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Preventing HIV Transmission among Partners of HIV-Positive Male Sex Workers in Mexico City: A Modeling Study

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Abstract

Mexico has a concentrated HIV epidemic, with male sex workers constituting a key affected population. We estimated annual HIV cumulative incidence among male sex workers' partners, and then compared incidence under three hypothetical intervention scenarios: improving condom use; and scaling up HIV treatment as prevention, considering current viral suppression rates (CVS, 60.7%) or full viral suppression among those treated (FVS, 100%). Clinical and behavioral data to inform model parameterization were derived from a sample (n=79) of male sex workers recruited from street locations and *Clínica Condesa*, an HIV clinic in Mexico City. We estimated annual HIV incidence among male sex workers' partners to be 8.0% (95% CI: 7.3–8.7). Simulation models demonstrated that increasing condom use by 10%, and scaling up HIV treatment initiation by 50% (from baseline values) would decrease the male sex workers-attributable annual incidence to 5.2%, 4.4% (CVS) and 3.2% (FVS), respectively. Scaling up the number of male sex workers on ART and implementing interventions to ensure adherence is urgently required to decrease HIV incidence among male sex workers' partners in Mexico City.

Keywords

epidemiology; men who have sex with men; Monte Carlo simulation methods; data imputation; HIV prevention

INTRODUCTION

The Mexico City metropolitan area (population 24.1 million) (1) has a concentrated human immunodeficiency virus (HIV) epidemic, with men who have sex with men (MSM) constituting a key affected population group. A recent study conducted in five regions of Mexico found that the metropolitan area of Mexico City has the highest HIV prevalence among MSM, 20.4% (95% CI: 18.7–22.2) (2), compared to 0.3% for the general adult population (15–49 years old) (3).

In Mexico City and elsewhere in the country, MSM who are also male sex workers are a particularly vulnerable population, at a greatly increased risk of violence, homophobia, and HIV infection (4). Previous studies, conducted in different cities in Mexico, have shown that male sex workers are usually young (5–7), and are more likely than the general population to engage in behaviors that place them at risk of acquiring HIV and other sexually transmitted infections (STIs), including unprotected intercourse and injection drug use (6–8).

In addition to individual-level risk behaviors, several social and structural factors likely contribute to the increased HIV prevalence among MSM and male sex workers in Mexico. For example, a very high proportion of MSM living with HIV do not know their status because of the absence of comprehensive, widespread testing programs (9), which in turn result in high rates of late antiretroviral treatment initiation (10, 11). Thus, despite the fact that Mexico has legislated universal access to antiretroviral treatment since 2003 (12), it remains unavailable for a large proportion of eligible persons.

Among male sex workers, another possible cause of high HIV prevalence is that many sex workers are paid more from clients to engage in unprotected sexual intercourse (7). This occurrence, known as “risk premium” in the economics literature, has also been observed in other settings (i.e., female sex workers in Mexico and India) (13, 14), and among male sex workers in Ecuador (15). In general, elevated risk for HIV acquisition among male sex workers has been associated with multiple sexual partners and inconsistent condom use with clients (16–24). It has also been shown that among female sex workers’ non-commercial partners in two Mexican cities, nearly one in ten tested positive for HIV/STIs (25).

Given the high prevalence of HIV among male sex workers and poor access to HIV treatment and care, more effective interventions are urgently needed to curb ongoing transmission among male sex workers and their partners. Using data from a pilot study (7) involving male sex workers in Mexico City, we sought to estimate male sex workers-attributable annual HIV incidence among partners of HIV-positive male sex workers, and to evaluate and compare the effectiveness of hypothetical behavioral and antiretroviral treatment-based prevention strategies to reduce transmission, using Monte Carlo simulation methods. Given the limited data available on male sex workers and MSM broadly in Mexico City, the objective of this paper is to provide evidence that could inform improved HIV prevention, treatment, and care services for these vulnerable populations.

METHODS

Setting

Data for this analysis were derived from an ongoing trial of conditional economic incentives to reduce HIV risk behavior among male sex workers in Mexico City (7). The participants were recruited by trained research staff through direct outreach from community sites where male sex workers are known to congregate (5, 7). Participants were also recruited from *Clínica Condesa* (a largest HIV service provider in Mexico City). For example, after using voluntary counseling and testing services and being referred to the research team. Strict procedures with separated roles (for clinical and research categories) were followed to ensure an understanding that regular clinic services would not be denied, regardless of their decision to enroll in the study.

The eligibility criteria for enrollment in the parent study were: male sex, age between 18 to 25 years, and was identified as a male sex worker. The exclusion criteria were an inability to read or speak Spanish or an inability to respond to the screening questionnaire due to the influence of drugs or alcohol. Eligible participants (n=273) were interviewed and asked to provide blood and urine samples for sexually transmitted infection (STI) testing, including HIV antibody and plasma RNA (ribonucleic acid) testing. All participants who tested positive for HIV were referred to care at *Clínica Condesa*. Data collection was conducted in collaboration with the Mexican National Institute of Public Health (INSP) and CISIDAT (Consortium for HIV/AIDS and TB Research). Behavioral interviews took place in a private area at *Clínica Condesa* using portable laptop computers with audio computer-assisted interviewing (A-CASI) questionnaires, during which participants were asked to self-report information about their number of sexual partners (commercial and non-commercial) in the past week, as well as additional information regarding their last three partners, including risk behaviors such as condom use and type of sexual act (receptive or insertive). Electronic records were de-identified and only code numbers were used for data analysis. Identifiable private information was available only to clinical staff (and used solely for follow-up and treatment referral purposes). The participants provided informed consent and all study procedures were reviewed and approved by the Brown University and the INSP research ethics boards.

Analytical sample

For this analysis, we restricted the sample to HIV-positive participants with a baseline measurement of plasma HIV RNA viral load. Of the 273 participants enrolled in the trial, 105 (38.5%) tested HIV-positive, of which 94 (89.5%) had a viral load recorded. We further restricted the modeling analysis to 79 participants, by excluding 15 participants with missing information on number of sexual partners.

Data imputation and mathematical model

We used a combination of clinical and self-reported risk behavior data to estimate weekly male sex workers-attributable HIV incidence among partners of HIV-infected male sex workers. The total number of sexual partners potentially susceptible to HIV infection included all partners (men or women) reported in the past week, and could be non-paying

partners and/or clients. Since the HIV status of each reported partner was unknown, in all modeling simulations, we randomly assigned 20% to be HIV-positive. A recent study, conducted in 24 Mexican cities throughout the country's five regions provided evidence that 20% is a good approximation for the HIV prevalence among male sex workers clients in Mexico city (2). Partners that were assigned HIV-positive status in the Monte Carlo simulations were removed from the susceptible pool and were subsequently not included in the HIV incidence calculations.

To estimate the risk of HIV transmission to each reported partner, we analyzed episode-level sexual behavior data for the last three clients (i.e., paying partners) in the past week, hereby denoted as most recent client (MRC), second most recent client (SRC) and third most recent client (TRC). The total number of reported past week receptive sexual acts, insertive sexual acts, receptive non-condom use, and insertive non-condom use was ascertained for the MRC, SRC, and TRC. If this information was missing or if the participant reported more than three partners in the past week, sexual behavior data was imputed and randomly generated from distributions parameterized with proportions reported for the sample's MRC (see Table I).

We defined receptive (and insertive) condom use as participants who reported that they (or their partner) used a condom every time they had sex with penetration during the last week. For partners for whom condom use was not 100%, we calculated a total number of unprotected sex acts as the sum of the number of unprotected receptive and insertive sex acts reported with that partner during the past week.

We used each participant's viral load measurement from the baseline assessment to estimate unique per-act risks of HIV transmission to that participant's partners. Each participant's per-act risk of HIV transmission was defined and calculated based on results of a study by Baggaley *et al.*, in which the relationship between probability of HIV transmission and plasma HIV RNA viral load (copies/mL) was estimated (26). Baggaley *et al.* conducted a systematic review and meta-analysis of the literature to assess the per-act and per-partner HIV transmission risk from anal intercourse exposure for heterosexuals and MSM. Based on the results of this study, for each participant-partner dyad, we defined the insertive and receptive per-act probability of HIV transmission as a function of participant's viral load. Specifically, there is an increase of 4.67 in per act risk of HIV transmission for receptive vs. insertive intercourse (26). We note that the overall HIV transmission probability per-partner per-week assumes that the relationship between the per-act and per-partner transmission probabilities with number of unprotected sex acts follows a Bernoulli process, which in turn assumes independence of risk for each sex act within a partnership (26).

Monte Carlo simulation

The analysis was conducted in SAS®* software (27), using Monte Carlo methodology (28) to generate simulations that produced estimates for weekly HIV incidence among partners of

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male sex workers. A SAS© macro was constructed such that for each Monte Carlo run, an HIV transmission event occurred at random between an HIV-positive male sex worker and a susceptible partner, depending on the HIV transmission probability per-participant/partner dyad. At each run, the number of HIV transmission events to the male sex worker's susceptible clients and non-paying partners was recorded.

We performed 1,000 simulation runs, and defined a mean as the point estimator for the number of weekly HIV transmission events among each male sex worker's partners. Assuming that the estimation represents a random week of the year, the annual HIV incidence (and respective confidence interval) among male sex workers' partners (% per year) in Mexico City was estimated by multiplying the weekly mean value by 52.

Scenarios considered

We used the SAS© macro to test each one of the three hypothetical intervention scenarios: (1) improving condom use; and (2), scaling up HIV treatment as prevention, considering observed current viral suppression rates (CVS, 60.7%) in the analytic sample, or idealized full viral suppression among those treated (FVS, 100%).

For the first set of scenarios, insertive and receptive condom use rates were scaled up by 5%, 10%, 15%, 20% and 25%. In this simulation, a condom use increase implies a decrease in proportion of total past week unprotected receptive sex acts, and consequently a smaller HIV transmission probability per-partner per-week.

For the second set of scenarios, we increased the proportion of HIV-positive participants on ART from 41% (current value at baseline assessment) to 51%, 61%, 71%, 81%, 89%, 97% and 100%. Note that even when we simulated the scenario in which all the male sex workers were on treatment but not all were fully suppressed (the CVS scenario), HIV transmissions to male sex workers' partners were still possible.

RESULTS

Clinical and behavioral results

A summary of the clinical and behavioral data collected from participants in the analytic sample used to parameterize the Monte Carlo simulation models are shown in Table I. Of the 79 HIV-positive and sexually-active male sex workers who contributed data to this analysis, a total of 405 unique sexual partners were reported during the past week. Study participants reported an average of 5.9 partners during the past week (SD = 6.7, range = 1 – 35).

Approximately one quarter of participants reported at least one receptive and at least one insertive sex act with their most recent partner. Fifty percent (n=22) reported no receptive sex acts with the MRC, and 64.6% (n=31) reported no insertive sex acts with their most recent partner in the past week. The former statistics refer only to the behavior with MRC, where the denominators were 44 and 48, respectively. Overall the male sex workers reported a high level of consistent condom use with MRC—77.1% and 73.8% for receptive and insertive sex acts, respectively—with their most recent partner in the past week. Note that the

statistics refer only to the behavior with MRC, which sample size differs from the analytical sample.

Among the male sex workers included in this analysis, 19 (24.1%) had an undetectable plasma HIV RNA viral load at baseline, while the majority (53.2%), had plasma RNA levels greater than 10,000 copies/mL. At study recruitment, 28 (35.4%) of male sex workers were on highly active antiretroviral therapy; of whom, 17 (60.7%) had achieved viral suppression.

HIV transmission events among male sex workers' partners

The results of the Monte Carlo simulations are shown in Figures 1 through 4. Overall, we estimated annual HIV incidence among male sex workers' partners to be 8.0% (95% CI: 7.3–8.7), with the 1,000 simulations generating, on average, 25.9 (95% CI: 23.6–28.2) new HIV transmission events per year among the 405 male sex workers' partners. Participants with plasma RNA greater than 100,000 copies/mL (21.0% at baseline) were estimated to contribute 40.0% of new infections. In contrast, the 38.0% of participants who had an HIV RNA plasma viral load <10,000 copies/mL at baseline contributed, on average, only 7.0% of the total number of male sex workers-attributable HIV infections generated in the Monte Carlo simulations (see Figure 1).

Figure 2 shows the joint contribution of risk behavior and viral load to male sex workers-attributable HIV transmission to male sex workers' paying and non-paying partners. Overall, male sex workers with a higher HIV RNA plasma viral load (greater than 100,000) contributed more weekly HIV transmission events than male sex workers who reported more than 4 unprotected sex acts per week. The greatest number of new HIV transmission events among male sex workers' partners were generated by male sex workers who reported 2 to 3 unprotected sex acts (per week) and had a plasma HIV RNA viral load greater than 100,000 copies/mL at study recruitment. Across all simulations, we observed no new male sex workers-attributable HIV transmissions from male sex workers to their partners for participants who were virally suppressed at baseline, and only a small number of transmission events among those whose observed HIV RNA plasma viral load was less than 10,000 copies/mL at baseline.

Intervention scenario results

In Figures 3 and 4, we summarize the results of hypothetical intervention scenarios to decrease HIV incidence among male sex workers' partners. Simulation models demonstrated that increasing condom use by 10.0% would decrease the male sex workers-attributable annual incidence to 5.2% (95% CI: 4.6–5.8). Scaling up HIV treatment initiation by 50.0% (from baseline values) resulted in an estimated annual HIV incidence of 4.4% (95% CI: 3.9–5.0) assuming baseline viral suppression rates; and 3.2% (95% CI: 2.7–3.7) assuming full viral suppression among all those treated.

Sensitivity analysis

In the sensitivity analyses, the estimated annual HIV incidence among male sex workers' partners presented a 29% decrease: from 7.3% (95% CI: 6.6–7.9) to 5.2% (95% CI: 4.6–5.8) per year when condom use was scaled up from 5% to 10%. For 96% receptive condom use,

and for 93% insertive condom use (which are equivalent to scaling up condom use 25%), the simulation showed that the estimated annual HIV incidence among male sex workers would decrease to 3.1% (95% CI: 2.6–3.5), Figure 4 Panel (A).

As shown in Figure 4, Panel (B), when the proportion of HIV-positive male sex workers on ART is increased from 51% to 100% assuming current viral suppression (CVS) rates, HIV incidence appeared to plateau. For example, the estimated HIV incidence was 2.5% when 100% of MSM were initiated on ART assuming CVS rates. In contrast, in an idealized scenario assuming 100% viral suppression, HIV incidence decreased to zero when all individuals were initiated on ART.

DISCUSSION

Model findings and interpretation

In this simulation study using empirical biometric data from a pilot trial of conditional economic incentives to reduce HIV risk among male sex workers in Mexico City, the risk of HIV transmission from male sex workers to their partners was found to be very high, with an estimated annual cumulative incidence of 8%. In hypothetical intervention scenarios, we found that scaling up ART programs, especially when full viral suppression is achieved, will significantly decrease the number of new HIV infections among male sex workers' partners. In addition, the simulation showed that the estimated annual HIV incidence among male sex workers' sexual partners would decrease significantly when condom use is scaled up. These results suggest that a combination of behavioral and biomedical interventions is required to reduce the rate of HIV transmission from HIV-positive male sex workers to their clients and non-paying sexual partners.

We believe that this high annual incidence among male sex workers' partners is due to several reasons. First, 53% of male sex workers reported high level of plasma HIV RNA viral load (i.e., more than 10,001 copies/mL). Second, only 35% of them are on ART, but only 61% of those on ART achieved viral suppression. In comparison to our findings, Balaji et al. (29) published a study showing a 3% annual incidence among young MSM in the United States, with estimates particularly pronounced for young Black MSM, who had an HIV prevalence of 17% and an estimated annual incidence of 5%. Given that our study was restricted to HIV-positive, sexually active male sex workers, it is therefore not surprising that our results show an even greater HIV incidence among partners of male sex workers.

The model suggests that male sex workers in the high plasma HIV RNA viral load category contributed a greater proportion of new cases to the overall HIV transmission than those who reported a higher than average number of unprotected sex acts. For example, the male sex workers who reported on average more than or equal to 4 unprotected sex acts per week, but who had a low plasma HIV RNA viral load (i.e., less than 10,000 copies/mL), contributed only 3% of the total number of new HIV transmission events. Therefore, increasing the availability of ART is likely to have a significantly protective and beneficial effect. This finding concurs with the UNAIDS/WHO July 2010 guideline revision (30), which, based on the latest scientific evidence, advocates earlier initiation of ART (31), to subsequently reduce the rate of AIDS and non-AIDS mortality, and to prevent HIV and

tuberculosis (TB) transmission in at-risk populations (32, 33). Previous studies have also emphasized the importance of scaling up treatment as prevention in order to improve and prolong the lives of infected MSM, which will have the expected benefit of reducing HIV transmission and the future HIV/AIDS burden in this population (34, 35).

Sensitivity analyses shows that greater reductions in new infections are likely to be observed when persons on ART achieve full viral suppression. Although findings have been inconsistent (36), recently, Remien et al. (37) found an association between sexual risk behavior and adherence to ART (but only among HIV-positive heterosexual men and not gay/bisexual men). These results and ours further underscore the importance of adherence support programs to ensure viral suppression and maximize the full preventive benefit of early ART initiation. Finally, declines in HIV incidence were observed when we scaled up condom use among male sex workers. Therefore, decreasing the number of unprotected sex acts among male sex workers and their partners is also important and should be a focus for health promotion efforts. Our findings and others studies (38, 39) suggest that earlier initiation of ART could reduce population-level incidence of HIV among sex workers in Mexico City and in other middle-income countries.

Model comparisons and limitations

This study is subject to a number of important limitations. First, we note that the analytical sample was small and consisted of only 79 HIV-positive male sex workers. However, we do not expect the small sample size to limit study power, as the primary unit of analysis was participant-partner dyad, of which more than 400 (in the past week) were reported. Second, even though little behavioral and clinical data (i.e., HIV status) were collected concerning the clients, we used detailed data about the male sex workers and their behaviors with the three most recent clients to parameterize the transmission models. Third, due to the sampling strategy, we suggest appropriate caution when generalizing these results to larger populations of male sex workers in Mexico City and elsewhere. This is particularly true given the nature of the study (with a detailed and long questionnaire, and the recruitment concentrated in few sites). For example, we cannot exclude the possibility that the interviewers might have interviewed male sex workers who were most obviously engaging in sex work activity (versus those working in hidden or non-public environments), and that there are systematic differences between those in the analytic sample and HIV-positive male sex workers from other locations in Mexico City who were not recruited.

Fourth, it is important to note that our model assumed zero HIV transmission in the hypothetical idealized scenario of perfect condom use. It should be highlighted that 100% correct and consistent condom use is rarely, if ever, observed in sexually active populations; for example, a cohort study of sexually active HIV serodiscordant heterosexual couples with follow-up of the sero-negative partner (conducted in the United States), showed that the proportionate reduction in HIV seroconversion with condom use was approximately 80% (40). Therefore, this theoretical scenario should be interpreted with caution.

Finally, the hypothetical intervention scenarios did not include other prevention modalities, including for example pre-exposure prophylaxis (PrEP) for HIV negative male sex workers and/or their clients. Given that PrEP has the potential to reduce HIV transmission in MSM

(41), future research should be conducted to examine the feasibility of this intervention in this setting. A recent study among female sex workers in Mexico showed that intimate relationship dynamics with male partners may pose potential barriers to PrEP acceptability and adherence (42). Further research is required to determine whether similar barriers are likely to be experienced by HIV negative male sex workers who wish to initiate PrEP therapy.

CONCLUSIONS

In summary, our model estimated high annual HIV incidence among partners of male sex workers in Mexico City, demonstrating a greatly elevated risk of HIV transmission from male sex workers to their sexual partners. Since decreasing plasma HIV RNA viral load and achieving full viral suppression (by increasing the number of male sex workers on ART), was shown to result in significant decreases in expected number of new infections, scaling up ART programs and implementing interventions to ensure adherence is urgently required to decrease male sex workers-attributable HIV incidence among male sex workers' partners in Mexico City.

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Figure 1. Distribution of HIV transmission events by HIV-positive male sex workers' viral load observed at baseline, when there is HIV transmission to paying and non-paying partners
Data shown represent the results of 1,000 Monte Carlo runs and 405 reported partners, for a total of 491 transmission events. a - Proportion of HIV-positive male sex workers in each viral load category.

Figure 2. Proportion (number) of HIV transmission events among male sex workers' partners, in Mexico City, due to average number of unprotected sex acts (reported per week) and viral load of the HIV-positive male sex workers

Each shaded area is a proportion relative to the largest number of 75 cases being 100 (full shading). The numeric values of the rates are used as the labels. Cells with no new male sex workers-attributable transmission are labeled "0". Data shown represent the results of 1,000 Monte Carlo runs and 405 reported partners, for a total of 485 transmission events. The Diamond Graph was adapted from Li *et al.* (44).

Figure 3. Estimated annual HIV incidence among male sex workers' partners (% per year) in Mexico City, for various scenarios

From left to right: Status Quo; increasing condom use by 10%; and scaling up HIV treatment as prevention by 50% considering current viral suppression rates (CVS, 60.7%) or full viral suppression among those treated (FVS, 100%).

Figure 4. Estimated annual HIV incidence among male sex workers' partners (% per year) in Mexico City

Panel (A) when percentage of receptive (RCU) and insertive (ICU) condom use is scaled up by 5% to 100%; Panel (B) percentage of male sex workers on ART are scaled up from 51% to 100%, considering current viral suppression rates (CVS, 60.7%) or full viral suppression among those treated (FVS, 100%).

Table I

Summary of clinical and behavioral parameter values for HIV-positive and sexually active male sex workers in Mexico City used to calibrate the Monte Carlo simulations, from 79 male sex workers, which had 405 partners.

Variables	Frequency (n, %) unless otherwise noted
Clinical Data	
Viral load	
log ₁₀ (median), IQR (<i>in natural units</i>)	4.2 (0 – 84,922)
Viral load (copies/mL)	
Undetectable	19 (24.1)
40 – 1,000	2 (2.5)
1,001 – 10,000	6 (7.6)
10,001 – 50,000	17 (21.5)
50,001 – 100,000	11 (13.9)
100,001	14 (17.7)
Treatment status at recruitment	
On ART	28 (35.4)
Viral suppression status among those treated ^a	
Yes	17 (60.7)
Risk Behaviors	
Total receptive ^b acts with MRC ^c (past week)	
0	22 (50.0)
1	12 (27.3)
2	6 (13.6)
3	4 (9.1)
Total insertive acts with MRC ^c (past week)	
0	31 (64.6)
1	12 (25.0)
2	4 (8.3)
3	1 (2.1)
Number of clients (seen during last week)	
Median (IQR)	4 (3 – 5)
Mean (SD)	5.9 (6.7)
Range	1 – 35
Condom use as the receptive partner with MRC ^c (past week)	
Consistent condom use	37 (77.1)
Condom use as the insertive partner with MRC ^c (past week)	
Consistent condom use	31 (73.8)

Abbreviations: ART – highly active antiretroviral therapy; SD – standard deviation; MRC – most recent client; IQR – interquartile range.

Notes: Ten of the 79 male sex workers, reported no sexual partners, and thus did not contribute with clinical and behavioral information for the simulation.

^a viral suppression defined (43) as less than 1,000 copies/mL is relative to the number of male sex workers that are on treatment;

^b Vaginal sex acts with MRC are not included;

^c The statistics refer only to the behavior with MRC.

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