Supplementary Material

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# Table S1. Model parameters

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Value** | **Sources** |
| **HIV** | | |
| HIV transmission probability per vaginal sex act |  |  |
| Acute infection | 0.0360 | Published literature (1) |
| Chronic infection | 0.0008 | Published literature (2, 3) |
| Advanced infection | 0.0042 | Published literature (2, 3) |
| HIV cofactor for anal sex transmission\* | 1.5 | Published literature (4, 5) |
| Duration of each HIV stage |  |  |
| From acute to chronic | 49 days | Published literature (2, 3, 6) |
| From chronic to AIDS | 9.0 years | Published literature (3, 7, 8) |
| From AIDS to death | 2.0 years | Published literature (2, 3) |
| **HSV-2** |  |  |
| HSV-2 transmission probability per anal sex act |  |  |
| Primary infection | 0.004 | Published literature (9) |
| Latent infection | 0.0 | Published literature (9) |
| Reactivation | 0.004 | Published literature (9) |
| Duration of each HSV-2 stage |  |  |
| From primary to latent | 20 days | Published literature (9) |
| From latent to reactivation | 78.5 days | Published literature (9) |
| From reactivation to latent | 12.8 days | Published literature (9) |
| HSV-2 shedding frequency | 14% | Published literature (9, 10) |
| **Chlamydia** |  |  |
| Chlamydia transmission probability per anal sex act | 0.17 | Published literature (11, 12) |
| Proportion of chlamydia infections |  |  |
| Becoming symptomatic among males | 0.30 | Published literature (13) |
| Successfully treated | 0.70 | Published literature (13) |
| Immune after treatment | 0.5 | Published literature (13) |
| Duration of |  |  |
| Symptomatic chlamydia infection | 16 weeks | Published literature (13) |
| Asymptomatic chlamydia infection | 90 weeks | Published literature (13) |
| Immunity | 520 weeks | Published literature (13) |
| **Gonorrhea** |  |  |
| Gonorrhea transmission probability per anal sex act | 0.46 | Published literature (14) |
| Proportion of gonorrhea infections |  |  |
| Becoming symptomatic among males | 0.64 | Published literature (13, 15, 16) |
| Successfully treated | 0.70 | Published literature (13) |
| Immune after treatment | 0.5 | Published literature (13) |
| Duration of |  |  |
| Symptomatic or asymptomatic infection if untreated | 20 weeks | Published literature (13) |
| Immunity | 52 weeks | Published literature (13) |
| **Syphilis** |  |  |
| Syphilis transmission probability per anal sex act | 0.20 | Average of male-to-female and female-to-male transmission probability (13) |
| Duration of |  |  |
| Incubation | 4.4 weeks | Published literature (13) |
| Primary syphilis | 6.6 weeks | Published literature (13) |
| Secondary syphilis | 15.6 weeks | Published literature (13) |
| Latent syphilis | 520 weeks | Published literature (13) |
| Proportion of |  |  |
| Primary cases seronegative after successful treatment | 0.40 | Published literature (13) |
| Primary syphilis cases successfully treated | 0.70 | Published literature (13) |
| Secondary syphilis cases successfully treated† | 30% lower than for primary syphilis | Published literature† (13, 17) |
| Reduction in health seeking behavior for secondary syphilis compared to primary syphilis | 0.5 | Published literature (13) |
| Duration from |  |  |
| Recovery in early disease to seronegative susceptible | 26 weeks | Published literature (13) |
| Recovery in late disease to seronegative susceptible | 52 weeks | Published literature (13) |
| **Sexual behavior** |  |  |
| Long-term (spousal) partnership formation rate | 0.12 | Representative value informed by rate of spousal partnership formation rate among the heterosexual population (18, 19) |
| Mean duration |  |  |
| Long-term (spousal) sexual partnership | 5 years | Representative value informed by duration of spousal partnerships among the heterosexual population (18, 19) |
| Short-term (casual) sexual partnership | 2 weeks | Representative value and informed by previous work (20, 21) |
| Number of short-term (casual) sex partners among individuals not in long-term (spousal) partnerships over the last year |  |  |
| Mean | 0.0-5.0 | Representative range informed by analyses of empirical data (22) |
| Variance | 0.0-5.0 |
| Number of short-term (casual) sex partners among individuals in long-term (spousal) partnerships over the last year |  |  |
| Mean | 0.0-2.5 | Representative range informed by analyses of empirical data (22) |
| Variance | 0.0-2.5 |
| Tuning parameter |  |  |
| Degree correlation (*κcorr*) | -10.0-10.0 | Representative range to generate wide variation in degree correlation(19) |
| Clustering (*κclus*) | 0.0-20.0 | Representative range to generate wide variation in clustering (19) |
| **Demographic factors** |  |  |
| Natural mortality rate per year by age group |  |  |
| 0-4 years | 0.04 |  |
| 5-69 years | 0.0026 |  |
| 70+ years | 0.0998 |  |

HIV denotes human immunodeficiency virus; HSV-2, herpes simplex virus type 2.

\*The transmission probability per one anal sex act is determined as the product of HIV transmission probability per coital act for vaginal sex time the HIV cofactor for anal sex transmission.

†Probability of treatment success was assumed to be 30% lower for secondary syphilis than for primary syphilis, due to the greater difficulty of diagnosing secondary syphilis symptoms and the lower efficacy of penicillin in treating syphilis of longer duration (13, 17).

# Figure S1. Scatterplots depicting the relationship between the prevalences of ever infection for the five STIs across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks.

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HIV denotes human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

**Table S2. Correlations between ever infection prevalences for each pair of STIs, along with their 95% confidence intervals, estimated using A) Spearman's rank correlation coefficient and B) the maximal information coefficient. The correlation coefficients were computed across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **Spearman's rank correlation coefficient (SRCC)** | | | | | | **Average** |
|  | **HIV**  **(95% CI)** | **HSV-2**  **(95% CI)** | **Chlamydia**  **(95% CI)** | **Gonorrhea**  **(95% CI)** | **Syphilis**  **(95% CI)** | **SRCC** |
| **HIV** |  | 0.66  (0.61, 0.70) | 0.66  (0.61, 0.71) | 0.85  (0.82, 0.87) | 0.78  (0.73, 0.82) | 0.74 |
| **HSV-2** | 0.66  (0.61, 0.70) |  | 0.89  (0.86, 0.91) | 0.85  (0.82, 0.87) | 0.62  (0.57, 0.68) | 0.76 |
| **Chlamydia** | 0.66  (0.61, 0.71) | 0.89  (0.86, 0.91) |  | 0.84  (0.82, 0.87) | 0.65  (0.60, 0.70) | 0.76 |
| **Gonorrhea** | 0.85  (0.82, 0.87) | 0.85  (0.82, 0.87) | 0.84  (0.82, 0.87) |  | 0.76  (0.72, 0.80) | 0.83 |
| **Syphilis** | 0.78  (0.73, 0.82) | 0.62  (0.57, 0.68) | 0.65  (0.60, 0.70) | 0.76  (0.72, 0.80) |  | 0.70 |
| 1. **Maximal information coefficient (MIC)** | | | | | | |
|  | **HIV**  **(95% CI)** | **HSV-2**  **(95% CI)** | **Chlamydia**  **(95% CI)** | **Gonorrhea**  **(95% CI)** | **Syphilis**  **(95% CI)** | **MIC** |
| **HIV** |  | 0.67  (0.58, 0.76) | 0.60  (0.53, 0.67) | 0.83  (0.76, 0.91) | 0.72  (0.66, 0.79) | 0.71 |
| **HSV-2** | 0.67  (0.58, 0.76) |  | 0.91  (0.84, 0.97) | 0.91  (0.85, 0.96) | 0.64  (0.56, 0.71) | 0.78 |
| **Chlamydia** | 0.60  (0.53, 0.67) | 0.91  (0.84, 0.97) |  | 0.82  (0.76, 0.87) | 0.60  (0.53, 0.67) | 0.73 |
| **Gonorrhea** | 0.83  (0.76, 0.91) | 0.91  (0.85, 0.96) | 0.82  (0.76, 0.87) |  | 0.73  (0.63, 0.81) | 0.82 |
| **Syphilis** | 0.72  (0.66, 0.79) | 0.64  (0.56, 0.71) | 0.60  (0.53, 0.67) | 0.73  (0.63, 0.81) |  | 0.67 |

CI denotes confidence interval; HIV, human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

**Figure S2. Scatterplots depicting the relationship between the incidence rates of infection for the five STIs across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks.**

****

HIV denotes human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

**Table S3. Correlations between incidence rates of infection for each pair of STIs, along with their 95% confidence intervals, estimated using A) Spearman's rank correlation coefficient and B) the maximal information coefficient. The correlation coefficients were computed across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **Spearman's rank correlation coefficient (SRCC)** | | | | | | **Average** |
|  | **HIV**  **(95% CI)** | **HSV-2**  **(95% CI)** | **Chlamydia**  **(95% CI)** | **Gonorrhea**  **(95% CI)** | **Syphilis**  **(95% CI)** | **SRCC** |
| **HIV** |  | 0.75  (0.70, 0.78) | 0.81  (0.77, 0.85) | 0.83  (0.79, 0.87) | 0.50  (0.42, 0.57) | 0.72 |
| **HSV-2** | 0.75  (0.70, 0.78) |  | 0.90  (0.88, 0.91) | 0.81  (0.78, 0.84) | 0.42  (0.34, 0.49) | 0.72 |
| **Chlamydia** | 0.81  (0.77, 0.85) | 0.90  (0.88, 0.91) |  | 0.87  (0.84, 0.89) | 0.50  (0.43, 0.57) | 0.77 |
| **Gonorrhea** | 0.83  (0.79, 0.87) | 0.81  (0.78, 0.84) | 0.87  (0.84, 0.89) |  | 0.50  (0.42, 0.58) | 0.75 |
| **Syphilis** | 0.50  (0.42, 0.57) | 0.42  (0.34, 0.49) | 0.50  (0.43, 0.57) | 0.50  (0.42, 0.58) |  | 0.48 |
| 1. **Maximal information coefficient (MIC)** | | | | | | |
|  | **HIV**  **(95% CI)** | **HSV-2**  **(95% CI)** | **Chlamydia**  **(95% CI)** | **Gonorrhea**  **(95% CI)** | **Syphilis**  **(95% CI)** | **MIC** |
| **HIV** |  | 0.69  (0.62, 0.77) | 0.76  (0.70, 0.83) | 0.80  (0.75, 0.86) | 0.37  (0.32, 0.43) | 0.66 |
| **HSV-2** | 0.69  (0.62, 0.77) |  | 0.91  (0.86, 0.95) | 0.83  (0.76, 0.90) | 0.35  (0.31, 0.39) | 0.70 |
| **Chlamydia** | 0.76  (0.70, 0.83) | 0.91  (0.86, 0.95) |  | 0.85  (0.77, 0.91) | 0.40  (0.35, 0.46) | 0.73 |
| **Gonorrhea** | 0.80  (0.75, 0.86) | 0.83  (0.76, 0.90) | 0.85  (0.77, 0.91) |  | 0.38  (0.34, 0.44) | 0.72 |
| **Syphilis** | 0.37  (0.32, 0.43) | 0.35  (0.31, 0.39) | 0.40  (0.35, 0.46) | 0.38  (0.34, 0.44) |  | 0.38 |

CI denotes confidence interval; HIV, human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

**Table S4. Distribution of mean proportion of the population with no, one, two, three, four, and five specific concurrent STI infections across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks. Infection presence is denoted by '1' and absence by '0'.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HIV** | **HSV-2** | **Chlamydia** | **Gonorrhea** | **Syphilis** | **Proportion (in %)** |
| 0 | 0 | 0 | 0 | 0 | 48.56 |
| 0 | 0 | 0 | 0 | 1 | 0.90 |
| 0 | 0 | 0 | 1 | 0 | 0.75 |
| 0 | 0 | 1 | 0 | 0 | 4.03 |
| 0 | 1 | 0 | 0 | 0 | 29.11 |
| 1 | 0 | 0 | 0 | 0 | 2.91 |
| 0 | 0 | 1 | 0 | 1 | 0.16 |
| 0 | 0 | 0 | 1 | 1 | 0.07 |
| 0 | 0 | 1 | 1 | 0 | 0.21 |
| 0 | 1 | 0 | 0 | 1 | 1.27 |
| 0 | 1 | 1 | 0 | 0 | 2.05 |
| 0 | 1 | 0 | 1 | 0 | 0.69 |
| 1 | 0 | 0 | 0 | 1 | 0.47 |
| 1 | 0 | 1 | 0 | 0 | 0.40 |
| 1 | 0 | 0 | 1 | 0 | 0.21 |
| 1 | 1 | 0 | 0 | 0 | 5.57 |
| 0 | 0 | 1 | 1 | 1 | 0.02 |
| 0 | 1 | 1 | 0 | 1 | 0.14 |
| 0 | 1 | 0 | 1 | 1 | 0.09 |
| 0 | 1 | 1 | 1 | 0 | 0.10 |
| 1 | 0 | 1 | 0 | 1 | 0.06 |
| 1 | 0 | 0 | 1 | 1 | 0.05 |
| 1 | 0 | 1 | 1 | 0 | 0.04 |
| 1 | 1 | 0 | 0 | 1 | 1.01 |
| 1 | 1 | 1 | 0 | 0 | 0.54 |
| 1 | 1 | 0 | 1 | 0 | 0.32 |
| 0 | 1 | 1 | 1 | 1 | 0.01 |
| 1 | 0 | 1 | 1 | 1 | 0.01 |
| 1 | 1 | 1 | 0 | 1 | 0.11 |
| 1 | 1 | 0 | 1 | 1 | 0.09 |
| 1 | 1 | 1 | 1 | 0 | 0.05 |
| 1 | 1 | 1 | 1 | 1 | 0.01 |

HIV denotes human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

**Table S5. Distribution of mean proportion of the population with no, one, two, three, four, and five specific ever STI infections across the 500 simulated STI epidemics in the 500 diverse MSM sexual networks. Infection presence is denoted by '1' and absence by '0'.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HIV** | **HSV-2** | **Chlamydia** | **Gonorrhea** | **Syphilis** | **Proportion (in %)** |
| 0 | 0 | 0 | 0 | 0 | 13.64 |
| 0 | 0 | 0 | 0 | 1 | 0.18 |
| 0 | 0 | 0 | 1 | 0 | 1.04 |
| 0 | 0 | 1 | 0 | 0 | 19.09 |
| 0 | 1 | 0 | 0 | 0 | 0.64 |
| 1 | 0 | 0 | 0 | 0 | 0.09 |
| 0 | 0 | 1 | 0 | 1 | 0.76 |
| 0 | 0 | 0 | 1 | 1 | 0.06 |
| 0 | 0 | 1 | 1 | 0 | 15.68 |
| 0 | 1 | 0 | 0 | 1 | 0.01 |
| 0 | 1 | 1 | 0 | 0 | 5.79 |
| 0 | 1 | 0 | 1 | 0 | 0.18 |
| 1 | 0 | 0 | 0 | 1 | 0.00 |
| 1 | 0 | 1 | 0 | 0 | 0.34 |
| 1 | 0 | 0 | 1 | 0 | 0.04 |
| 1 | 1 | 0 | 0 | 0 | 0.01 |
| 0 | 0 | 1 | 1 | 1 | 4.27 |
| 0 | 1 | 1 | 0 | 1 | 0.35 |
| 0 | 1 | 0 | 1 | 1 | 0.01 |
| 0 | 1 | 1 | 1 | 0 | 17.73 |
| 1 | 0 | 1 | 0 | 1 | 0.03 |
| 1 | 0 | 0 | 1 | 1 | 0.01 |
| 1 | 0 | 1 | 1 | 0 | 1.73 |
| 1 | 1 | 0 | 0 | 1 | 0.00 |
| 1 | 1 | 1 | 0 | 0 | 0.14 |
| 1 | 1 | 0 | 1 | 0 | 0.01 |
| 0 | 1 | 1 | 1 | 1 | 8.73 |
| 1 | 0 | 1 | 1 | 1 | 1.91 |
| 1 | 1 | 1 | 0 | 1 | 0.01 |
| 1 | 1 | 0 | 1 | 1 | 0.00 |
| 1 | 1 | 1 | 1 | 0 | 2.70 |
| 1 | 1 | 1 | 1 | 1 | 4.82 |

HIV denotes human immunodeficiency virus; HSV-2, herpes simplex virus type 2; MSM, men who have sex with men; STI, sexually transmitted infection.

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