The Role of Bathhouses and Sex Clubs in HIV Transmission

Findings From a Mathematic Model

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Summary: Bathhouses and sex clubs were identified as primary venues for HIV transmission during the original HIV epidemic. Because HIV incidence is increasing in some high-risk groups, their potential role in HIV transmission is being examined again. We present an extension of the Bernoulli process model of HIV transmission to incorporate subpopulations with different behaviors in sex acts, condom use, and choice of partners in a single period of time. With this model, we study the role that bathhouses and sex clubs play in HIV transmission using data from the 1997 Urban Men's Health Study. If sexual activity remains the same, we find that bathhouse closures would likely lead to a small increase in HIV transmission in the period examined by this study, although this impact is less than that which would be achieved through a 1% change in current condom use rates. If, conversely, bathhouse closure leads to a reduction of the sexual activity that was in the bathhouse by at least 2%, HIV transmission would be lowered.

Key Words: bathhouse, Bernoulli process, condom use, HIV prevalence, mathematic model, sex clubs, syphilis

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In the 1980s and early 1990s, sexually transmitted disease (STD) rates in men who have sex with men (MSM) fell after the adoption of safer sex behavior among those who were affected most strongly in the early years of the HIV/AIDS epidemic.[1] In the United States, however, there continues to be a substantial amount of high-risk sexual behavior and HIV infection among MSM.[2–6] Although most demographic categories have seen decreases in HIV incidence, MSM remain at high risk and studies have shown increasing STD rates and risk behavior among MSM.[1,7] They make up approximately 45% of newly reported HIV/AIDS diagnoses,[8,9] and the annual incidence ranges from high levels of 1.2% to 8.0%.[10] In addition, in several large US cities, where approximately 25% of MSM have HIV, nearly 50% are unaware of their infection.[10]

Research has documented that commercial sex venues, such as bathhouses, provide opportunities for casual and anonymous sex among MSM.[11–14] Bathhouses have been associated with behaviors that increase risk for STDs and HIV, including sex with multiple partners and unprotected sex.[12,15,16]

In the early 1980s, bathhouses were identified as a nexus of HIV transmission. As a result, bathhouses were the topic of heated debate among public health officials, government leaders, and the gay community.[17–21] Many states developed policies to regulate bathhouse behavior; the most extreme of these was advocating bathhouse closure.[17–19,22] Alternatively, opponents of bathhouse closure argued that bathhouses could be used as venues to promote HIV and STD prevention interventions among high-risk and hard-to-reach populations.[23]

By the late 1980s, much of the public debate over bathhouses ended, because many of the bathhouses were shut down.[24] Many bathhouses are currently operating around the United States in major US cities, however.[24,25]

Recent research indicates that men who attend bathhouses have been shown to engage in more sexually risky behavior than those who do not.[26] A case-control study in New York City showed that MSM with syphilis were more likely to have visited bathhouses than controls;[27] surveillance data have indicated high rates of bathhouse patronage among MSM with repeat syphilis infections.[28] A second case-control study from Los Angeles demonstrated that MSM who attend bathhouses and sex clubs have an increased risk of contracting syphilis as compared with those MSM who do not patronize bathhouses and sex clubs.[29] Other US and international studies have shown that bathhouse patronage was associated with hepatitis A, syphilis, and lymphogranuloma venereum.[1]

Some jurisdictions have existing regulations that would provide a basis for the closure of bathhouses, and doing so has been suggested as a public health intervention to limit STD and HIV transmission.[19,30] Historically, most of the policies aimed at regulating bathhouse behavior have been based on little, if any, data.[22] Alternatively, because they provide access to a population engaging in sexual risk behavior, they have been and could be used as venues to promote HIV and STD prevention interventions.[23] Although numerous bathhouse interventions to reduce high-risk sexual behavior have been

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suggested, developed, and implemented, most of these have not been evaluated for effectiveness.[23,31] One exception is a study by Woods et al,[22] which assesses how changes in bathhouse architecture, mandated by city-wide policies, affect the sexual behavior of MSM.

Thompson[32] considered the role that a small yet high-risk subset of a population has on HIV transmission by comparing it with a population with uniform risk. Because there were few data regarding HIV available at that time, the model was constructed so that it would rely on few parameters. The availability of behavioral data that enables risk behavior to be differentiated among MSM enabled us to develop an HIV transmission model that explicitly considers behaviors in various subpopulations.

We sought to estimate the potential impact of bathhouse closure on HIV transmission in comparison to an alternative of a reduction in risk behavior by those attending bathhouses. To accomplish this, we constructed a transmission model based on the Bernoulli process model of HIV infection originally developed by Pinkerton et al[33] to determine how the closure of bathhouses would affect HIV transmission. We extend the model to include subpopulations with different behaviors and the presence of syphilis, populate the model with data from a survey of MSM, and estimate the implications of various bathhouse policies on HIV transmission.

METHODS

Mathematic Model

In the Bernoulli process model, each sex act is treated as an independent Bernoulli trial; that is, the probability of infection from 1 act is a constant and is independent of all other acts. In our model, we defined the probability of HIV transmission by sex act and not by partnership because of the detail of the data that we used.*

Let π_T be the HIV prevalence of the total population, and α_u (α_p) be the probability of an individual acquiring HIV from 1 unprotected (protected) sex act with an HIV-infected partner. Note that α_p can be represented as $\beta\alpha_u$, where $(1-\beta)\cdot 100\%$ is the percent effectiveness of condoms. Pinkerton et al[33] established that the probability (P_1) of an individual acquiring HIV after m acts, where x% of them are protected with a single ("main") partner of unknown HIV status is as follows:

$$P_1 = \pi_T(1-(1-\alpha_u)^{(1-x)m}(1-\alpha_p)^{xm}) \tag{1}$$

Similarly, these investigators established that for a person who has n total acts, of which y% are protected, each with different (or "nonmain") partners of unknown HIV status, the probability (P_2) of becoming infected is as follows:

$$P_2 = 1-(1-\pi_T\alpha_u)^{(1-y)n}(1-\pi_T\alpha_p)^{yn} \tag{2}$$

We can combine equations 1 and 2 to find the probability of an individual not acquiring HIV after m contacts with 1 (main) partner (x% of which are protected) and n additional contacts, each with different (nonmain) partners (y% of which are protected).

In this article, we have extended the Bernoulli transmission framework to account for different subpopulations, each with different behavioral characteristics and HIV prevalences. This development provides the machinery to analyze the effect that bathhouses have on HIV transmission.

To compare different bathhouse policies, we need to distinguish between sexual behaviors of those who visit bathhouses and those who do not, as indicated by the data. Indeed, it is useful to consider several different categories of behavior. To this end, we define "types" of individuals based on a variety of criteria and effectively divide the population into subpopulations in which all individuals in a subpopulation have the same type. The data indicate that there may be significant differences across groups, including whether an individual visits bathhouses, has a main partner, or is HIV-positive.

Consequently, we first divide the population into individuals who visit bathhouses and those who do not. Call these subpopulations BH and NB, respectively. Let π_{BH} (π_{NB}) be the HIV prevalence of BH (NB). For each subpopulation (BH and NB), we define 2 additional subpopulations for each based on the presence or absence of a main partner. For those men who currently have a main partner, their contacts are split between a main partner and others from the population of MSM at large. Those who do not have a main partner draw all their contacts from the population at large. Finally, we further divide each of these 4 subpopulations by HIV-positive and HIV-negative status, for a total of 8 subpopulations (4 of which are BH and 4 of which are NB).

For a given individual in subpopulation i, we define

- m_i as the number of sex acts with a main partner
- x_i as the percentage of main partner sex acts that are protected
- n_i as the number of sex acts with nonmain partners
- y_i as the percentage of nonmain partner sex acts that are protected

Because the effect that bathhouses have on the spread of HIV is the main topic of this study, we are also concerned with the proportion of the sex acts that are with members of BH. We denote this proportion as z. We define z_{BH} as the proportion of nonmain contacts of members of BH that are with other members of BH. Similarly, we define z_{NB} as the proportion of nonmain contacts of members of NB that are with members of BH. We can extend the Bernoulli model to express the probability of a member of BH not acquiring HIV with partners of unknown HIV status in a time window of a year by the following:

$$\begin{aligned}\overline{P_{xm,ynz_{BH}}} &= \underbrace{[1-\pi_T[1-(1-\alpha_p)^{xm}(1-\alpha_u)^{(1-x)m}]]}_{A}\\ &\times \underbrace{(1-\pi_{BH}\alpha_p)^{yz_{BH}n}}_{B}\underbrace{(1-\pi_{BH}\alpha_u)^{(1-y)z_{BH}n}}_{C}\\ &\times \underbrace{(1-\pi_{NB}\alpha_p)^{y(1-z_{BH})n}}_{D}\underbrace{(1-\pi_{NB}\alpha_u)^{(1-y)(1-z_{BH})n}}_{E}\end{aligned} \tag{3}$$

where we removed the indices on m, x, n, and y for simplicity. Each labeled term in equation 3 represents the probability of not acquiring HIV, given a set of partners and acts. The

*Note that we also modeled the probability of HIV transmission by partnership, and the conclusion of whether closing a bathhouse would increase or decrease HIV prevalence does not change. Readers interested in the details of this analysis can contact the authors.

partners and acts corresponding to each term are described as follows:

A: m sex acts with main partner (x% protected)
B: $yz_{BH}n$ protected sex acts with nonmain partners who are bathhouse patrons
C: $(1 - y)z_{BH}n$ unprotected sex acts with nonmain partners who are bathhouse patrons
D: $y(1 - z_{BH})n$ protected sex acts with nonmain partners who are not bathhouse patrons
E: $(1 - y)(1 - z_{BH})n$ unprotected sex acts with nonmain partners who are not bathhouse patrons

Now, let $P_{xm,ynz_{BH}} := 1 - \overline{P_{xm,ynz_{BH}}}$ be the probability that 1 individual from BH acquires HIV, given the set of behavior parameters m, x, n, y, and z_{BH}. A similar equation exists for the individuals from NB.

If we assume that everyone in a given subpopulation has the same behavior parameters, then equation 3 can be used to calculate the expected number of new HIV cases for that subpopulation. For clarity, let us index BH by i and NB by j. Summing over all subpopulations gives us the expected number of new HIV cases for the population as a whole as follows:

$$\sum_{i=1}^{M_{BH}} (P_{x_i m_i, y_i n_i z_{BH}}) \times N_i + \sum_{j=1}^{M_{NB}} (P_{x_j m_j, y_j n_j z_{NB}}) \times N_j \qquad (4)$$

where N_k represents the number of people in subpopulation k, and the M_{BH} (=4) bathhouse subpopulations are indexed by i and the M_{NB} (=4) nonbathhouse subpopulations are indexed by j.†

Given a set of parameters, equation 4 makes it possible to compare the average total number of new infections in a year, given that a bathhouse is open or closed. It is clear that the parameters z_{BH} and z_{NB}, indicating the degree of mixing between BH and NB, are going to be different depending on whether the bathhouse is open or closed; we estimated these values from the data. We also examined the impact of other differences in behavioral parameters to indicate changes brought on by policies, system changes, or interventions.

For analysis on the subpopulations to be accurate, certain identities must hold. For example, the number of sex acts that the members of BH have with the members of NB can be calculated from the data as the number of total acts by a BH individual times the percentage of those acts outside the bathhouse times the proportion of those acts with the NB population. The number of sex acts that the members of NB have with the members of BH can correspondingly be calculated from data as the number of total acts by an NB individual times the proportion of those acts with the BH population. Clearly, these 2 numbers of sex acts should be the same. Similarly, the number of protected and unprotected acts each must also match. For a variety of reasons, survey data on sexual behavior contain some inaccuracies, however, and as result, the identities do not precisely hold. Even if every member of the population is sampled in the survey, it is possible that someone reports having a sex act in the survey but his partner does not report it. It is also possible that someone recalled their condom use during the act differently. Additionally, we are using averages within each of the subpopulations (ie, we do not explicitly model each individual's behavior), and not all individuals within a community were included in the survey. In our results, we therefore used an error tolerance of 33%; that is, we only considered data points of our parameters if each of these described identities had an error of <33%.

†For BH and NB, the subpopulations are main/HIV-positive, main/HIV-negative, no main/HIV-positive, and no main/HIV-negative.

Including Syphilis

The presence of primary or secondary (P&S) syphilis has been shown to increase the probability of HIV acquisition and transmission dramatically. Estimates of this increase range from 3 to 15 times the probability without syphilis, although most studies have focused on heterosexual transmission and many have combined all genital ulcerative diseases together (including chancroid and genital herpes simplex virus infection).[34–36] Because of the increase in syphilis rates among MSM in major US cities,[37] the model may more accurately reflect transmission under varying scenarios if syphilis can be incorporated.

Because we included the effect of syphilis into the model by using the same process as in the previously described model and the equations become much more cumbersome, we simply provide a qualitative explanation and provide mathematic details in the Appendix.

In the most specific consideration, syphilis can change the rate of infectivity of an individual in different ways depending on whether the individual without HIV has syphilis, whether his partner has syphilis, or whether both have the disease. To calculate the probability of infection for a susceptible individual, we use a similar method as in equation 3 but extend the equation to incorporate changes in infectivity rates depending on whether 1 of the partners, both, or none has syphilis.

To extend the model, we take into the account the susceptible individual's syphilis status and the proportion of his contacts that are with syphilis-positive individuals. The former implies that the total number of subpopulations under consideration doubles (positive or negative for syphilis). The latter is determined simply by the syphilis prevalence of the corresponding subpopulation. When neither individual with sexual contact has syphilis, the same infectivity rates are used as before. When the individual in question has syphilis but his partner does not, the appropriate transmission probability (α_u or α_p) is multiplied by some constant, a. When the individual in question does not have syphilis but his partner does, the appropriate transmission probability is multiplied by a different constant, b. When both individuals in question have syphilis, the appropriate transmission probability is multiplied by yet another constant, c (see equations 5 and 6 in the Appendix for the full model). This general model can also be simplified for the case when the infectivity rates are not different for all these combinations by making the constants $a = b = c$.

Data

The primary data source for behavioral data was the Urban Men's Health Study (UMHS), which was conducted in 1997 and has been described elsewhere.[2] Briefly, the survey was conducted via telephone in 4 urban centers (San Francisco, Los Angeles, New York City, and Chicago) and focused on geographic areas that were believed to contain the most MSM in each city. Survey participants were MSM and were asked about their number of sex partners in the past year overall and about the number of sex partners with whom they had engaged in receptive or insertive anal intercourse and other behaviors. They were also asked about venues in which they met sex partners and about condom use. For their 4 most recent sex partners, they were asked about behavior, condom use, and the venue where they met the specific partner. All behavioral data were taken from this survey, as were data for HIV prevalence in the BH and NB MSM populations.

Data from the UMHS were used to define the subpopulations (BH and NB, HIV-infected and noninfected) and partnerships (main and nonmain) described in the model section. When variable values for the subpopulations were not different at $P < 0.05$, we used the overall mean for the variable in question. Because the data for the last 4 partners were specific by partner and less likely to be subject to recall error, we used the last 4 partners to determine the rates of condom use, number of sex acts, and, for BH MSM, the proportion of sex acts with nonmain partners that occurred with a partner met at a bathhouse venue. The means for each variable were calculated using all nonmissing values for the respective field in the data rather than discarding observations that had missing values for some fields. Only anal sex acts were considered as risky sex acts for the model (see Table 1 for a summary of the survey data and significance across subpopulations).

The distinction between those who have a main partner and those who do not was determined by the survey respondent citing that he had a special commitment to or was in love with a particular person. The number of acts that are with main partners is 34.65, and the estimated condom use with main partners is 58%. Neither of these is significantly different across subpopulations. Based on data from the last 4 partners, approximately 22% of the bathhouse patrons' nonmain sex acts occur in the bathhouse. This implies that 78% of their nonmain sex acts occur outside of the bathhouse and are distributed among bathhouse patrons and nonbathhouse patrons. The way in which we distribute the acts outside of the bathhouse is as follows. If there are 2 bathhouse patrons who have 10 acts each outside of the bathhouse and 10 nonbathhouse patrons who have 5 acts each outside of the bathhouse, there are 2 * 10 + 10 * 5 = 70 total acts to be distributed outside of the bathhouse. 2 * 10/70 * 100% is the percentage of the acts that any given member of either population has with bathhouse patrons while outside of the bathhouse when the bathhouse is open. The true value using data from Table 1 is 54.4%. Multiplying the true value with the percentage of BH acts that take place outside of the bathhouse (78%), we obtain the percentage of BH acts outside of the bathhouse that take place with other BH patrons. This also gives us the number of BH acts with BH patrons outside of the bathhouse, and by adding the number of acts within the bathhouse (22% of the BH total acts), we obtain the number of acts of BH with BH. By converting this to percentages, we estimate that 64.3% of the bathhouse patrons' nonmain sex acts are with other bathhouse patrons; that is, the total number of acts between BH patrons includes the nonmain acts that take place in the bathhouse plus the remainder of their sex acts outside of the bathhouse but divided among the overall population, some of which are with other bathhouse patrons and some of which are not. Given a percentage of the bathhouse patrons' nonmain sex acts that are with other bathhouse patrons, we can derive the percentage of sex acts that nonbathhouse patrons have with bathhouse patrons to account for the total number of sex acts of the population.

When bathhouses are closed, we assume that all nonmain sex acts are drawn uniformly from the total number of sex acts in the population, which is based on the population sizes of BH and NB and the number of sex acts of each group. In this case, an estimated 60% of the (would be) bathhouse patrons' nonmain sex acts are with other (would be) bathhouse patrons; that is, in the absence of bathhouses, there is a "natural" mixing of the entire population, whereas the presence of the bathhouse skews this mixing so that bathhouse patrons have relatively more sex acts with each other. Therefore, z_{BH} is always smaller when bathhouses are closed than when they are open.

Data for the probability of HIV transmission, protective effect of condoms, prevalence of P&S syphilis, and syphilis multiplier effect were taken from the literature (see Table 2 for

TABLE 1. Summary of Data From the 1997 UMHS

Total Population (11,646 MSM)							
Bathhouse Patrons (29.4%)				Nonbathhouse Patrons (70.6%)			
With Main Partner (41%)		Without Main Partner (59%)		With Main Partner (49%)		Without Main Partner (51%)	
HIV$^+$	HIV$^-$	HIV$^+$	HIV$^-$	HIV$^+$	HIV$^-$	HIV$^+$	HIV$^-$
25.4%	74.6%	25.4%	74.6%	16.5%	83.5%	16.5%	83.5%
Number nonmain sex acts in Past 12 months							
128.98	58.59	141.22	70.83	16.64	11.18	28.87	33.99
Percentage condom use with nonmain partners							
76.0%				83.0%			

Any differences in values shown are significant at the 0.05 level.

TABLE 2. Epidemiologic Variables Used for Base Case and Sensitivity Analysis Along With Corresponding References

Variable	Value	Range	References
Per-act HIV transmission risk (α)	0.01	0.005–0.03	45, 46
Protective effect of condoms ($1 - \beta$)	0.9	0.90–0.95	47
Syphilis prevalence (P&S) (Π_s)	0.005	0.001–0.05	48
Syphilis multiplier effect (a, b, c)*	3	3–15	34, 35, 36

*In our calculations, the same value for increased likelihood of HIV transmission was used regardless of whether either partner or both partners had syphilis. Hence, a = b = c = 3.

the variables, their abbreviations in the model, baseline values, ranges, and sources).

RESULTS

Results are reported by computing the annual HIV attack rates. The HIV attack rate is defined as the number of new HIV cases in a year divided by the number of susceptible people (ie, people currently without HIV) in the populations under consideration. It is useful in demonstrating relative degrees to which the epidemic is spreading under different scenarios.

Figure 1 shows the HIV attack rate, given the number of acts as listed in the data section with 80% condom use for the NB, 75% condom use for the BH, an overall syphilis prevalence of 0.5%, and a syphilis multiplier of 3. The attack rate is shown as a function of z_{BH}, that is, a function of the percentage of the bathhouse patrons' nonmain sex acts that are with other bathhouse patrons. In Figure 1, we make all calculations under the assumption that the total number of sex acts is the same under both scenarios of bathhouses closed and open. We also examine the sensitivity of the results to this assumption in later analysis.

In all results that we have seen, the attack rate can be closely approximated by a linear relation, as depicted in Figure 1. In general, the attack rate can be shown to be a concave function with respect to z_{BH}. In addition, for the given data, the attack rate is a strictly decreasing function of z_{BH}. This monotonicity is significant because it means that the HIV attack rate is always higher when bathhouses are closed. This conclusion is a consequence of the attack rate decreasing and the fact that z_{BH} is always larger when the bathhouses are open than when the bathhouses are closed, given that the number of acts remains the same. Consequently, it follows that under the stated assumptions, the attack rate increases with bathhouse closure. In experiments using other values for behavioral parameters, we have found that the decreasing nature of the function is driven by the relatively larger number of nonmain acts of the bathhouse patron population and the higher HIV prevalence among the bathhouse patrons. Single points on Figure 1 indicate the points corresponding to bathhouses being open or closed.

Figure 2 compares the effects of varying rates of condom use and the number of acts with the effect of bathhouse closure on the attack rate. The top curve is calculated with the same parameter values as in Figure 1 and is again shown as a function of z_{BH}. The 2 curves below it represent the attack rates when the condom use of the BH increases by 5 percentage points (to 80%) and 10 percentage points (to 85%), respectively. Each of these 3 curves is calculated under the assumption that there is no change in the number of sex acts in the event of bathhouse closure.

The 3 individual scatter points, conversely, represent the attack rates calculated with the parameter values for Figure 1 with the bathhouse open but where the number of sex acts for the BH does decrease in the event of bathhouse closure. The analysis is done for several values of the potential percentage reduction in the bathhouse patrons' nonmain partner sex acts that took place in the bathhouse. The reduction in acts is referred to as bathhouse patron act reduction (BHP AC) in Figure 2. The remainder of the acts (including nonmain partner acts outside of the bathhouse and main partner acts) are assumed to be unchanged. An entire curve is not traced in this case, because the bathhouse is assumed to be closed, making it unnecessary to plot it as a function of z_{BH}; we only consider the nonskewed natural mixing of the population that occurs when the bathhouse is closed, corresponding to 1 value of z_{BH}, and hence 1 point on the graph. Note that the natural percentage of bathhouse patrons' acts with other bathhouse patrons with bathhouses closed decreases as the number of sex acts is scaled down, because they are having fewer acts.

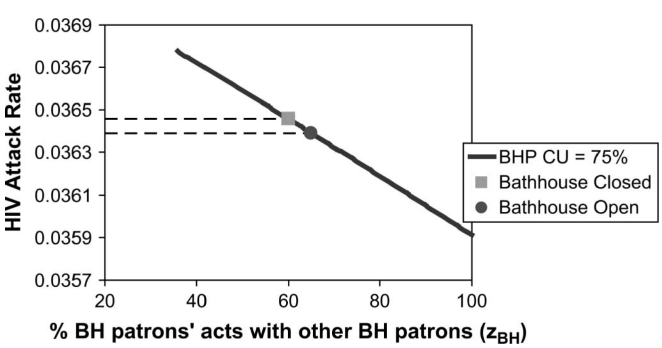

FIGURE 1. HIV attack rate as a function of z_{BH} when the bathhouse patron condom use (BHP CU) is 75%, non-BHP CU is 80%, overall syphilis prevalence is 0.5%, and the syphilis multiplier is 3.

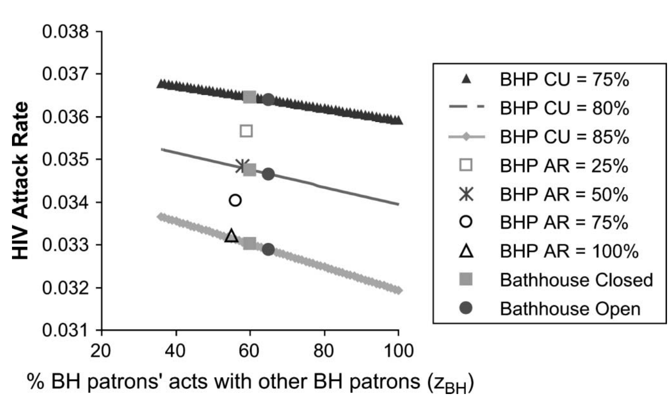

FIGURE 2. HIV attack rate for varying levels of bathhouse patron condom use (BHP CU) and BHP AR attributable to BH closure, with other parameters set as in Figure 1.

Under the stated assumptions, this result suggests that increasing BH condom use from 75% to 80% has a much larger effect on the attack rate than bathhouse closure. Similarly, a change in the number of sex acts also has a much larger effect on the attack rate than that of closure alone; that is, if the reduction in sex acts with the bathhouse closed were sufficiently large, closing the bathhouse could be effective in reducing HIV transmission. This would assume that the bathhouse patrons were not able to replace their bathhouse sex acts by meeting sex partners in other venues. Not shown on the graphs but also noteworthy is the fact that the effect of bathhouse closure is roughly equal to a 0.2% change in the condom use of the bathhouse patrons.

Figure 3 demonstrates the effects that our assumptions regarding syphilis have on the results. We consider syphilis prevalence values of 0.5%, 5%, and 10% (the bottom 3 curves, respectively). Additionally, whereas all previous results assumed that the presence of syphilis caused the probability of infection per sex act to increase by a factor of 3, Figure 3 considers the case in which syphilis causes the probability of infection to increase by a factor of 15 (top curve). We consider this sensitivity because there is variation in the literature on the effect of syphilis.

It should be noted that although the graph in Figure 3 varies with different values of the syphilis multiplier effect and the underlying syphilis prevalence, the overall conclusion does not change. In other words, we expect that the attack rate is still going to be a decreasing function of z_{BH} and that, as a result, bathhouse closures are expected to create an increase in the attack rate unless the reduction in acts is large enough.

Table 3 shows the sensitivity of the attack rate for different parameter values. In this table, the base case corresponds to the base case parameter values as listed in Table 2. All other attack rates correspond to the base case parameter values, except where explicitly stated (eg, $\alpha = 0.005$ corresponds to the base case parameter values, except that α is changed from 0.010 to 0.005). The best case scenario corresponds to the parameter values that produce the lowest attack rate, namely, $\alpha = 0.005$, $(1 - \beta) = 0.95$, $\pi_S = 0.001$, and syphilis multiplier = 3. The worst case scenario corresponds to the values that produce the highest attack rate, namely, $\alpha = 0.030$, $(1 - \beta) = 0.900$, $\pi_S = 0.050$, and syphilis multiplier = 15. Notice that although the magnitude of the attack rate values changes, it remains higher for the case of open versus closed bathhouses.

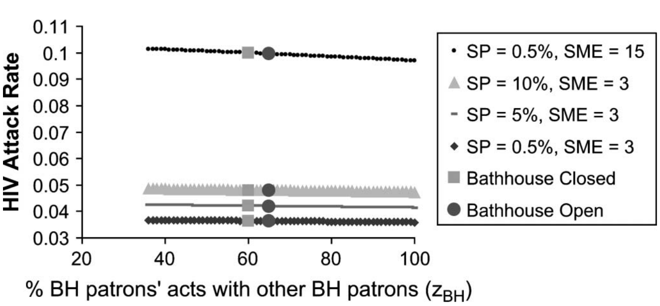

FIGURE 3. HIV attack rate for different syphilis prevalence (SP) and syphilis multiplier effect (SME) values, where bathhouse (BH) patron condom use is 75% and non-BH patron condom use is 80%.

TABLE 3. Annual Attack Rate for Different Parameter Values

	BH Closed	BH Open	50% BHP AR After BH Closure	80% BHP CU BH Closed	80% BHP CU BH Open
Best case scenario	0.016527	0.016504	0.015803	0.015608	0.015566
$\alpha = 0.005$	0.018653	0.018621	0.017822	0.017772	0.017722
95% condom effectiveness	0.032832	0.032782	0.031397	0.031010	0.030924
Base case	0.036459	0.036392	0.034841	0.034744	0.034643
$\alpha = 0.030$	0.099704	0.099452	0.095999	0.095758	0.095437
Worst case scenario	0.168488	0.167775	0.161414	0.161145	0.160333

The base case corresponds to the values reported in Table 2.
BH indicates bathhouse.

We have assumed that sexual activity remains the same during bathhouse closure. It is possible that sexual activity would decrease after bathhouse closure, although we have no data on this issue. In Figure 4, we show the resulting HIV attack rate from bathhouse closure as a function of percentage decrease in sexual activity. The base case for an open bathhouse from Figure 1 is shown as a horizontal dashed line for comparison. It is assumed that the base case of BH condom use is 75%, nonbathhouse condom use is 80%, overall syphilis prevalence is 0.5%, and the syphilis multiplier is 3. From Figure 4 , we see that if bathhouse closure leads to a reduction of bathhouse patrons' sexual activity within the bathhouse of at least 2%, HIV transmission would be reduced as compared with keeping the bathhouse open. Note that part of the reason for the decreased HIV attack rate with decreased sexual activity is that the relative percentage of sexual acts with condom use increases.

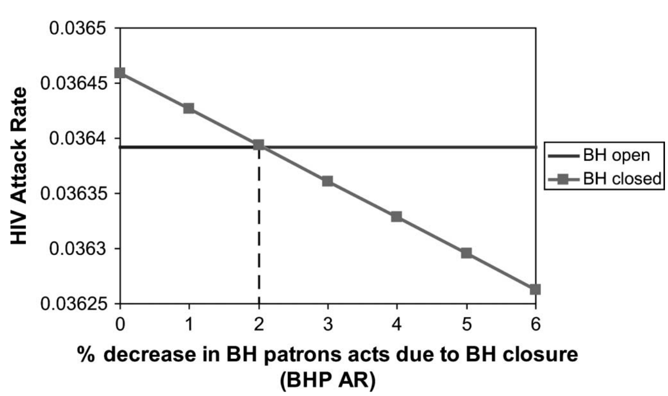

FIGURE 4. HIV attack rate for bathhouse (BH) closure as a function of the percentage decrease in BH sexual activity within the bathhouse attributable to BH closure. BH condom use is 75%, non-BH condom use is 80%, overall syphilis prevalence is 0.5%, and the syphilis multiplier is 3. The horizontal dashed line is for the base case of keeping the BH open.

DISCUSSION

The results of the model suggest that given the characteristics of the MSM population of the 4 survey cities (and the assumption that these characteristics do not change), bathhouse closure would result in an increase in the HIV attack rate. The magnitude of the effect of the closure would be small compared with the effect of a change in condom use or the number of sex acts, however. Therefore, these results need to be coupled with those of other studies; that is, if one can show that condom use does not change but the number of sex acts decreases dramatically as a result of closure, Figure 2 suggests that bathhouse closure would lead to a decrease in the attack rate. Conversely, if by leaving the bathhouses open, one can show that condom use increases (eg, by condom use enforcement or promotion or education at the bathhouse venue), the policy of keeping bathhouses open may result in a lower HIV attack rate. Indeed, leaving bathhouses open facilitates such intervention programs because it makes access to the MSM group with the highest prevalence and highest number of sex acts much more reachable. Nevertheless, one study has found little effect on risk behavior of bathhouse policies focused on regulating the amount of public versus private space in the facilities. The authors suggested that such policies may have moved risk behavior of bathhouse patrons to different venues rather than causing it to decline.[38] The impact of these and other potential interventions remains speculative, because there has been little evaluation.[16,23]

The results must be interpreted with consideration of the model's limitations. First and foremost, as a single-stage model, it only serves as a short-term predictor because it ignores the effects of secondary infections. It does not differentiate between acute and chronic HIV infection. Evidence in the literature suggests that HIV infectivity differs over time. Wawer et al[36] state that HIV infectivity is much higher during the acute stage (3-month period after initial infection) than during the chronic stage, which is compounded by the fact that during the first 3 months, the virus has likely not been detected. Conversely, Rapatski et al[39] find that most of the transmission occurs in the later stage of the disease. Either way, it could be important to have a model that can capture temporal differences in HIV infectivity.

If the aforementioned factors were included, it is possible that the graph in Figure 1 could become steeper. This steepness, or lack thereof, however, is what determines how the effect of bathhouse closure compares with a change in condom use and number of sex acts. A change in steepness could possibly result in a different conclusion regarding the role of bathhouses in HIV transmission when changes in behaviors are considered.

An additional limitation of the model is that some of the data estimators for the parameters included in the model rely on the survey respondent's last 4 partners. The assumption that a respondent's condom use behavior over the course of an entire year is accurately reflected by his condom use with his last 4 partners, for example, may not always be valid. Moreover, the survey only includes city residents of 4 US cities and does not reach the surrounding areas, which may contain MSM who visit city bathhouses. The UMHS survey, however, is the most comprehensive to date.

Another factor that we did not consider was club (recreational) drug use. The use of club drugs such as crystal methamphetamine has been shown to increase sexual risk-taking behavior and is associated with increased HIV and STD transmission.[40–42] Research has documented the prevalence of club drugs at specific gay events such as circuit parties. It is possible that many bathhouse patrons use substances before arriving at the venue. It may also be possible that bathhouse patrons acquire substances from other bathhouse patrons, however. Environment may influence club drug use and, by extension, risk behavior, suggesting that if bathhouses were closed, club drug use preceding sex might diminish. We should mention that although we did not have accurate estimates of the prevalence of drug use in bathhouses, the model could be easily extended to determine the impact of drug use on transmission by using the same approach that we used for including syphilis, and it is possible that drug use is already incorporated in the survey responses, because condom use was lower among bathhouse patrons.

The Centers for Disease Control and Prevention estimate that 25% of the US population who are HIV-positive do not know it.[43] Unfortunately, the data available from the UMHS survey did not allow us to model knowledge of infection. If the data were available, we could create new classes of those who know they are infected and those who do not in the same way that syphilis was modeled.

Finally, an implicit underlying assumption in our model is that the disproportionate mixing of the BH and NB is eliminated as a result of bathhouse closure; that is, those who were bathhouse patrons before closing would no longer disproportionately have more sex with each other than with the rest of the population after closure. This assumption seems quite intuitive in the short term. The bathhouse patrons would still remain high-activity members of the population in terms of partner numbers, however. As time passes, the degree to which the high-activity members would organize private venues similar to the bathhouse through, for instance, coordination via the Internet is unpredictable. Recent literature already suggests that the Internet is serving as a "cyber-bathhouse" in the sense that many high-activity or high-risk MSM can easily arrange private environments similar to bathhouses, with even less regulation than in bathhouses.[44]

In future work, we plan to extend this model to a multistage setting. One of the benefits of this extension is that it eliminates some of the aforementioned limitations. A multistage model should also be useful in determining the importance of modeling subpopulations when considering HIV transmissions, because the impact of transmissions is compounded over time.

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REFERENCES

1. Fenton KA, Imrie J. Increasing rates of sexually transmitted diseases in homosexual men in Western Europe and the United States: why? *Infect Dis Clin North Am*. 2006;19:311–331.
2. Catania JA, Osmond D, Stall RD, et al. The continuing HIV epidemic among men who have sex with men. *Am J Public Health*. 2001;91:907–914.
3. Stall RD, Hays RB, Waldo CR, et al. The gay '90s': a review of research in the 1990s on sexual behavior and HIV risk among men who have sex with men. *AIDS*. 2000;14(Suppl3):S101–S114.
4. Centers for Disease Control and Prevention. Increases in unsafe sex and rectal gonorrhea among men who have sex with men—San Francisco, 1994–1997. *MMWR Morb Mortal Wkly Rep*. 1999;48:45–48.
5. Ekstrand ML, Stall RD, Paul JP, et al. Gay men report high rates of unprotected anal sex with partners of unknown or discordant HIV status. *AIDS*. 1999;13:1525–1533.
6. Chen SY, Gibson S, Katz MH, et al. Continuing increases in sexual risk behavior and sexually transmitted diseases among men who have sex with men, San Francisco, 1999–2001. *Am J Public Health*. 2002;92:1387–1388.
7. Centers for Disease Control and Prevention. Twenty-five years of HIV/AIDS United States, 1981–2006. *MMWR Morb Mortal Wkly Rep*. 2006;55:585–589.
8. Centers for Disease Control and Prevention. HIV/AIDS surveillance report 2005. Vol. 17. Atlanta: US Department of Health and Human Services, Centers for Disease Control and Prevention; 2006:1–54.
9. Centers for Disease Control and Prevention. Epidemiology of HIV/AIDS—United States, 1981–2005. *MMWR Morb Mortal Wkly Rep*. 2006; 55:589–592.
10. Centers for Disease Control and Prevention. HIV prevalence, unrecognized infection, and HIV testing among men who have sex with men—five US cities, June 2004–April 2005. *MMWR Morb Mortal Wkly Rep*. 2005;54:597–601.
11. Woods WJ, Binson D, Mayne TJ, et al. Facilities and HIV prevention in bathhouse and sex club environments. *J Sex Res*. 2001;38:68–74.
12. Van Beneden CA, O'Brien K, Modesitt S, et al. Sexual behaviors in an urban bathhouse 15 years into the HIV epidemic. *J Acquir Immune Defic Syndr*. 2002;30:522–526.
13. Elwood WN, Williams ML. Sex, drugs, and situation: attitudes, drug use, and sexual risk behaviors among men who frequent bathhouses. *J Psychol Hum Sexuality*. 1998;10:23–44.
14. Weinberg MS, Williams CJ. Gay baths and the social organization of impersonal sex. *Soc Probl*. 1975;23:124–136.
15. Newell GR, Mansell PW, Wilson MB, et al. Risk factor analysis among men referred for possible acquired immune deficiency syndrome. *Prev Med*. 1985;14:81–91.
16. Binson D, Woods WJ, Pollack L, et al. Differential HIV risk in bathhouses and public cruising areas. *Am J Public Health*. 2001;91:1482–1486.
17. Shilts R. *And the Band Played On: Politics, People, and the AIDS Epidemic*. New York: St. Martin's Press; 1987.
18. Disman C. The San Francisco bathhouse battles of 1984: civil liberties, AIDS risk, and shifts in health policy. *J Homosex*. 2003;44:71–129.
19. Burris S. Legal aspects of regulating bathhouses: cases from 1984 to 1995. *J Homosex*. 2003;44:131–151.
20. Rabin JA. The AIDS epidemic and gay bathhouses: a constitutional analysis. *J Health Polit Policy Law*. 1986;10:729–747.
21. Berube A. The history of gay bathhouses. *J Homosex*. 2003;44:33–53.
22. Woods WJ, Binson D, Pollack LM, et al. Public policy regulating private and public space in gay bathhouses. *J Acquir Immune Defic Syndr*. 2003;32:417–423.
23. Wohlfeiler D, Potterat JJ. Using gay men's sexual networks to reduce sexually transmitted disease (STD)/Human Immunodeficiency Virus (HIV) transmission. *Sex Transm Dis*. 2005;32(10 Suppl):S48–S52.
24. McCoy CB, Inciardi JA. *Sex, Drugs, and the Continuing Spread of AIDS*. Los Angeles, CA: Roxbury Publishing; 1995.
25. Woods WJ, Tracy D, Binson D. Number and distribution of gay bathhouses in the United States and Canada. *J Homosex*. 2003;44:55–70.
26. Xia Q, Tholandi M, Osmond DH, et al. The effect of venue sampling on estimates of HIV prevalence and sexual risk behaviors in men who have sex with men. *Sex Transm Dis*. 2006;33:545–550.
27. Paz-Bailey G, Meyers A, Blank S, et al. A case-control study of syphilis among men who have sex with men in New York City. *Sex Transm Dis*. 2004;31:581–587.
28. Ciesielski C, Tabidze I. Repeat syphilis infections in men who have sex with men, 2000–2005, Chicago, IL [abstract D7e]. Presented at: National STD Prevention Conference; 2006; Jacksonville.
29. McLean C, Kaur A, Kerndt PR, et al. Case-control study of risk factors for acquiring infectious syphilis among men who have sex with men—Los Angeles, 2000 [abstract]. *Intl J STD AIDS*. 2001;12(Suppl2):188.
30. Farley T. Cruise control. *Wash Mon*. 2002;37–41.
31. Binson D, Blea L, Cotten PD, et al. Building an HIV/STI prevention program in a gay bathhouse: a case study. *AIDS Educ Prev*. 2005;17:386–399.
32. Thompson JR. Understanding the AIDS epidemic: a modeler's odyssey. In: Wallenius D, Shier T (eds). *Mathematical Modeling*. New York: CRC Press; 1999:41–69.
33. Pinkerton SD, Abramson PR, Holtgrave DR. The Bernoulli-process model of HIV transmission. In: Holtgrave Dr, ed. *Handbook of Economic Evaluation of HIV Prevention Programs*. New York: Plenum Press; 1998:13–32.
34. Rottingen JA, Cameron DW, Garnett GP. A systematic review of the epidemiologic interactions between classic sexually transmitted diseases and HIV. *Sex Transm Dis*. 2001;28:579–597.
35. Taylor MM, Hawkins K, Gonzalez A, et al. Use of the serologic testing algorithm for recent HIV seroconversion (STARHS) to identify recently acquired HIV infections in men with early syphilis in Los Angeles County. *J Acquir Immune Defic Syndr*. 2005;38:505–508.
36. Wawer MJ, Gray RH, Sewankambo NK, et al. Rates of HIV-1 transmission per coital act, by stage of HIV-1 infection, in Rakai, Uganda. *J Infect Dis*. 2005;191:1403–1409.
37. Peterman TA, Heffelfinger JD, Swint EB, et al. The changing epidemiology of syphilis. *Sex Transm Dis*. 2005;32(Suppl):S4–Sl0.
38. Woods WJ, Binson D, Mayne TJ, et al. HIV/sexually transmitted disease education and prevention in US bathhouses and sex club environments. *AIDS*. 2000;14:625–626.
39. Rapatski BL, Suppe F, Yorke JA. HIV epidemics driven by late disease stage transmission. *J Acquir Immune Defic Syndr*. 2005;38:241–253.
40. Colfax G, Guzman R. Club drugs and HIV infection: a review. *Clin Infect Dis*. 2006;42:1463–1469.
41. Colfax GN, Mansergh G, Guzman R, et al. Drug use and sexual risk behavior among gay and bisexual men who attend circuit parties: a venue-based comparison. *J Acquir Immune Defic Syndr*. 2001;28:373–379.
42. Mansergh G, Colfax GN, Marks G, et al. The circuit party men's health survey: findings and implications for gay and bisexual men. *Am J Public Health*. 2001;91:953–958.
43. Centers for Disease Control and Prevention. Revised recommendations for HIV testing of adults, adolescents, and pregnant women in health-care settings. *MMWR Recomm Rep*. 2005;55:(RR-14):1–17.
44. Bull SS, McFarlane M, Lloyd L, et al. The process of seeking sex partners online and implications for STD/HIV prevention. *AIDS Care*. 2004;16:1012–1020.
45. DeGruttola V, Seage GR III, Mayer KH, et al. Infectiousness of HIV between male homosexual partners. *J Clin Epidemiol*. 1989;42:849–856.
46. Vittinghoff E, Douglas J, Judson F, et al. Per-contact risk of human immunodeficiency virus transmission between male sexual partners. *Am J Epidemiol*. 1999;150:306–311.
47. Pinkerton SD, Abramson PR. Effectiveness of condoms in preventing HIV transmission. *Soc Sci Med*. 1997;44:1303–1312.
48. Centers for Disease Control and Prevention. Trends in primary and secondary syphilis and HIV infections in men who have sex with men—San Francisco and Los Angeles, California, 1998–2002. *MMWR*. 2004;53:575–578.

APPENDIX

To incorporate the effects of syphilis, we divided each subpopulation (BH and NB) further by whether the individuals are positive or negative for syphilis. The probabilities of HIV infection are different for each of the subpopulations. When populating our earlier HIV transmission model, we had data that indicated the number of sex acts by subpopulation. When we expand the model to include syphilis status, however, our data do not specify which partners have syphilis; thus, we take an expectation over the syphilis prevalence in the corresponding population to determine the number of acts across each of the subpopulations.

For an individual from BH who is positive for syphilis, his probability of not acquiring HIV with the behavior parameters x, m, y, n, and z_{BH} is given by the following:

$$\overline{PP_{xm,ynz_{BH}}} = \underbrace{[1-\pi_T[\pi_S[1-(1-c\alpha_p)^{xm}(1-c\alpha_u)^{(1-x)m}]+(1-\pi_S)[1-(1-a\alpha_p)^{xm}(1-a\alpha_u)^{(1-x)m}]]]}_{A+B}$$
$$\times \underbrace{(1-\pi_{BH}c\alpha_p)^{yz_{BH}\pi_S n}}_{C}\underbrace{(1-\pi_{BH}c\alpha_u)^{(1-y)z_{BH}\pi_S n}}_{D}$$
$$\times \underbrace{(1-\pi_{NB}c\alpha_p)^{y(1-z_{BH})\pi_S n}}_{E}\underbrace{(1-\pi_{NB}c\alpha_u)^{(1-y)(1-z_{BH})\pi_S n}}_{F}$$
$$\times \underbrace{(1-\pi_{BH}a\alpha_p)^{yz_{BH}(1-\pi_S)n}}_{G}\underbrace{(1-\pi_{BH}a\alpha_u)^{(1-y)z_{BH}(1-\pi_S)n}}_{H}$$
$$\times \underbrace{(1-\pi_{NB}a\alpha_p)^{y(1-z_{BH})(1-\pi_S)n}}_{H}\underbrace{(1-\pi_{NB}a\alpha_u)^{(1-y)(1-z_{BH})(1-\pi_S)n}}_{I} \quad (5)$$

where the indices are suppressed again for clarity. For an individual from BH who is syphilis-negative, his probability of not acquiring HIV with the behavior parameters x, m, y, n, and z_{BH} is given by the following:

$$\overline{PN_{xm,ynz_{BH}}} = \underbrace{[1-\pi_T[\pi_S[1-(1-b\alpha_p)^{xm}(1-b\alpha_u)^{(1-x)m}]+(1-\pi_S)[1-(1-\alpha_p)^{xm}(1-\alpha_u)^{(1-x)m}]]]}_{A+B}$$
$$\times \underbrace{(1-\pi_{BH}b\alpha_p)^{yz_{BH}\pi_S n}}_{C}\underbrace{(1-\pi_{BH}b\alpha_u)^{(1-y)z_{BH}\pi_S n}}_{D}$$
$$\times \underbrace{(1-\pi_{NB}b\alpha_p)^{y(1-z_{BH})\pi_S n}}_{E}\underbrace{(1-\pi_{NB}b\alpha_u)^{(1-y)(1-z_{BH})\pi_S n}}_{F}$$
$$\times \underbrace{(1-\pi_{BH}\alpha_p)^{yz_{BH}(1-\pi_S)n}}_{G}\underbrace{(1-\pi_{BH}\alpha_u)^{(1-y)z_{BH}(1-\pi_S)n}}_{H}$$
$$\times \underbrace{(1-\pi_{NB}\alpha_p)^{y(1-z_{BH})(1-\pi_S)n}}_{I}\underbrace{(1-\pi_{NB}\alpha_u)^{(1-y)(1-z_{BH})(1-\pi_S)n}}_{J} \quad (6)$$

As before, each labeled term in these equations represents the probability of not acquiring HIV, given a set of partners and acts. The partners and acts corresponding to each term are described as follows:

A + B: m sex acts with a main partner who is syphilis-positive, x% of which are protected (weighted with probability π_S), and m sex acts with a main partner who is syphilis-negative, x% of which are protected [weighted with probability $(1-\pi_S)$]

C: $yz_{BH}\pi_S n$ protected sex acts with nonmain partners who are bathhouse patrons and syphilis-positive

D: $(1-y)z_{BH}\pi_S n$ unprotected sex acts with nonmain partners who are bathhouse patrons and syphilis-positive

E: $y(1-z_{BH})\pi_S n$ protected sex acts with nonmain partners who are not bathhouse patrons and are syphilis-positive

F: $(1-y)(1-z_{BH})\pi_S n$ unprotected sex acts with nonmain partners who are not bathhouse patrons and are syphilis-positive

G: $yz_{BH}(1-\pi_S)n$ protected sex acts with nonmain partners who are bathhouse patrons and syphilis-negative

H: $(1-y)z_{BH}(1-\pi_S)n$ unprotected sex acts with non-main partners who are bathhouse patrons and syphilis-negative

I: $y(1-z_{BH})(1-\pi_S)n$ protected sex acts with nonmain partners who are not bathhouse patrons and are syphilis-negative

J: $(1-y)(1-z_{BH})(1-\pi_S)n$ unprotected sex acts with nonmain partners who are not bathhouse patrons and are syphilis-negative

We can combine equations 5 and 6 to represent the total number of new HIV cases for all BH subpopulations by the following:

$$\sum_{i=1}^{M_{BH}}[1-(1-\pi_S)\overline{PN_{x_i m_i, y_i n_i z_{BH}}}-(\pi_S)\overline{PP_{x_i m_i, y_i n_i z_{BH}}})]\times N_i \quad (7)$$

where there are M_{BH} (=8) BH subpopulations indexed by i and N_i members in subpopulation i. With an identical development, we can include the NB subpopulations in equation 7 and it still has the same form as equation 3, with the only difference being that each population is split into 2 groups by syphilis status and each corresponding probability of infection is more complicated. The total number of new HIV cases for the entire population is then represented by the following:

$$\sum_{i=1}^{M_{BH}}[1-(1-\pi_S)\overline{PN_{x_i m_i, y_i n_i z_{BH}}}-(\pi_S)\overline{PP_{x_i m_i, y_i n_i z_{BH}}})]\times N_i + \sum_{j=1}^{M_{NB}}[1-(1-\pi_S)\overline{PN_{x_j m_j, y_j n_j z_{NB}}}-(\pi_S)\overline{PP_{x_j m_j, y_j n_j z_{NB}}})]\times N_j \quad (8)$$

where there are M_{NB} (=8) NB subpopulations indexed by j and N_j members in subpopulation j.