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Sexual Health

Supplementary Material

Modelling the potential role of saliva use during masturbation in the transmission of *Neisseria gonorrhoeae* at multiple anatomical sites

Xianglong Xu[A,B,C], *Eric P. F. Chow*[A,B,D], *Jason J. Ong*[A,B,C], *Mingwang Shen*[C], *Chongjian Wang*[E], *Jane S. Hocking*[D], *Christopher K. Fairley*[A,B,C], *and Lei Zhang*[A,B,C,E,*]

[A]Melbourne Sexual Health Centre, Alfred Health, 580 Swanston Street, Carlton, Vic. 3053, Australia.

[B]Faculty of Medicine, Central Clinical School, Nursing and Health Sciences, Monash University, 99 Commercial Road, Melbourne, Vic. 3004, Australia.

[C]China Australia Joint Research Center for Infectious Diseases, School of Public Health, Xi'an Jiaotong University Health Science Centre, Xi'an, Shaanxi 710061, PR China.

[D]Centre for Epidemiology and Biostatistics, Melbourne School of Population and Global Health, The University of Melbourne, 207 Bouverie Street, Carlton, Vic. 3053, Australia.

[E]Department of Epidemiology and Biostatistics, College of Public Health, Zhengzhou University, Zhengzhou 450001, Henan, China.

[*]Correspondence to: Lei Zhang China Australia Joint Research Center for Infectious Diseases, School of Public Health, Xi'an Jiatong University Health Science Center, Xi'an, Shaanxi 710061, PR China Email: lei.zhang1@monash.edu

Supplementary Material S1

Literature review

We searched PubMed, up to the 28 of June 2021, for reports of studies assessing the role of masturbation in the transmission of *N. gonorrhoeae*. We used the search terms (gonorrh* [Title/Abstract]) AND (masturbation [Title/Abstract] OR masturbation [MeSH]).Of the six identified sources, none assessed the role of masturbation in the transmission of *N. gonorrhoeae*. The role ofusing saliva as a lubricant for masturbation in *N. gonorrhoeae*transmission at each anatomical site (oropharynx, urethra and anorectum) is still unknown.

Supplementary Material S2

Method

Study design

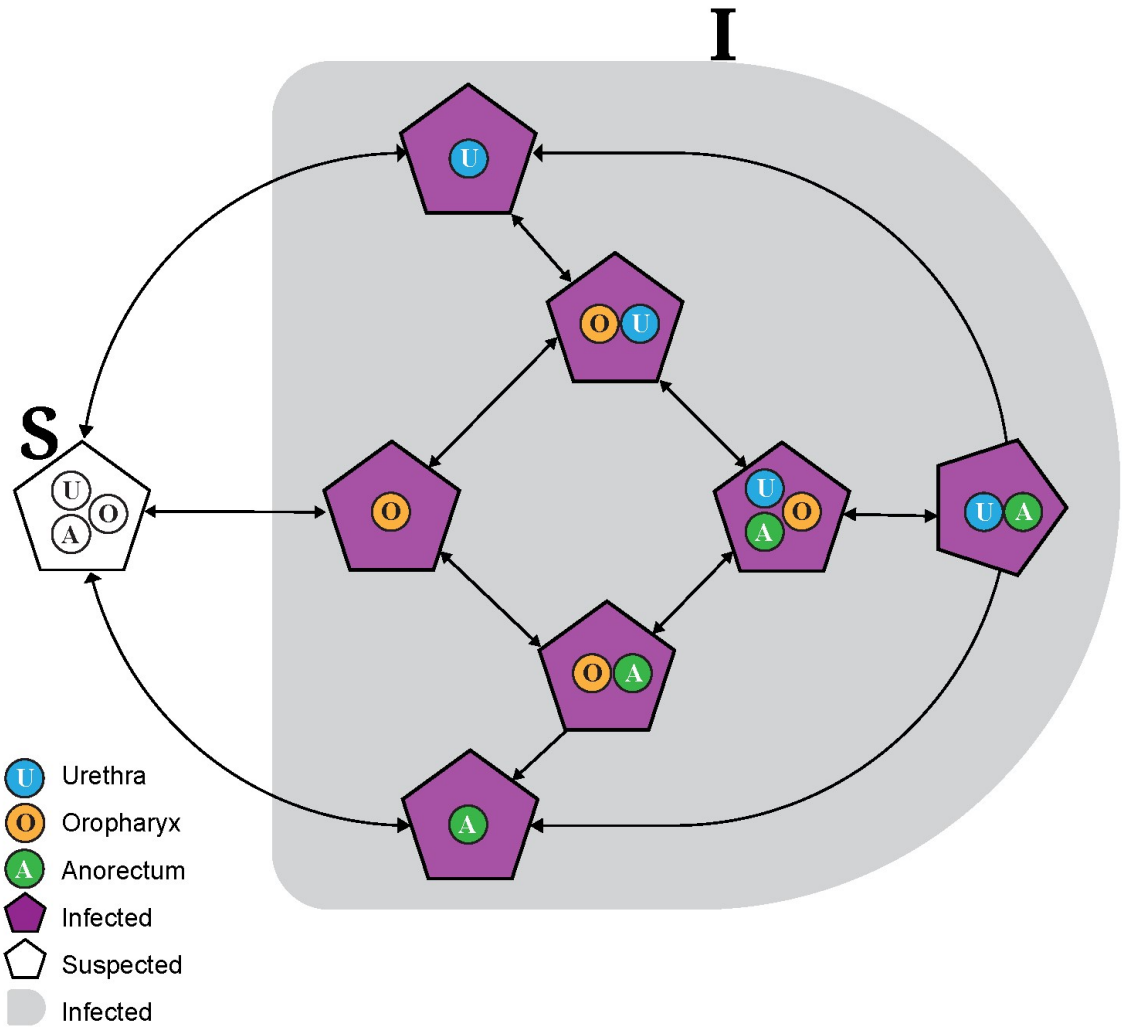

Figure S1. A compartmental model for the transmission dynamics of *Neisseria gonorrhoeae* in men who have sex with men.

U: only urethral infections; O: only oropharyngeal infections; A: only anorectal infections; Anorectum (A); OU: only oropharyngeal and urethral infections; UA: only urethral and anorectal infections; OA: only oropharyngeal and anorectal infections; OUA: oropharyngeal, urethral and anorectal infections; arrow signifies the direction of infection and clearance.

Differential equations

Force of infection

The force of infection Λ takes the following form(1, 2):

$$\Lambda = \lambda \cdot P$$

$$\lambda = (1 - (1 - \beta \cdot (1 - \varepsilon_c \cdot C))^{\frac{f}{2}})$$

$$\mathrm{N} = \mathrm{S} + I_o + I_u + I_a + I_{ou} + I_{ua} + I_{oa} + I_{oua}$$

$$P_o = I_o/N$$

$$P_u = I_u/N$$

$$P_a = I_a/N$$

$$P_{ou} = I_{ou}/N$$

$$P_{ua} = I_{ua}/N$$

$$P_{oa} = I_{oa}/N$$

$$P_{oua} = I_{oua}/N$$

$$P_{\mathrm{o\_all}} = P_o + P_{ou} + P_{oa} + P_{oua}$$

$$P_{\mathrm{a\_all}} = P_a + P_{oa} + P_{ua} + P_{oua}$$

$$P_{\mathrm{u\_all}} = P_u + P_{ou} + P_{ua} + P_{oua}$$

$$P_{\mathrm{ou\_all}} = P_{ou} + P_{oua}$$

$$P_{\mathrm{ua\_all}} = P_{ua} + P_{oua}$$

$$P_{\mathrm{oa\_all}} = P_{oa} + P_{oua}$$

$$a1 = \lambda_{oo} P_{\mathrm{o\_all}} + \lambda_{ao} P_{\mathrm{a\_all}} + \lambda_{uo} P_{\mathrm{u\_all}}$$

$$a2 = \lambda_{oa} P_{\mathrm{o\_all}} + \lambda_{ua} P_{\mathrm{u\_all}}$$

$$a3 = \lambda_{ou} P_{\mathrm{o\_all}} + \lambda_{au} P_{\mathrm{a\_all}}$$

Differential equations of model 1: with sequential sex practice

$$\frac{dP_s}{dt} = -a1 \cdot P_s + \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_s + \gamma_a \cdot P_{\mathrm{a}} - a3 \cdot P_s + \gamma_u \cdot P_u$$

$$\frac{dP_o}{dt} = a1 \cdot P_s - \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_{\mathrm{o}} + \gamma_a \cdot P_{oa} - a3 \cdot P_o + \gamma_u \cdot P_{ou} - \lambda_{ooa} \cdot P_o - \lambda_{oou} \cdot P_o$$

$$\frac{dP_u}{dt} = a3 \cdot P_s - \gamma_u \cdot P_{\mathrm{u}} - a1 \cdot P_{\mathrm{u}} + \gamma_o \cdot P_{ou} \ - a2 \cdot P_u + \gamma_a \cdot P_{ua} - \lambda_{uua} \cdot P_u - \lambda_{ua2} \cdot P_o$$

$$\frac{dP_a}{dt} = a2 \cdot P_s - \gamma_a \cdot P_{\mathrm{a}} - a1 \cdot P_{\mathrm{a}} + \gamma_o \cdot P_{oa} - a3 \cdot P_a + \gamma_u \cdot P_{ua} - \lambda_{aoa} \cdot P_a - \lambda_{aua} \cdot P_a + \lambda_{ua2} \cdot P_o$$

$$\frac{dP_{ou}}{dt} = a1 \cdot P_{\mathrm{u}} - \gamma_o \cdot P_{ou} + a3 \cdot P_{\mathrm{o}} - \gamma_u \cdot P_{ou} - a2 \cdot P_{ou} + \gamma_a \cdot P_{oua} + \lambda_{oou} \cdot P_o$$

$$\frac{dP_{oa}}{dt} = \ a2 \cdot P_{\mathrm{o}} - \gamma_a \cdot P_{oa} + a1 \cdot P_{a_{\mathrm{all}}} - \gamma_o \cdot P_{oa} - a3 \cdot P_{oa} + \gamma_u \cdot P_{oua} + \lambda_{ooa} \cdot P_o + \lambda_{aoa} \cdot P_a$$

$$\frac{dP_{ua}}{dt} = a2 \cdot P_{\mathrm{u}} - \gamma_a \cdot P_{ua} + a3 \cdot P_{\mathrm{a}} - \gamma_u \cdot P_{ua} - a1 \cdot P_{ua} + \gamma_o \cdot P_{oua} + \lambda_{uua} \cdot P_u + \lambda_{aua} \cdot P_a$$

$$\frac{dP_{oua}}{dt} = a2 \cdot P_{ou} - \gamma_a \cdot P_{oua} + a1 \cdot P_{ua} - \gamma_o \cdot P_{oua} + a3 \cdot P_{oa} - \gamma_u \cdot P_{oua}$$

Differential equations of model 2: model 1+ masturbation

$$\frac{dP_s}{dt} = -a1 \cdot P_s + \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_s + \gamma_a \cdot P_{\mathrm{a}} - a3 \cdot P_s + \gamma_u \cdot P_u - \ \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_o}{dt} = a1 \cdot P_s - \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_{\mathrm{o}} + \gamma_a \cdot P_{oa} - a3 \cdot P_o + \gamma_u \cdot P_{ou} - \lambda_{ooa} \cdot P_o - \lambda_{oou} \cdot P_o - \ \lambda.ohu1 \cdot P_o$$

$$\frac{dP_u}{dt} = a3 \cdot P_s - \gamma_u \cdot P_{\mathrm{u}} - a1 \cdot P_{\mathrm{u}} + \gamma_o \cdot P_{ou} \ - a2 \cdot P_u + \gamma_a \cdot P_{ua} - \lambda_{uua} \cdot P_u - \lambda_{ua2} \cdot P_o + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_a}{dt} = a2 \cdot P_s - \gamma_a \cdot P_{\mathrm{a}} - a1 \cdot P_{\mathrm{a}} + \gamma_o \cdot P_{oa} - a3 \cdot P_a + \gamma_u \cdot P_{ua} - \lambda_{aoa} \cdot P_a - \lambda_{aua} \cdot P_a + \lambda_{ua2} \cdot P_o - \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{ou}}{dt} = a1 \cdot P_{\mathrm{u}} - \gamma_o \cdot P_{ou} + a3 \cdot P_{\mathrm{o}} - \gamma_u \cdot P_{ou} - a2 \cdot P_{ou} + \gamma_a \cdot P_{oua} + \lambda_{oou} \cdot P_o + (\lambda.ohu1 \cdot P_o)$$

$$\frac{dP_{oa}}{dt} = \ a2 \cdot P_{\mathrm{o}} - \gamma_a \cdot P_{oa} + a1 \cdot P_{a_{\mathrm{all}}} - \gamma_o \cdot P_{oa} - a3 \cdot P_{oa} + \gamma_u \cdot P_{oua} + \lambda_{ooa} \cdot P_o + \lambda_{aoa} \cdot P_a - (\lambda.ohu1 \cdot P_{oa}) - \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{ua}}{dt} = a2 \cdot P_{\mathrm{u}} - \gamma_a \cdot P_{ua} + a3 \cdot P_{\mathrm{a}} - \gamma_u \cdot P_{ua} - a1 \cdot P_{ua} + \gamma_o \cdot P_{oua} + \lambda_{uua} \cdot P_u + \lambda_{aua} \cdot P_a + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{oua}}{dt} = a2 \cdot P_{ou} - \gamma_a \cdot P_{oua} + a1 \cdot P_{ua} - \gamma_o \cdot P_{oua} + a3 \cdot P_{oa} - \gamma_u \cdot P_{oua} + (\lambda.ohu1 \cdot P_{oa}) + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

Differential equations of model 3: model 2 - sequential sex practices

$$\frac{dP_s}{dt} = -a1 \cdot P_s + \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_s + \gamma_a \cdot P_{\mathrm{a}} - a3 \cdot P_s + \gamma_u \cdot P_u - \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_o}{dt} = a1 \cdot P_s - \gamma_o \cdot P_{\mathrm{o}} - a2 \cdot P_{\mathrm{o}} + \gamma_a \cdot P_{oa} - a3 \cdot P_o + \gamma_u \cdot P_{ou} - \lambda.ohu1 \cdot P_o$$

$$\frac{dP_u}{dt} = a3 \cdot P_s - \gamma_u \cdot P_{\mathrm{u}} - a1 \cdot P_{\mathrm{u}} + \gamma_o \cdot P_{ou} - a2 \cdot P_u + \gamma_a \cdot P_{ua} + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_a}{dt} = a2 \cdot P_s - \gamma_a \cdot P_{\mathrm{a}} - a1 \cdot P_{\mathrm{a}} + \gamma_o \cdot P_{oa} - a3 \cdot P_a + \gamma_u \cdot P_{ua} - \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{ou}}{dt} = a1 \cdot P_{\mathrm{u}} - \gamma_o \cdot P_{ou} + a3 \cdot P_{\mathrm{o}} - \gamma_u \cdot P_{ou} - a2 \cdot P_{ou} + \gamma_a \cdot P_{oua} + (\lambda.ohu1 \cdot P_o)$$

$$\frac{dP_{oa}}{dt} = a2 \cdot P_{\mathrm{o}} - \gamma_a \cdot P_{oa} + a1 \cdot P_{\mathrm{a}} - \gamma_o \cdot P_{oa} - a3 \cdot P_{oa} + \gamma_u \cdot P_{oua} - (\lambda.ohu1 \cdot P_{oa}) - \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{ua}}{dt} = a2 \cdot P_{\mathrm{u}} - \gamma_a \cdot P_{ua} + a3 \cdot P_{\mathrm{a}} - \gamma_u \cdot P_{ua} - a1 \cdot P_{ua} + \gamma_o \cdot P_{oua} + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

$$\frac{dP_{oua}}{dt} = a2 \cdot P_{ou} - \gamma_a \cdot P_{oua} + a1 \cdot P_{ua} - \gamma_o \cdot P_{oua} + a3 \cdot P_{oa} - \gamma_u \cdot P_{oua} + (\lambda.ohu1 \cdot P_{oa}) + \lambda.ohu2 \cdot P_{\mathrm{o\_all}}$$

P represents the prevalence of *Neisseria gonorrhoeae*; β represents the per-act transmission; C is the percentage of condom use in anal intercourse; ε_c is the efficacy of condom in preventing transmission of sexually transmitted infections and f is the frequency of sexual acts that may facilitate transmission. f is calculated based on the frequency of sexual acts data(1). S = S(t) is the number of susceptible MSM; I = I(t) is the number of infected MSM; I_o is the number of MSM with oropharyngeal infection only; $I_u$is the number of MSM with urethral infection only; $I_a$is the number ofMSM with rectal infection only; $I_{ou}$is the number of MSM with oropharyngeal and urethral infection only; $I_{ua}$is the number of MSM with rectal, and urethral infection only; $I_{oa}$is the number of MSM with oropharyngeal

and rectal infection only; $I_{oua}$is the number MSM with oropharyngeal, rectal, and urethral infection; P_o is the *Neisseria gonorrhoeae* prevalence of infected only at oropharyngeal; P_u is the *Neisseria gonorrhoeae* prevalence of infected only at urethral; P_a is the *Neisseria gonorrhoeae* prevalence of infected only at rectal site; $P_{ou}$is the *Neisseria gonorrhoeae* prevalence of infected only at oropharyngeal and urethral sites; $P_{ua}$is the *Neisseria gonorrhoeae* prevalence of infected only at rectal, and urethral sites; P_{oa} is the *Neisseria gonorrhoeae* prevalence of infected only at oropharyngeal and rectal sites; $P_{oua}$is the *Neisseria gonorrhoeae* prevalence of infected at oropharyngeal, rectal, and urethral sites. λ: rate of conversion from susceptible to infected individuals, it is a function of per-act transmission probability, frequency of sex acts, condom use and condom efficacy, the product of λ and site-specific prevalence defines the 'force of infection' at the specific site; λ_{ij}: the rate of conversion from the site i to j (λoo: kissing (oropharynx to oropharynx); λao: rimming (anorectum to oropharynx); λoa: rimming (oropharynx to anorectum); λau: anal sex (anorectum to urethra); λua: anal sex (urethra to anorectum); λuo: oral sex (urethra to oropharynx); λou: oral sex (oropharynx to urethra)); The rate of conversion at various sites due to sequential sexual practices (λooa: conversion at anorectum due to sequential oral sex followed by anal sex; λaoa: conversion at oropharynx due to sequential anal sex followed by oral sex; λoou: conversion at urethra due to spiting saliva on own penile; λua2: conversion at anus due to using saliva as a lubricant for penile-anal sex; λuua: conversion at anorectum due to sequential oral sex followed by riming; λaua: conversion at urethra due to sequential riming followed by oral sex) ; λohu1: conversion at urethra due tosolo masturbation; λohu2: conversion at urethra due tomutual masturbation; β_{ij}: The per-act transmission probabilityfrom the site i to j;ε_c: The efficacy of condom in preventing transmission of infection; C: The percentage of condom use in anal sex; f_{ij}:The frequency of sexual practices from the site i to j (including oral sex, anal sex, kissing, and rimming);γ: The rate of infection clearance; γ_u: The rate of oropharyngeal infection clearance; γ_a: The rate of anorectal infection clearance; γ_o: The rate of urethral infection clearance

Data resource

Table S1. Site-specific prevalence of gonorrhoea

		Prevalence/Mean value (95%CI)						
	Sample size	Oropharyngeal only	Urethral only	Rectal only	Oropharyngeal and urethra	Oropharyngeal and rectum	Urethra and rectum both	Oropharyngeal and urethra and rectum
Xu(2)	4,873 (First time visiting MSHC)		Empirical data: 0.31 (0.18-0.52)	3.16 (2.70-3.70)	Empirical data: 0.21 (0.11-0.40)		Empirical data: 1.19 (0.91-1.55)	Empirical data: 0.72 (0.51-1.01)
		2.96 (2.51-3.49)	Calibrated to community level data:0.01 (0.00-0.02)		Calibrated to community level data: 0.01 (0.00-0.02)	2.46 (2.05-2.94)	Calibrated to community level data: 0.05 (0.02-0.08)	Calibrated to community level data: 0.03 (0.01-0.05)
Spicknall(3) .	3,049		Empirical data:2.09 (1.63-2.69)		Empirical data:0.98 (0.67- 1.42)		Empirical data:1.21 (0.86-1.68)	Empirical data:0.75 (0.49-1.14)
		8.50 (7.54-9.55)	Calibrated to community level data:0.20 (0.07-0.32)	6.80 (5.93-7.76)	Calibrated to community level data:0.10 (0.03-0.16)	3.40 (2.81-4.13)	Calibratedto community level data:0.12 (0.04-0.19)	Calibrated to community level data:0.07 (0.02-0.12)
Pol (4)	393		Empirical data:2.54 (1.29-4.78)		Empirical data:1.53 (0.62-3.47)		Empirical data:0.76 (0.20-2.40)	Empirical data: 0.25 (0.01-1.63)
		2.04	Calibrated to community level	3.56	Calibratedto community	1.53	Calibratedto community level data:0.03	Calibrated to community level data:0.01

		(0.95-4.14)	data:0.10 (0.04-0.16)	(2.04-6.04)	level data:0.06 (0.02-0.10)	(0.62-3.47)	(0.01-0.05)	(0.00-0.02)
Footman (5)	179		Empirical data:0 (0-0)		Empirical data:0.56 (0.03-3.55)		Empirical data:0(0-0)	Empirical data:0(0-0)
		0.56 (0.03-3.55)	Calibrated to community level data:0(0-0)	3.91 (1.72-8.21)	Calibrated to community level data:0.02 (0.01-0.04)	2.23 (0.72- 5.98)	Calibrated to community level data:0(0-0)	Calibrated to community level data:0(0-0)
van Liere(6)	271,242 consultations		Empirical data: 0.85 (0.81-0.89)		Empirical data: 0.33 (0.31-0.36)		Empirical l data: 0.95 (0.91-0.99)	Empirical data: 0.73 (0.69-0.77)
		3.02 (2.95-3.09)	Calibrated to community level data:0.03 (0.01-0.06)	10.17 (10.05-10.30)	Calibrated to community level data:0.01 (0.00-0.02)	1.69 (1.64-1.75)	Calibratedto community level data:0.04 (0.01-0.06)	Calibratedto community level data:0.03 (0.01-0.05)
Hiransuthikul(7)	1,610	3.91 (3.04-5.01)	1.93 (1.34-2.76)	5.84 (4.77-7.13)	0.31 (0.11-0.77)	2.24 (1.60-3.12)	0.87 (0.50-1.49)	0.37 (0.15-0.85)

Note: MSHC did not test for urethral NG among asymptomatic MSM before 2018, so multi-site infections would be biased towards symptomatic patients. Hence, we used NG data for 2018-19. We calculated the confidence interval for each parameter using this method (8-10). Empirical data: The prevalence of urethral gonorrhoea infection in the community at a given point in time will be much lower than STI clinics. Asymptomatic urethral gonorrhoea is uncommon (7.69%) (11), but when it occurs, it is likely to be infectious for 3 to 5 months before the natural clearance. Therefore, the proportion of urethral gonorrhoea cases that are potentially infectious will be the prevalence of urethral gonorrhoea infection in STI clinics multiplied by 1/52 (infectious for one week till treatment) plus an additional asymptomatic 7.69% of cases who will be infectious for 3 to 5 months. Based on this information, we used previously published methods (1) to calibrate the prevalence of individuals with urethral infection in the community assuming about 92.3% will present symptoms shortly after a successful infection.

Model parameters

Table S2. Biological and behavioural data of *Neisseria gonorrhoeae* for model parameterization and calibration

Parameters	**Value (95%CI)**	**Reference/Notes**
Proportion of men using condoms for anal sex in the past 12 months with casual partners (%)	46.90(34.50- 59.30)	(1)
Efficacy of condoms for preventing *N. gonorrhoeae* transmission when used for anal sex (%)	87.50(80.00-95.00)	(1)
Frequency of kissing (days)	6.31(0.00-13.12)	(1)
Frequency of oral sex (days)	13.53(0.00-28.11)	(1)
Frequency of rimming (days)	38.57(0.00-80.15)	(1)
Frequency of anal sex (days)	26.44(0.00-54.94)	(1)
Duration of untreated *N. gonorrhoeae* at the oropharynx (asymptomatic infection) (weeks)	12.00(10.00-14.00)	(1)
Duration of *N. gonorrhoeae* at the urethra (symptomatic infection) (weeks)	1.00(0.90-1.10)	(1)
Duration of untreated *N. gonorrhoeae* at the urethra (asymptomatic infection) (weeks)	12.00(10.00- 14.00)	(1)
Duration of untreated *N. gonorrhoeae* at the anorectum(weeks)	49.43(48.00- 52.00)	(1)
Proportion of urethral infections that are asymptomatic (%)	7.69(4.09-13.67)	(11)
Proportion of MSM received throat swab in the past 12 months (%)	79.65(63.70-95.60)	Footnote *a,*(12)
Proportion of MSM received anal swab in the past 12 months (%)	79.65(63.70-95.60)	Footnote *a,*(12)
Proportion of MSM received urine test in the past 12 months (%)	79.65(63.70-95.60)	Footnote *a,*(12)
Proportion of ' oral sex and anal sex' in the same sex episode (%)	29.41(24.82-34.00)	Footnote *b,*(13).
Proportion of 'oral sex and rimming' in the same sex episode (%)	70.5 (67.94-72.94)	Footnote *c,*(13, 14).
Proportion of men using saliva as a lubricant during anal sex, the saliva is coming from the insertive (top) partner (%)	68.52(65.92-71.01)	(14)
Proportion of men having oral sex and then anal sex when they have both oral sex and anal sex (%)	80.00(80.00-80.00)	Footnote *d*(15, 16).

Proportion of men having oral sex and then rimming their partner when they perform both oral sex and rimming (%)	80.00(80.00-80.00)	Footnote e
Masturbation parameters		
Frequency of solo masturbation (days)	2.0 (1.4-3.5)	Footnote f, (17)
Frequency of mutual masturbation (days)	5.36 (3.5 – 80.15)	Footnote g, (18, 19).
Proportion of saliva use for solo masturbation, %	37.7(33.3-42.3)	Footnote h, (20).
Proportion of saliva use for mutual masturbation, %	33.6(29.4-38.1)	Footnote i,(20).

Footnote:

The proportion of gay and bisexual men attending sexual health clinics tested for *N. gonorrhoeae* in 2017 was 95.6%. The proportion of gay and bisexual men attending general practice clinics tested for *N. gonorrhoeae* in 2017 was 63.7%. We used the proportion of gay and bisexual men attending sexual health clinics tested as the lower bound. We used the proportion of gay and bisexual men attending general practice clinics tested as the upper bound. We used the mean value of the upper bound and lower as value.

The proportion of men who had receptive oral sex in their last sexual encounter that we used was 73.0%, and the proportion who had insertive anal sex was 34.0%. To determine proportion who had both oral sex and anal sex in the same encounter we used the proportion of anal sex (34.0%) as upper bound, and the value of the proportion of anal sex (34.0%) multiply the proportionof oral sex (73.0%) as the lower bound. The mean value is the average of the upper bound and lower bound.

The proportion of men who had insertive rimming in their last sexual encounter that we used was 70.5%, and the proportion of insertive oral sex was 75.0% To determine proportion who had both oral sex and anal sex in the same encounter we used the value of the proportion of oral sex multiply prevalence of rimming as lower bound and proportion of rimming behavior as upper bound. The mean value is the average of the upper bound and lower bound.

We estimated that the proportion of men who had oral sex followed by anal sex to be 80% based on expert opinion andpublished data.

This was calculated by subtracting 100% from the estimate in d.

LGBTQ males masturbated approximately two to five times a week. We estimated the frequency of solo masturbation was 3.5(2.0-5.0) times per week. Therefore, the estimated frequency of solo masturbation was 2.0 (1.4-3.5) days.

According to results of the Durex Global Sex Survey 2005, the frequency of sex in Australia was 108(18). The proportion of for mutual masturbation was 63.0%(19). The mean proportion of frequency of mutual masturbation was 365/ (108*63.0%) =365/68=5.36 days. Solo masturbation is more common than mutual masturbation. The lower bound was the upper bound of solo masturbation. The upper bound of (kissing, oral sex, rimming, or anal sex) was 80.15; therefore, we choose this as the upper bound of mutual masturbation.

Among 446 participants, the proportion of using saliva as lube when masturbating was168 (37.7%).

Among 446 participants, the proportion of masturbated my partner off using my saliva as lube was 149 (33.4%). The proportion of my partner masturbating me off with his saliva as lube was 151 (33.9%). Therefore, we got the proportion of saliva use for mutual masturbation 150(33.6%).

Table S3. Masturbation parameters of sensitivity analysis

Group	Parameters	Value
1	Increased to double the frequency of solo masturbation	4.00(2.80-7.00)
2	Increased to double the frequency of mutual masturbation	10.72(7.00-160.30)
3	Increased to double the proportion ofsaliva used for solo masturbation	75.40(66.60-84.60)
4	Increased to double the proportion of saliva use for mutual masturbation	67.20(58.80-76.20)
5	Decreased to half the frequency of solo masturbation	1.00(0.70-1.75)
6	Decreased to half the frequency of mutual masturbation	2.68(1.75-40.08)
7	Decreased to half the proportion ofsaliva used for solo masturbation	18.85(16.65-21.15)
8	Decreased to half the proportion of saliva use for mutual masturbation	16.8(14.7-19.05)

Reference

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Supplementary Material S3

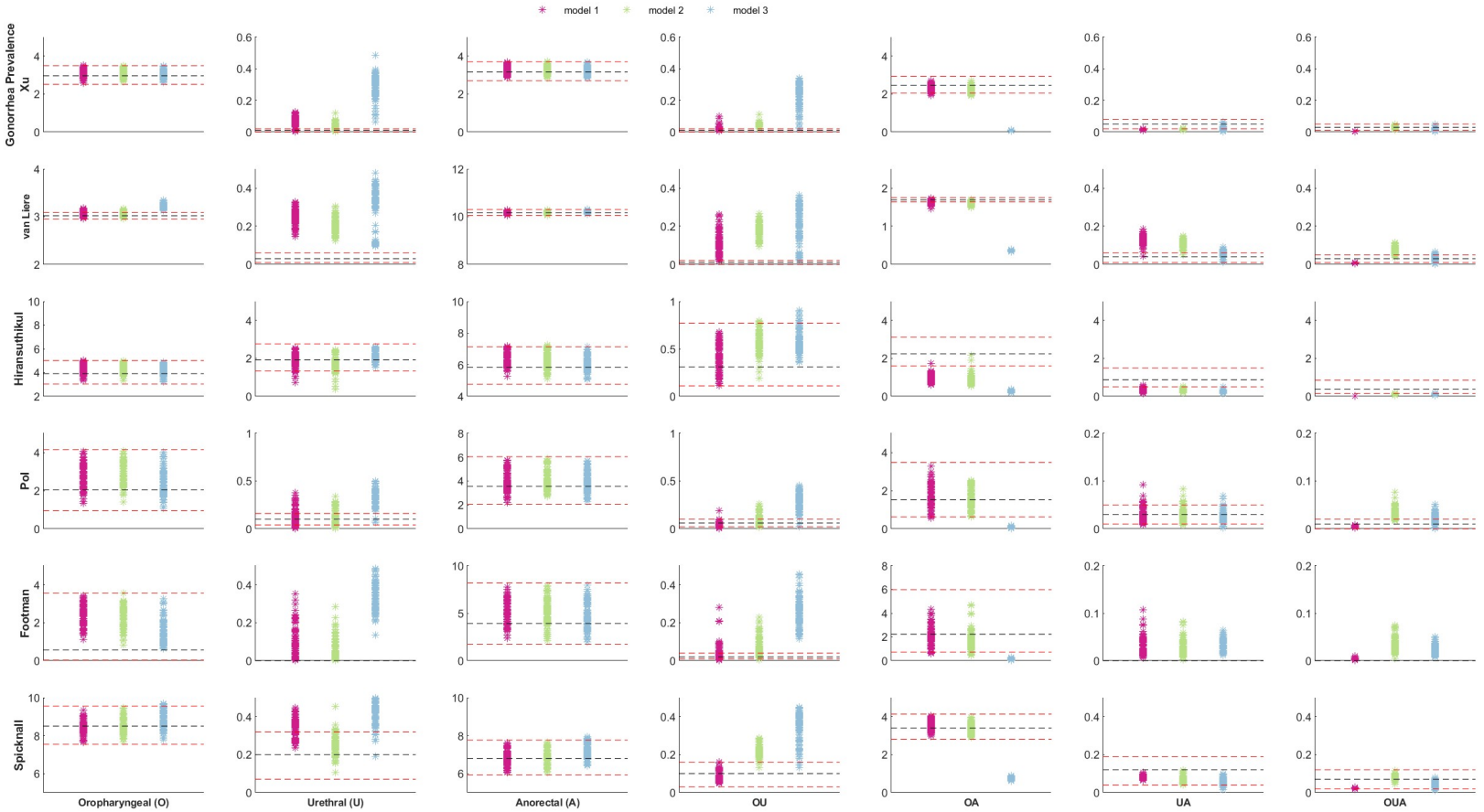

Figure S2. Model calibration and gonorrhoea data fitting to site-specific infection across six different datasets.

Red dashed lines denote 95% confidence intervals. Black dashed lines denote the mean value.Model 1: anal sex, oral sex, rimming, kissing, sequential oral/anal sex, using saliva as a lubricant for anal sex and sequential oral sex/riming; model 2 (Model 1 + masturbation); (Model 3 - sequential practices but + masturbation);Xu(1), van Liere(2),Hiransuthikul(3), Pol (4), Footman (5),and Spicknall(6).

Table S4. Root Mean Squared Error and Cohens' d of calibrated gonorrhoea models across six different datasets

Models	Root Mean Squared Error Mean, 95% Confidence Interval	Statistical analysis T-test, Absolute value of Cohens' d
Xu(1)		
Model 1	0.0021(95%CI 0.0009 to 0.0028)	Ref.
Model 2	0.0022(95%CI 0.0010 to0.0031)	**Model 2 vs. Model 1, p value <0.01, d=0.38**
Model 3	0.0213(95%CI 0.0200 to0.0218)	Model 3 vs. Model 1, p value <0.01, d=37.53 Model 3 vs. Model 2, p value <0.01, d=34.41
van Liere(2)		
Model 1	0.0029(95%CI 0.0020 to0.0032)	Ref.
Model 2	0.0029(95%CI 0.0022 to0.0032)	**Model 2 vs. Model 1, p value =0.47, d=0.10**

Model 3	0.0137(95%CI 0.0132 to0.0138)	Model 3 vs. Model 1, p value <0.01, d=46.00 Model 3 vs. Model 2, p value<0.01, d= 49.28
Hiransuthikul(3)		
Model 1	0.0128(95%CI 0.0103 to0.0137)	Ref.
Model 2	0.0132(95%CI 0.0109 to 0.0141)	**Model 2 vs. Model 1, p value <0.01,d = 0.43**
Model 3	0.0181(95%CI 0.0161 to0.0192)	Model 3 vs. Model 1, p value= 0.1052, d =5.79 Model 3 vs. Model 2, p value <0.01, d=5.65
Pol(4)		
Model 1	0.0024(95%CI 0.0009 to0.0030)	
Model 2	0.0028(95%CI 0.0013 to0.0036)	**Model 2 vs. Model 1, p value <0.01,d=0.81**
Model 3	0.0096(95%CI 0.0071to0.0108)	Model 3 vs. Model 1, p value<0.01,d=7.84 Model 3 vs. Model 2, p value <0.01,d =7.31
Footman(5)		
Model 1	0.0041(95%CI 0.0012 to 0.0052)	Ref.
Model 2	0.0048(95%CI0.0018 to0.0063)	**Model 2 vs. Model 1, p value <0.01,d= 0.74**
Model 3	0.0143(95%CI 0.0082 to 0.0168)	Model 3 vs. Model 1, p value<0.01,d=5.76 Model 3 vs. Model 2, p value <0.01,d =5.11
Spicknall(6)		

Model 1	0.0015(95%CI 0.0011 to0.0016)	Ref.
Model 2	0.0018(95%CI 0.0012 to 0.0021)	**Model 2 vs. Model 1, p value <0.01,d721 =1.37**
Model 3	0.0232(95%CI 0.0211 to0.0239)	Model 3 vs. Model 1, p value<0.01,d731 =39.30 Model 3 vs. Model 2, p value <0.01,d723 =37.30

Note: Model 1: anal sex, oral sex, rimming, kissing, sequential oral/anal sex, using saliva as a lubricant for anal sex and sequential oral sex/riming; model 2 (Model 1 + masturbation); (Model 3 - sequential practices but + masturbation).

Table S5. The proportion of gonorrhoea incidence by masturbation across six different datasets, %

	Proportion of incidence by masturbation		
	Solo Masturbation (mean, 95%CI)	Mutual masturbation (Mean, 95%CI)	Overall masturbation (Mean, 95%CI)
Xu (1)			
Model 2	4.9 (95%CI 3.0 to 9.4)	0.2(95%CI 0.0 to 2.0)	5.2(95% 3.2 to 10.1)
Model 3	21.6(95%CI 5.0 to 31.7)	2.0(95%CI 0.0 to 10.1)	24.5(95%5.0 to 38.7)
van Liere(2)			

Model 2	9.7(95%CI 4.5 to 17.3)	0.6(95%CI 0.0 to 5.4)	10.6(95% 5.8 to 17.3)
Model 3	14.7(95%CI 2.5 to 25.3)	1.1(95%CI 0.0 to 6.1)	16.7(95% 2.6 to 27.3)
Hiransuthikul(3)			
Model 2	7.1(95%CI 2.0 to 12.1)	0.6(95%CI 0.1 to 3.9)	8.4(95% 2.0 to 13.0)
Model 3	10.1(95%CI 6.1 to15.1)	1.0(95%CI 0.3 to 7.1)	11.3(95% 7.5 to 17.3)
Pol (4)			
Model 2	7.5(95%CI 3.4 to 17.7)	0.4(95%CI 0.0 to 4.2)	8.1(95% 3.8 to 19.8)
Model 3	25.2(95%CI 8.7 to 40.8)	2.2(95%CI 0.1to 9.1)	27.8(95% 8.8 to 44.1)
Footman(5)			
Model 2	7.3(95%CI 2.4 to 18.2)	0.6(95%CI 0.1 to 5.0)	8.3(95% 2.7 to 20.4)
Model 3	27.3(95%CI 14.8 to 42.5)	2.8(95%CI 0.9 to 11.2)	30.5(95% 16.7 to 45.9)
Spicknall(6)			
Model 2	7.8 (95%CI 4.1 to 13.6)	0.4(95%CI 0.0 to 4.7)	8.8(95% 4.6 to 14.1)
Model 3	14.0 (95%CI 5.5 to 20.7)	1.2(95%CI 0.0 to 6.3)	15.5(95% 5.9 to 23.9)

Note: Gonorrhoea Model 1: anal sex, oral sex, rimming, kissing, sequential oral/anal sex, using saliva as a lubricant for anal sex and sequential oral sex/riming; model 2 (Model 1 + masturbation); (Model 3 - sequential practices but + masturbation).

Table S6.The estimated proportion of gonorrhoea incidence at oropharynx, urethra and anorectum using models with or without masturbation across six different datasets, %

	Oropharynx	Anorectum	Urethra
Xu(1)			
Model 1	59.8	21.7	18.5
Model 2	59.0	21.2	19.8
Model 3	38.6	14.0	47.4
van Liere(2)			
Model 1	33.9	29.9	36.3
Model 2	32.8	28.4	38.8
Model 3	31.0	30.7	38.3
Hiransuthikul(3)			
Model 1	46.8	23.4	29.8
Model 2	47.9	22.5	29.6
Model 3	49.2	22.5	28.3
Pol(4)			
Model 1	51.7	23.3	25.0

Model 2	49.2	21.6	29.1
Model 3	30.6	16.2	53.2
Footman(5)			
Model 1	49.4	27.2	23.5
Model 2	46.1	27.2	26.6
Model 3	21.3	19.9	58.8
Spicknall(6)			
Model 1	56.4	18.6	24.9
Model 2	54.9	17.0	28.0
Model 3	51.7	14.9	33.4

Note: Gonorrhoea Model 1: anal sex, oral sex, rimming, kissing, sequential oral/anal sex, using saliva as a lubricant for anal sex and sequential oral sex/riming; model 2 (Model 1 + masturbation); (Model 3 - sequential practices but + masturbation).

Sensitivity analysis

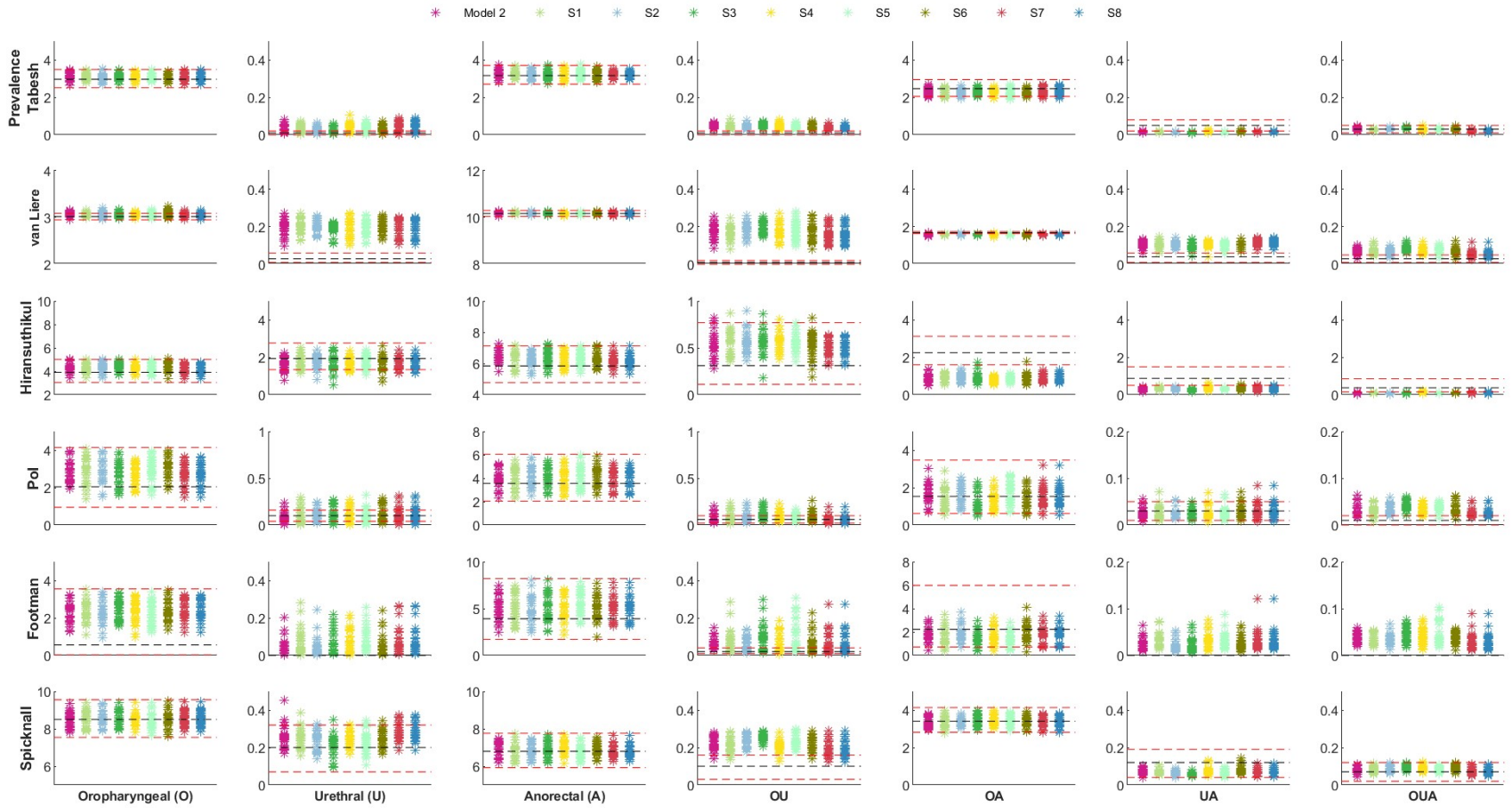

Figure S3. Model 2 calibration and gonorrhoea data fitting to site-specific infection across six different datasets.

Red dashed lines denote 95% confidence intervals. Black dashed lines denote the mean value.Xu(1), van Liere(2),Hiransuthikul(3), Pol (4), Footman (5),and Spicknall(6).1)S1: increased to double the days of the frequency of solo masturbation; 2) S2: increased to double the days of the frequency of mutual masturbation; 3)S3: increased to double the proportion of saliva used for solo masturbation; 4) S4: increased to double the proportion of saliva use for mutual masturbation; 5) S5: decreased to half the days of the frequency of solo masturbation; 6) S6: decreased to half the days of the frequency of mutual masturbation; 7) S7: decreased to half the proportion of saliva used for solo masturbation; 8) S8: decreased to half the proportion of saliva use for mutual masturbation.

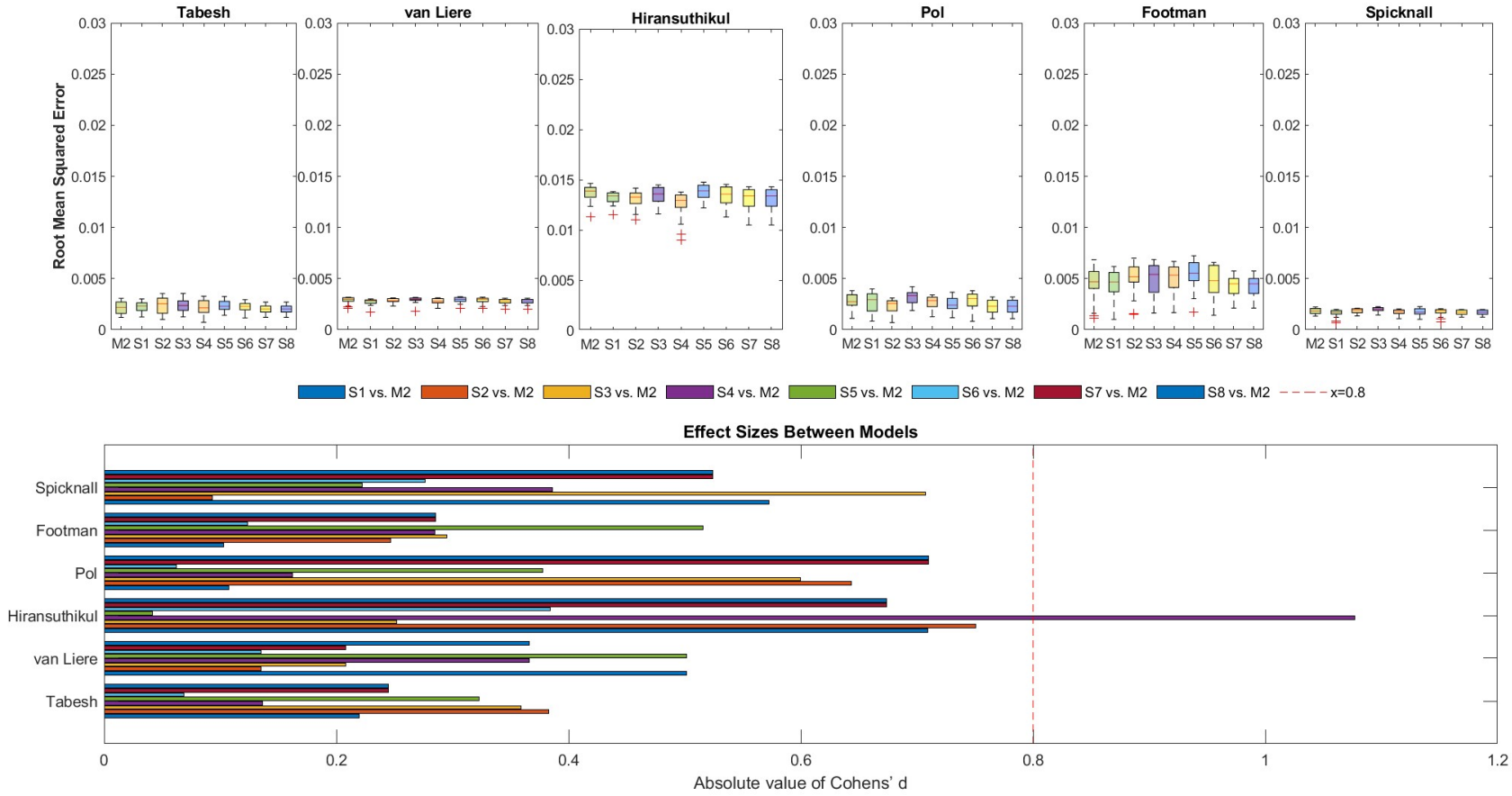

Figure S4.Sensitivity analysis of root mean squared error and effect size of calibrated gonorrhoea model 2 with masturbation across six different datasets

Xu(1), van Liere(2),Hiransuthikul(3), Pol (4), Footman (5),and Spicknall(6). 1)S1: increased to double the days of the frequency of solo masturbation; 2) S2: increased to double the days of the frequency of mutual masturbation; 3)S3: increased to double the proportion of saliva used for solo masturbation; 4) S4: increased to double the proportion of saliva use for mutual masturbation; 5) S5: decreased to half the days of the frequency of solo masturbation; 6) S6: decreased to half the days of the frequency of mutual masturbation; 7) S7: decreased to half the proportion of saliva used for solo masturbation; 8) S8: decreased to half the proportion of saliva use for mutual masturbation.

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