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The role of commercial sex venues in the HIV epidemic among men who have sex with men in King County, WA

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According to the US Centers for Disease Control and Prevention, more than 500,000 Americans have died from AIDS since the epidemic began,¹ and more than 1 million Americans are currently infected with HIV.² Men who have sex with men continue to be the group most affected by HIV/AIDS in the US. In 2005 an estimated 50% of newly diagnosed, reportable HIV infections nationwide were transmitted through male-male sexual contact.¹ In King County, Washington (comprising Seattle and many of its suburbs) men who have sex with men comprise fully 64% of cases identified since 2003,³ and there is evidence that high-risk behaviors⁴ and STI incidence^{5–8} are rising in this population.

Commercial sex venues catering exclusively to men, including gay bathhouses and sex clubs, have operated in the US for at least a century.⁹ Bathhouses and sex clubs differ in some respects, but share the traits of charging entrance fees, admitting only men, and allowing sex on premises.¹⁰ In the early 1980s, commercial sex venues became widely considered to facilitate HIV spread.^{11–13} A committee convened by the National Research Council concluded that commercial sex venues functioned similarly to “shooting galleries” used by injection drug users to “promote transmission-related behavior at a rate far beyond that possible outside these settings.”¹⁴ Sharply contentious efforts to close or regulate commercial sex venues were made by local health officials across the US.¹⁵ Opponents of closures argued that the policy would simply move unsafe sex into other sites more out of reach of HIV prevention efforts.¹⁶ Lacking epidemiologic evidence relating commercial sex venue characteristics and HIV risk,¹⁷ cities often had to choose among policy approaches based on anecdotal evidence. An increase in direct HIV prevention and testing, and basic epidemiologic research, within commercial sex venues began in the 1990s and continues into the present,^{18–26} but the fraction of new infections attributable to commercial sex venues remains unknown.

This analysis uses data from three recent surveys and mathematical modeling to examine the impact that commercial sex venues have on the HIV epidemic among men who have sex with men in one large US county. These include two probability surveys that present the first description of commercial sex venue patron composition and behavior throughout an entire US county or metropolitan area,¹⁰ including relatively detailed information on HIV risk behaviors both in commercial sex venues and elsewhere. Our primary aim is to estimate a range for the number of HIV infections currently attributable to the presence of commercial sex venues in King County given a set of plausible scenarios. This requires the simulation of HIV incidence among King County men who have sex with men in several theoretical, counterfactual scenarios in which commercial sex venues no longer exist, and in a scenario reflecting conditions as reported in recent years. We explore a range of assumptions about the degree to which current commercial sex venue contacts would be

forgone or replaced, and presume that those replaced would match the behaviors that commercial sex venue patrons reported engaging in outside of commercial sex venues.

METHODS

To simulate HIV transmission in the various scenarios, we constructed a series of compartmental, discrete-time deterministic mathematical models, specified and solved in Stella (Isee Systems, Lebanon, NH). Model equations comprised initial conditions (e.g. proportions of men initially uninfected) and transition-related parameters (e.g. partnership formation rate, patterns of serostatus-based partner selection, per-sex act infectivity). Our discrete-time simulation time step was one day, reflected in all rates calculated from our data.

A key resource was data from a recent pair of probability samples of commercial sex venue patrons in King County, conducted in 2004 and 2006,¹⁰ which we will call CSV2004 and CSV2006. These surveys sampled men from three commercial sex venues in King County. To estimate many of our model parameters, we conducted descriptive statistical analyses of the more in-depth CSV2004 data to identify self-reported HIV prevalence among commercial sex venue patrons, and frequency of unprotected anal intercourse (UAI) by self-reported serostatus. The surveys also asked commercial sex venue attendees about their use of other venues for meeting sexual partners, and the rates of sexual contact, acts, and condom use at those venues, information we use in our counterfactual scenarios.

Our findings were supplemented with information from a 2003 population-based, random-digit-dial survey of Seattle men who have sex with men,²⁷ which we call RDD2003. This survey informed several key parameter estimates, particularly regarding the makeup and behaviors of men who do not visit commercial sex venues.

Our models were parameterized using only recent data sets since they are intended to represent the current biobehavioral system of HIV spread among Seattle men who have sex with men. Our models are not intended to capture the full trajectory of the HIV epidemic in this population (either into the past or the distant future) since we do not believe that sexual behavior has or will remain constant over long time frames, especially regarding usage of commercial sex venues versus alternative venues.

Mathematical models

We constructed two general classes of models: one reflecting current HIV transmission among King County men who have sex with men (*main model*), and the other modeling transmission in counterfactual situations in which commercial sex venues no longer exist (*counterfactual model*). Certain important model assumptions were speculative, so we varied their respective parameters, some individually and some in a combined sensitivity analysis, detailed below. We describe the general model structure and its assumptions here; more mathematical detail may be found in the online appendix.

Main model

Model compartments—The main model included 10 compartments of men who have sex with men, distinguished by commercial sex venue patron status (L), sexual activity level inside and outside commercial sex venues (A), and HIV serostatus (H) (Figure 1). Commercial sex venue patrons were categorized by both commercial sex venue activity levels (high/low) and outside activity levels (high/low). High activity for either location was defined as reporting 2+ UAI partners there in the previous three months. Commercial sex venue patrons' activity class was defined by their combination of inside- and outside-

commercial sex venue activity levels (four combinations total). Due to the limited information available from RDD2003, all non-commercial sex venuepatron men who have sex with men were placed into one activity class. The five total activity classes were each further subdivided into susceptible (HIV-negative) and infected (HIV-positive).

The initial distribution of men across the 10 compartments (n_{ah}) was based primarily on self-reported HIV prevalence and UAI contact rates in CSV2004 (for commercial sex venue compartments) and HIV prevalence in RDD2003 (for noncommercial sex venue compartments). The initial sizes of the total commercial sex venue population and sexually active non-commercial sex venue population were calculated using a previous estimate of the men who have sex with men population size in King County,²⁸ and findings from RDD2003 regarding sexual activity and frequency of visiting commercial sex venues in the previous year. The distribution was adjusted for the presence of undiagnosed HIV-positive men, and for a bias towards frequent commercial sex venue visitors in CSV2004 (see online appendix). Table 1 details model notation; many variables should be indexed by time, although we omit this for notational simplicity. Tables 2 and 3 summarize initial conditions and parameter values for the main model.

Model transitions—The model contains three types of transitions: HIV acquisition, entry, and exit. We assumed no movement among activity classes. We detail each transition type in turn.

HIV acquisition—Movement from HIV-negative to HIV-positive compartments is a function of (1) sexual activity levels of each compartment; (2) patterns of mixing by serostatus given these activity levels; and (3) per-partnership HIV transmissibility for commercial sex venue and non-commercial sex venue partnerships. The model only reflects UAI, since this behavior is widely believed to be the predominant route of male-to-male sexual HIV transmission.²⁹

(1) Separate commercial sex venue and outside-commercial sex venue UAI partnership formation rates (c_{lah}) were defined for each activity-level/HIV-status combination, based on reports by men in each respective group from CSV2004 and RDD2003. These rates were adjusted for the presence of undiagnosed HIV-positive men; commercial sex venue rates were also adjusted for a bias towards frequent commercial sex venue visitors in CSV2004. The final UAI partnership formation rates for each group in the main model (Table 3) equal the five percent trimmed mean number of UAI partners per day for each activity-level/HIV-status group in the adjusted datasets. Trimmed means were used due to small numbers of subjects in certain activity level-HIV status groups in the survey. See online appendix for more detail. From these values, we specified the total number of contacts for all men in activity class a with serostatus h in location l at a given time ($= c_{lah} n_{ah}$), which we call d_{lah}

(2) We assumed proportional mixing by activity class, but preferential selection of sex partners by HIV status (serosorting). To parameterize the latter, we used data from CSV2004, and a method described previously³⁰ based on the odds ratio in the 2×2 table of apparent serostatus for insertive and receptive partners. In calculating this odds ratio, we assigned positive or negative serostatuses to partners whose status was reported as unknown by respondents, based on the proportion of partnerships reported by self-identified positive and negative men, respectively. A single odds ratio, calculated using data from all partnerships, was used because the observed values disaggregated by activity level and location were not significantly different ($p>0.05$). The resulting value ($OR_{aa}=2.82$) reflects the increased odds of selecting a UAI partner of one's own HIV status.

This odds ratio, combined with the d_{lah} values derived in the previous step, and the assumption of random mixing by activity class, define a unique set of contact rates for each pair of compartments in each location. For the full process of determining these rates given the odds ratio and marginal contact rates, see the appendix. From these values we calculate the number of UAI partners of discordant HIV status for each compartment per timestep (α_{laia}).

(3) The number of discordant UAI partnerships among HIV-negative compartments was multiplied by a value representing per-partnership HIV transmission probability to arrive at the number of new HIV infections. The per-partnership transmission probability was calculated using the formulas $(1-(1-\beta_R)^{z_R})$ and $(1-(1-\beta_I)^{z_I})$, where β_R and β_I represent per-act probability of HIV transmission for receptive and insertive UAI, respectively, and z_R and z_I equal the number of receptive and insertive UAI acts per partnership. We assumed one UAI acts per commercial sex venue partnership.. We assumed no seropositioning and complete role versatility, such that in serodiscordant relationships, the seronegative partner was insertive 50% of the time. The mean number of UAI acts for men who have sex with men partnerships initiated outside of commercial sex venues is not well-documented—so we systematically varied this from 2–20; here we assumed in each case that half the acts in each partnership were insertive for each partner. The per-act HIV transmission probabilities for insertive and receptive UAI were derived from previous findings.³¹ Our calculation of these probabilities is presented in the Appendix.

Entry and exit—HIV transmission dynamics were simulated over a ten year period in each model run. Departure occurred with constant probability (e_{ah}), based on an expected membership in the population of 40 years for HIV-negative men and 10 years post-infection for HIV-positive men. Numbers of men entering each compartment (ω_{ah}) were set to equal numbers of departures from the system leaving each respective compartment during a one-year simulation run without entry. This ensures a roughly steady-sized population.

Model equations: The difference equations resulting from this model are:

$$n_{a0}(t+1)-n_{a0}(t)=\omega_{a0}-\left[\sum_{a_r=1}^5\sum_{l=0}^1\alpha_{laa_r}(1-(1-\beta_I)^{z_I})\right]-\left[\sum_{a_i=1}^5\sum_{l=0}^1\alpha_{laia}(1-(1-\beta_R)^{z_R})\right]-(\varepsilon_{la0}\times n_{a0})$$

$$n_{a1}(t+1)-n_{a1}(t)=\omega_{a1}+\left[\sum_{a_r=1}^5\sum_{l=0}^1\alpha_{laa_r}(1-(1-\beta_I)^{z_I})\right]+\left[\sum_{a_i=1}^5\sum_{l=0}^1\alpha_{laia}(1-(1-\beta_R)^{z_R})\right]-(\varepsilon_{la1}\times n_{a1})$$

with all notation defined in Table 1. The time index (t) is included for the n values only for ease of presentation.

Counterfactual model

The structure, assumptions, and initial conditions for the counterfactual model equal the main model in nearly every way. The sole difference is the partnership formation rates for commercial sex venue men, modified to estimate behaviors in a counterfactual setting without commercial sex venues.

The mean number of commercial sex venue partnerships—including those in which UAI did or did not occur—was identified for each of the activity-level/HIV-status groups from CSV2004. (Again, 5% trimmed means were used, due to some small subgroup sizes.) These

mean commercial sex venue partnerships were assumed to be measures of the number of “replaceable” partnerships for each group member in a counterfactual scenario.

Calculation of replacement partnerships—We assumed that the best evidence of counterfactual behaviors with these “replaceable” partners lie in the indicators of past sexual behaviors *outside* of commercial sex venues among the commercial sex venuegoing population. In CSV2004 subjects were asked to report recent sexual behavior, including UAI, with partners met through twelve types of non-commercial sex venue sources, such as bars, parties, parks, friends, and the Internet. This allowed for a determination of the proportion of sexual partnerships initiated through each source, and the probability that a partnership of each type would involve UAI. The sum of the product of these two sets of numbers provided a weighted average for each activity-level/HIV-status group, representing the probability that any given non-commercial sex venue sexual partnership would result in UAI for members of each group. Table 4 shows estimates of the two sets of probabilities.

To arrive at counterfactual UAI partnership formation rates for each activity-level/HIV-status group, the weighted average probability of UAI for non-commercial sex venue partnerships was multiplied by the number of “replaceable” partnerships for each group (Table 5). The degree to which these partnerships would, indeed, be replaced one-for-one, or in some smaller proportion, in a counterfactual scenario is entirely unknown. We therefore systematically varied the degree of replacement of partners by multiplying the commercial sex venue partnership rates by 1.00, 0.75, 0.50, 0.25, and 0—to arrive at a set of alternate counterfactual scenarios with these different levels of commercial sex venue partnership replacement. (Table 6 shows the 100% replacement rates.) For the sake of mathematical tractability, the replacement partnerships in the counterfactual scenarios were assumed to occur entirely between pairs of men who had been commercial sex venue patrons in the main model. Just as we assumed that each commercial sex venue UAI partnership consists of a single UAI act, we defined replacement UAI partnerships as consisting of one UAI act.

Attributable number

For each counterfactual scenario, we defined the “attributable number” as the difference in the 10-year cumulative number of new HIV infections between the main model and the counterfactual scenario.

Sensitivity analysis

To explore the effect of parameter value uncertainty on simulated HIV transmission, and to assess the importance of each parameter on HIV incidence, we performed sensitivity analyses using Latin hypercube sampling (LHS) methods.^{32–34} Each of the eight commercial sex venue patron UAI partnership formation rates, the noncommercial sex venue men who have sex with men partnership formation rate, and the log of the serosorting odds ratio were subjected to LHS-generated variability. The Crystal Ball (Oracle Corp., Denver) add-in for Microsoft Excel (Microsoft Corp., Redmond) was used to perform LHS. One hundred sampling iterations were run, providing 100 sets of unique parameter values. Further details, including selection of the distributions for each variable, are in the online appendix.

The 100 sets of parameter values were entered into Stella for both the main model and each of the five counterfactual scenarios, generating 600 total outcomes. We used the attributable number across scenarios as our dependent variable, and modeled this as a function of input parameters using SPSS 16.0 (SPSS, Inc., Chicago). First, we examined scatterplots of each parameter variable by the attributable number outcome to assess monotonicity. Separate analyses were run using the sensitivity analysis data for the main model and five

counterfactual models. We then performed partial correlation analysis to identify statistical relationships between parameter inputs and outcomes, and, where applicable, to identify the strength and direction of the linear relationship between each parameter and the model outcome (partial correlation analysis results are presented in the Appendix).

RESULTS

Main model calibration

The annual number of incident HIV cases simulated by the main model ranged from approximately 550–900 cases in the scenario assuming 20 UAI acts per noncommercial sex venue partnership, down to only 100 assuming two UAI acts per noncommercial sex venue partnership (Figure 2). The actual number of new HIV cases among men who have sex with men in King County appears to have been between 200–300 cases annually in recent years.³ Our models assigning 5–10 UAI acts per noncommercial sex venue partnership projected HIV incidence close to that range. The true mean number of UAI acts per men who have sex with men partnership involving UAI is unknown, but a preliminary analysis of data collected from two recent population-based studies of men who have sex with men in King County found that the number is likely between two and nine (T. Menza, written communication, January 2008). Our findings here are consistent with this estimate.

Attributable number findings

Figure 3 summarizes the attributable number of incident HIV cases in the counterfactual models under the 5 and 10 UAI acts per replacement partnership scenarios (panels 3a and 3b, respectively). Each line per panel plots a different value for level of partnership replacement in the absence of commercial sex venues. In both cases, replacement of 50% or more of commercial sex venue partners resulted in yearly attributable number values below zero. That is, for these scenarios our model predicts a net *increase* in the number of incident HIV infections in the absence of commercial sex venues in every year. Only when replacement drops to 25% does the attributable number approximate zero, indicating that this scenario would result in little or no change in HIV incidence. The only counterfactual scenario that consistently projected fewer annual infections than the main model was that representing zero replacement partnerships. In no case, however, did these yearly margins reach even 30 additional HIV infections. We performed these analyses for each additional scenario (i.e., 2, 10, and 20 UAI acts per replacement partnership), with similar qualitative findings.

Sensitivity analysis

Figure 4 presents yearly attributable number estimates from the sensitivity analyses. Results from each set of 100 parameter values selected in the LHS are shown, assuming 10 UAI acts per partnership, and applied to the 100%, 75%, 50%, 25%, and no replacement levels. Most attributable numbers—at all time points, in each replacement scenario—fall within 20 incident cases of the corresponding main findings (Figure 3a). Nearly all of the attributable number estimates from the 25% replacement scenario were close to zero, consistent with the main results noted above. Each of the scenarios assigning 50% or greater replacement of commercial sex venue partners predicted higher HIV incidence in the absence of commercial sex venues, with near unanimity across the 100 sets of sensitivity analysis outcomes.

DISCUSSION

Under our model assumptions, commercial sex venues in King County appear to contribute little to the local HIV epidemic among men who have sex with men. If commercial sex

venues ceased to exist in King County, and commercial sex venue patrons were to forego as many as 75% of their lost commercial sex venue contacts, overall HIV incidence would not likely decrease from its current level. If, in the absence of commercial sex venues, would-be commercial sex venue patrons were to replace even half of their missed bathhouse and sex club contacts, it appears that HIV incidence among men who have sex with men might increase slightly. In no scenario did we find that even 25 new cases of HIV per year may be attributable to the presence of commercial sex venues in the region. These qualitative findings were relatively insensitive to a variety of key assumptions.

Our findings are largely a reflection of the types of HIV risk behaviors that respondents in the 2004 King County commercial sex venue survey reported engaging in, both within inside and outside of bathhouses and sex clubs. Specifically, commercial sex venue patrons were less likely to report having anal sex—protected and unprotected—with partners met in bathhouses and sex clubs than with partners met within other popular venues. For example, of respondents with exactly one partner during their recent bathhouse or sex club visit, the proportion reporting UAI with their most recent sex partner is 22% for Internet partners, 20% for bar partners, and 10% for commercial sex venue partners. The pattern is reversed for oral sex (64%, 71%, and 85%, respectively). Also worth noting is that only 18% of RDD2003 respondents attended a commercial sex venue in the previous year. Of those who had, 42% reported visiting only once or twice a year, and fewer than 10% stated that they visited commercial sex venues more than once a month (MR Golden, written communication, September 2007). Thus, the population of routine commercial sex venue patrons is a relatively small segment of men who have sex with men in King County.

Limitations

A number of limitations may affect the accuracy and generalizability of the study findings. We modeled HIV transmission probabilities as homogenous within a specific type of act (UIAI and URAI). In reality, this probability varies by factors such as stage of infection³⁵ and ART usage.³⁶ We also imagine that the true network of sexual partnerships among men who have sex with men in King County likely exhibits additional structural complexity beyond that we have considered. However, in general these factors might be expected to affect both our main model and our counterfactual model in the same direction and in a generally similar way, and our main finding represented the relative magnitude of these two scenarios. Thus, although all of these represent additional features of importance to HIV epidemiology generally, we feel confident that they would not strongly alter our qualitative findings.

Many of the parameter values in our models are based on a 2004 survey with a low participation rate (30%), which calls into question the representativeness of our parameter values within the full King County commercial sex venue-patron population. However, this survey has been compared statistically to a 2006 probability sample of King County bathhouse and sex club patrons with a 61% participation rate, and no evidence of selection bias was evident.¹⁰

A key assumption, of course, is that no large differences in methods of finding sex partners would develop if commercial sex venues no longer existed. It is entirely possible, as some bathhouse closure critics have stated, that certain venues of only marginal interest now—such as private sex parties and public sex in parks and restrooms—could take on a different character and substantial importance in HIV transmission if bathhouses and sex clubs were no longer an option for men who have sex with men.¹⁶ There is some evidence that, in recent years, frequency of HIV risks in commercial sex venues may be declining, while frequency of risks from Internet partnerships increasing.³⁷ We expect that the attributable number of HIV infections due to commercial sex venues would, in this case, be lower than

we project. This evidence also serves to highlight the context-dependent nature of our findings: every combination of time and place offers its own set of sexual opportunities and restrictions, and behavioral patterns are likely responsive to these structural forces. Our findings should therefore be generalized only to those communities in which it is likely that men have similar levels of usage, and behaviors while using, other venues than bathhouses and sex clubs for meeting sex partners.

Nevertheless, these findings are striking, in that they suggest that bathhouses and sex clubs may not be among the primary facilitators of HIV transmission among men who have sex with men populations. It is possible that, in another era—with different patterns of UAI and condom use among men who have sex with men and before the widespread use of the Internet to find sex partners—commercial sex venues played a central role in the epidemic. However, our findings provide some evidence that public health officials cannot currently rely on the elimination of gay bathhouses and sex clubs to achieve large reductions in HIV transmission among men who have sex with men.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.

Model of HIV transmission among sexually active King County men who have sex with men

Note: For definitions of variable notation, see Tables 1, 2, and 3.

FIGURE 2.

Incident HIV infections, by year and number of UAI acts per non-CSV partnership

FIGURE 3.
Attributable number of HIV infections by year, number of UAI acts per non-CSV partnership, and percent of CSV partnerships replaced

a) 100% replacement

b) 75% replacement

c) 50% replacement

d) 25% replacement

FIGURE 4.

Attributable number of HIV cases for 100 sensitivity analysis runs, by year and degree of replacement of CSV partnerships

TABLE 1

Model notation

Notation	Parameter
A	Activity level: $a=1$, low activity in CSVs, low activity outside $a=2$, low activity in CSVs, high activity outside $a=3$, high activity in CSVs, low activity outside $a=4$, high activity in CSVs, high activity outside $a=5$, non-CSV men
H	HIV status (0=HIV-negative, 1=HIV-positive)
L	Location of behaviors (0=CSV, 1=outside)
T	Time period (in days)
n_{ah}	Number of men in activity level a , HIV status h compartment
C_{lah}	Daily UAI partnership formation rate in location l , for activity level a , HIV status h compartment
β_R	Per-UAI act HIV acquisition probability for discordant receptive UAI partner
β_I	Per-UAI act HIV acquisition probability for discordant insertive UAI partner
ω_{ah}	Number of men entering, per day, activity level a , HIV status h compartment
e_{ah}	Daily probability of exiting population, activity level a , HIV status h compartment
d_{lah}	Number of UAI partnerships initiated in location l for all members of activity level a , HIV status i compartment
α_{lajir}	Number of discordant UAI partnerships in location l between an insertive partner with activity level a_i and receptive partner with activity level a_r

TABLE 2

Summary of model initial conditions

<u>Determination of King County MSM populations</u>				
		<u>Population</u>		<u>Sources of data</u>
All King County MSM		43,150		(17)
CSV patron population (yearly)		8,052	(18.7%)	(60)
Non-CSV MSM population		35,098	(81.3%)	
Sexually active non-CSV MSM population (61% of non-CSV population)		21,498		(61)
<u>Model compartments</u>				
CSV patrons:		<u>Notation</u>		
HIV-negative, low CSV activity, low outside activity		n_{10}	5,881 (73.0%)	(42), (60), (62)
HIV-negative, low CSV activity, high outside activity		n_{20}	285 (3.5%)	
HIV-negative, high CSV activity, low outside activity		n_{30}	279 (3.5%)	
HIV-negative, high CSV activity, high outside activity		n_{40}	190 (2.4%)	
HIV-positive, low CSV activity, low outside activity		n_{10}	1,129 (14.0%)	
HIV-positive, low CSV activity, high outside activity		n_{20}	95 (1.2%)	
HIV-positive, high CSV activity, low outside activity		n_{30}	46 (0.6%)	
HIV-positive, high CSV activity, high outside activity		n_{40}	148 (1.8%)	
		All CSV patrons	8,052 (100.0%)	
Non-CSV patron, sexually active MSM:				
HIV-negative		n_{50}	16,903 (78.6%)	(60)
HIV-positive		n_{51}	4,595 (21.4%)	
		All non-CSV patrons	21,498 (100.0%)	

Note: Initial conditions were adjusted for undiagnosed HIV infections. Distribution of CSV patrons was based on frequencies of behaviors, by self-reported HIV status in 2004 King County CSV survey, adjusted for a bias towards frequent visitors in the 2004 CSV survey. (See Appendix for a description of these adjustments.)

Summary of model parameters

TABLE 3

Parameter	Notation	Values	Sources of data
<u>UAI partnership formation rates (daily), HIV-negative CSV patrons</u>			
Activity level (a):	(CSV, outside of CSV)	Outside of CSV	(42;60;62)
	C_{010}, C_{110}	0.0007	0.0010
	C_{020}, C_{120}	0.0007	0.0390
	C_{030}, C_{130}	0.0343	0.0010
	C_{040}, C_{140}	0.0343	0.0390
<u>UAI partnership formation rates (daily), HIV-positive CSV patrons</u>			
Activity level (a):	C_{011}, C_{011}	0.0022	0.0011
	C_{021}, C_{021}	0.0022	0.0724
	C_{031}, C_{031}	0.1036	0.0011
	C_{041}, C_{041}	0.1036	0.0724
	(HIV negative, HIV positive)		
UAI partnership formation rate (daily), HIV-negative and HIV-positive non-CSV MSM	C_{150}, C_{151}	0.0033	(60)
<u>Per-UAI act HIV acquisition probability for discordant receptive UAI partner</u>			
	β_R	0.82	(63) ^d
<u>Per-UAI act HIV acquisition probability for discordant insertive UAI partner</u>			
	β_I	0.18	
<u>Odds ratio for strength of assortative mixing by HIV status</u>			
	OR_{ad}	2.82	(42)
<u>Rates of entry and exit from populations^b</u>			
Daily probability of exit from population, HIV-negative compartments	ν_{d0}	0.0001	
Daily probability of exit from population, HIV-positive compartments	ν_{d1}	0.0003	
Daily probability of entry to population, HIV-negative	ω_{d0}	0.0001	
Daily probability of entry to population, HIV-positive	ω_{d1}	0.0003	

^a see Appendix for calculation of probabilities.

^b Exit rates set to equal daily probability of exit over 40 years of membership in sexually active population for all HIV-negative compartments and 10 years of membership in sexually active population for HIV HIV-positive compartments. Entry rates for all compartments set to equal observed daily exit rates for compartment during year 1 of simulation.

TABLE 4

Number of sex partners in CSV, by HIV status-CSV activity level group

HIV status-CSV activity level group		Partnership formation rate ^a
HIV-negative:	Low CSV activity	0.08
	High CSV activity	0.29
HIV-positive:	Low CSV activity	0.12
	High CSV activity	0.31

^aPer day, all sex partners

TABLE 5

Frequency of partnerships in non-CSV venues and percent had UAI with last partner in venue, 2004 CSV survey

Venue	% of non-CSV partners	% had UAI with last partner in venue. ^a
Internet	32.6%	21.7%
Bar	13.4%	19.7%
Park	11.5%	12.8%
Phone chat	10.7%	26.8%
Through friends	6.7%	14.9%
Gym	5.4%	3.0%
Video arcade	5.0%	5.9%
Rest room	2.8%	6.3%
Sex party	2.5%	28.6%
Personal ad	0.4%	0.0%
Circuit party	0.1%	0.0%
Other	9.0%	19.4%
Total	100.0%	18.1%

Note: Data in table is combined across mv status-activity level groups. Venue data was stratified by HIV status-outside activity level for counterfactual partner formation rate assignment.

TABLE 6

Parameter values for counterfactual models

HIV status-activity level group	Partnership formation rate^a
HIV-negative:	
Low CSV-Low outside activity	0.008
Low CSV-High outside activity	0.029
High CSV-Low outside activity	0.029
High CSV-High outside activity	0.107
HIV-positive:	
Low CSV-Low outside activity	0.015
Low CSV-High outside activity	0.084
High CSV-Low outside activity	0.038
High CSV-High outside activity	0.216

^aDaily rate assuming 100% replacement of CSV partnerships. Limited to UAI partnerships.