | 0.20 | 0.60 | 0.0025 |
| High | 0 | 0 | 0.40 | 0.60 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 4** | | | | |
|  |  |  |  |  |
| Zero | 0.995 | 0.005 | 0.005 | 0.0001 |
| Low | 0.95 | 0.03 | 0.02 | 0.0001 |
| Medium | 0.03 | 0.07 | 0.90 | 0.0005 |
| High | 0.04 | 0.04 | 0.09 | 0.83 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 5** | | | | |
|  |  |  |  |  |
| Zero | 0.98 | 0.01 | 0.01 | 0.005 |
| Low | 0.98 | 0.01 | 0.01 | 0.0005 |
| Medium | 0.05 | 0.15 | 0.8 | 0.0025 |
| High | 0.025 | 0.06 | 0.17 | 0.75 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 6** | | | | |
|  |  |  |  |  |
| Zero | 0.95 | 0.03 | 0.02 | 0.001 |
| Low | 0.93 | 0.05 | 0.02 | 0.001 |
| Medium | 0.20 | 0.20 | 0.60 | 0.005 |
| High | 0.04 | 0.08 | 0.21 | 0.67 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 7** | | | | |
|  |  |  |  |  |
| Zero | 0.995 | 0.005 | 0.005 | 0.000025 |
| Low | 0.95 | 0.03 | 0.02 | 0.000025 |
| Medium | 0.03 | 0.07 | 0.90 | 0.000125 |
| High | 0 | 0 | 0.05 | 0.95 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 8** | | | | |
|  |  |  |  |  |
| Zero | 0.98 | 0.01 | 0.01 | 0.000125 |
| Low | 0.98 | 0.01 | 0.01 | 0.000125 |
| Medium | 0.05 | 0.15 | 0.80 | 0.000625 |
| High | 0 | 0 | 0.20 | 0.80 |
|  |  |  |  |  |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 9** | | | | |
|  |  |  |  |  |
| Zero | 0.95 | 0.03 | 0.02 | 0.00025 |
| Low | 0.93 | 0.05 | 0.02 | 0.00025 |
| Medium | 0.20 | 0.20 | 0.60 | 0.00125 |
| High | 0 | 0 | 0.40 | 0.60 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 10** | | | | |
|  |  |  |  |  |
| Zero | 0.90 | 0.06 | 0.04 | 0.0005 |
| Low | 0.99 | 0.005 | 0.005 | 0.0005 |
| Medium | 0.20 | 0.20 | 0.60 | 0.0025 |
| High | 0 | 0 | 0.40 | 0.60 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 11** | | | | |
|  |  |  |  |  |
| Zero | 0.90 | 0.06 | 0.04 | 0.001 |
| Low | 0.99 | 0.005 | 0.005 | 0.001 |
| Medium | 0.20 | 0.20 | 0.60 | 0.005 |
| High | 0.04 | 0.08 | 0.21 | 0.67 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 12** | | | | |
|  |  |  |  |  |
| Zero | 0.90 | 0.06 | 0.04 | 0.00025 |
| Low | 0.99 | 0.005 | 0.005 | 0.00025 |
| Medium | 0.20 | 0.20 | 0.60 | 0.00125 |
| High | 0 | 0 | 0 | 1.00 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 13** | | | | |
|  |  |  |  |  |
| Zero | 0.75 | 0.15 | 0.10 | 0.0005 |
| Low | 0.99 | 0.005 | 0.005 | 0.0005 |
| Medium | 0.90 | 0.05 | 0.03 | 0.02 |
| High | 0.90 | 0.05 | 0.03 | 0.02 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 14** | | | | |
|  |  |  |  |  |
| Zero | 0.75 | 0.15 | 0.10 | 0.001 |
| Low | 0.99 | 0.05 | 0.02 | 0.001 |
| Medium | 0.95 | 0.03 | 0.01 | 0.01 |
| High | 0.95 | 0.03 | 0.01 | 0.01 |
|  |  |  |  |  |
| **Sexual behaviour transition matrix 15** | | | | |
|  |  |  |  |  |
| Zero | 0.75 | 0.15 | 0.10 | 0.00025 |
| Low | 0.93 | 0.05 | 0.02 | 0.00025 |
| Medium | 0.80 | 0.10 | 0.05 | 0.05 |
| High | 0.80 | 0.10 | 0.05 | 0.05 |
|  |  |  |  |  |

Table S11. Distribution of number of short-term condomless partners in each risk category for women

|  |  |  |
| --- | --- | --- |
| Risk category | Probability | Number of short-term condomless partners |
| Zero | 100% | 0 |
| 1+ | Age 15-24:  30%  20%  15%  12%  9%  6%  4%  2%  2%  Age 25+:  70%  15%  15% | 1  2  3  4  5  6  7  8  9  1  2  3 |

Table S12. Values of (values determining probability of transitioning between short term partner risk behaviour groups) for women.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | **Short term partners group in period t** | | |
| **Short term partners group in period t-1** | Zero (*n* = 0) | | | Any (*n* = 1-9) |
| **Sexual behaviour transition matrix 1** | | |
|  |  | | |  |
| Zero | 0.995 | | | 0.005 |
| Any | 0.99 | | | 0.01 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 2** | | |
|  |  | | |  |
| Zero | 0.995 | | | 0.005 |
| Any | 0.98 | | | 0.02 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 3** | | |
|  |  | | |  |
| Zero | 0.995 | | | 0.005 |
| Any | 0.95 | | | 0.05 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 4** | | |
|  |  | | |  |
| Zero | 0.995 | | | 0.005 |
| Any | 0.85 | | | 0.15 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 5** | | |
|  |  | | |  |
| Zero | 0.995 | | | 0.005 |
| Any | 0.75 | | | 0.25 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 6** | | |
|  |  | | |  |
| Zero | 0.99 | | | 0.01 |
| Any | 0.99 | | | 0.01 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 7** | | |
|  |  | | |  |
| Zero | 0.99 | | | 0.01 |
| Any | 0.98 | | | 0.02 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 8** | | |
|  |  | | |  |
| Zero | 0.99 | | | 0.01 |
| Any | 0.95 | | | 0.05 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 9** | | |
|  |  | | |  |
| Zero | 0.99 | | | 0.01 |
| Any | 0.85 | | | 0.15 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 10** | | |
|  |  | | |  |
| Zero | 0.99 | | | 0.01 |
| Any | 0.75 | | | 0.25 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 11** | | |
|  |  | | |  |
| Zero | 0.98 | | | 0.02 |
| Any | 0.99 | | | 0.01 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 12** | | |
|  |  | | |  |
| Zero | 0.98 | | | 0.02 |
| Any | 0.98 | | | 0.02 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 13** | | |
|  |  | | |  |
| Zero | 0.98 | | | 0.02 |
| Any | 0.95 | | | 0.05 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 14** | | |
|  |  | | |  |
| Zero | 0.98 | | | 0.02 |
| Any | 0.95 | | | 0.05 |
|  |  | | |  |
|  |  | | |  |
| **Sexual behaviour transition matrix 15** | | |
|  |  | | |  |
| Zero | 0.98 | | | 0.02 |
| Any | 0.75 | | | 0.25 |
|  |  | | |  |
|  |  | | |  |

Table S11. Values of (factor determining relative level of sexual risk activity)

|  |  |  |
| --- | --- | --- |
| **Age group (a=1,10)** | **Males (g=1)** | **Females (g=2)** |
| 15- | 0.30 | 2.30 |
| 20- | 0.50 | 2.30 |
| 25- | 1.20 | 2.20 |
| 30- | 1.20 | 1.00 |
| 35- | 0.90 | 0.50 |
| 40- | 0.30 | 0.35 |
| 45- | 0.30 | 0.10 |
| 50- | 0.30 | 0.05 |
| 55- | 0.10 | 0.05 |
| 60- | 0.08 | 0.03 |