

# Potential Impact of Existing Interventions and of Antiretroviral Use in Female Sex Workers on Transmission of HIV in Burkina Faso: A Modeling Study

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**Background:** The impact and cost-effectiveness of antiretroviral treatment (ART) as prevention is likely to vary depending on the local context. Burkina Faso has a concentrated mature HIV epidemic where female sex workers (FSW) are thought to have driven HIV transmission.

**Methods:** A dynamic HIV transmission model was developed using data from the Yerelon FSW cohort in Bobo-Dioulasso and population surveys. Compared with current ART provision [status quo (SQ)], the model estimated the proportion of HIV infections averted or incremental life-years gained per additional person-year of ART over 20 years for ART targeting different subgroups or expanding eligibility to all HIV-infected individuals compared with SQ.

**Results:** Modeling suggests that condom use within commercial sex has averted 40% of past HIV infections. Continuing SQ averts 35%–47% of new infections over 20 years compared with no ART. Expanding ART eligibility to all HIV-infected individuals and increasing recruitment (80% per year) could avert a further 65% of new infections, whereas targeting full-time FSW or all FSWs achieved less impact but was more efficient in terms of life-years

gained per 100 person-years of ART. Local HIV elimination is possible with expanded ART provision to FSWs but requires condom use within commercial sex to be maintained at high levels.

**Conclusions:** Increasing FSW recruitment onto ART could be a highly efficient method for reducing HIV transmission in concentrated epidemic settings but should not be undertaken at the expense of existing interventions for FSWs. Specialized clinics providing multiple interventions for FSWs should be a fundamental component of prevention in concentrated epidemics.

**Key Words:** antiretrovirals, female sex worker, Burkina Faso, treatment as prevention, modeling, HIV transmission

(*J Acquir Immune Defic Syndr* 2015;68:S180–S188)

## INTRODUCTION

Despite evidence of high efficacy of antiretroviral treatment (ART) in reducing heterosexual transmission of HIV, the population-level effectiveness of HIV treatment as prevention (TasP) is unclear.<sup>1</sup> The randomized trial HPTN 052 confirmed observational studies that showed that ART initiation at higher CD4<sup>+</sup> count thresholds had a pronounced impact on transmission in serodiscordant couples.<sup>2,3</sup> Data from observational studies also support a reductive effect on transmission, although at a lesser magnitude than the 96% reduction observed in HPTN 052. One meta-analysis found a 42% reduction in transmission risk,<sup>4</sup> whereas others found a 92% reduction.<sup>5,6</sup> Results of observational studies have been highly heterogeneous, with estimates of impact including a 26% reduction in China,<sup>7</sup> a 38% reduction in acquisition of HIV in those living in areas with high ART (>40%) coverage compared with low (<10%) in South Africa,<sup>8</sup> and no impact in a cohort in Uganda.<sup>9</sup>

Factors influencing effectiveness remain unclear but likely include adherence to treatment and retention in care.<sup>10</sup> There is concern that expansion of ART as a method of prevention and not just as a therapeutic intervention might overburden health systems, which struggle with diagnosing and treating those with advanced disease, particularly in settings of generalized epidemics.<sup>11,12</sup> Such programs could lead to diversion of resources from established prevention programs and an increase in drug resistance, thus leading to suboptimal individual and public

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This study was funded by France's Agence Nationale de Recherches sur le SIDA et les Hépatites (ANRS). Additional funding was provided by the Wellcome Trust and through the UK's Department for International Development (DFID)-funded Knowledge Programme on HIV/AIDS and STI and the Research Programme Consortium.

Presented at the 18th Conference on Retroviruses and Opportunistic Infections, March 3–27, 2011, Boston, MA, abstract #773; and at the 20th Conference on Retroviruses and Opportunistic Infections, February 28–March 6, 2013, Atlanta, GA, abstract #881.

The authors have no conflicts of interest to disclose.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site ([www.jaids.com](http://www.jaids.com)).

Members of Yerelon Study Group are listed in the Appendix 1.

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health outcomes.<sup>13,14</sup> Modeling suggests that expanding ART treatment to those with a CD4<sup>+</sup> count <500 cells per microliter would be cost-effective in a wide variety of settings,<sup>15,16</sup> but little data from real world experience exist. Variations in the epidemiology of HIV might alter the cost-effectiveness of TasP and warrant additional study.<sup>17,18</sup>

Female sex workers (FSW) remain an important HIV core group in many regions, such as West Africa.<sup>19–22</sup> Results of trials of TasP targeting FSW are not yet available.<sup>23</sup> Predictive models using data on sexual behavior and biological measures remain one of the most useful means of estimating the role of expanding treatment on HIV transmission. Models constructed around concentrated epidemics in Asia have found that the relative benefits of ART expansion in FSW are highly dependent on condom use and epidemic size.<sup>24,25</sup> Few models have been constructed around FSW in West Africa, where successful targeted interventions have been in place since the 1990s, which could influence gains of ART expansion.<sup>26,27</sup>

Burkina Faso is one of several nations in which the incidence of HIV has declined, despite limited availability of ART until recently.<sup>28,29</sup> The aim of this study was to model the impact of various ART prioritization strategies within the concentrated mature epidemic of Bobo-Dioulasso and to determine the most efficient strategy in terms of HIV infections averted (HIA) and life-years gained (LYG).

## METHODS

### Model Description

A deterministic compartmental model simulating heterosexual HIV transmission was developed using data from the Yerelon cohort of FSWs (ANRS 1222) in Bobo-Dioulasso and from multiple population surveys. The cohort was established in 1998 to determine optimal interventions to minimize risk of HIV infection in high-risk women in Bobo-Dioulasso; it provided regular STI and HIV testing and treatment in an adapted public clinic.<sup>30–32</sup> The program also promoted condom use throughout Bobo-Dioulasso by using former FSWs as “peer educators” to disseminate information on condom negotiation and sexual health, and to distribute condoms at clinics and areas of sex work on a regular basis.<sup>33</sup> It provided HIV and general medical care in the same setting, including ART from 2003 onwards.

The model categorizes individuals into subgroups on the basis of gender and sexual risk behavior based on behavioral data compiled from general and high-risk population surveys (Table 1): FSW stratified into occasional (OSW) or full-time sex workers (FTSW), male clients, and medium-risk (those reporting casual partnerships as well as main) and low-risk subgroups (those reporting main partnerships only), resulting in 7 subgroups (see **Figure S1, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). Commercial subgroups were defined based on the mean number of clients per year,<sup>30</sup> as reported by women in the cohort database. Model details are provided in the Supplemental Digital Content (<http://links.lww.com/QAI/A597>).

The model assumes that once a person becomes infected with HIV, they are in the initial acute phase of infection (see **Figure S2, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). They then progress to the latent or chronic phases of infection, divided into the period when the CD4<sup>+</sup> count is greater than 350 cells per microliter, followed by a period when the CD4<sup>+</sup> count <350 cells per microliter but >200 cells per microliter, and another period when the CD4<sup>+</sup> count ≤200 cells per microliter. They then enter a short period with higher plasma viremia before experiencing clinical AIDS and death.

### Model Parameterization

Biological parameters such as the HIV transmission probability and other natural history parameters were determined from a review of the literature using data from meta-analyses preferentially when available (see **Table S1, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). Progression rates through the HIV-related model compartments were based on data from the eART-linc collaboration, using data from African cohorts.<sup>56</sup>

Behavioral parameters such as condom use during last sex act were derived from cohort data, general population surveys, and from surveys among FSW and their clients (Table 1).<sup>30,39–41</sup> Projections of condom use for years in which data were not available were calculated by fitting linear slopes to available estimates (see **Figure S3, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>).

### ART Parameters

ART was introduced into the model in 2004, for individuals with a CD4<sup>+</sup> count ≤200 cells per microliter and to those with a CD4<sup>+</sup> count <350 cells per microliter after 2009, at 25% yearly recruitment, which was calibrated to achieve coverage levels of 60% of those eligible by 2012, based on national data.<sup>39,47</sup> Yearly loss to follow-up (LTFU) was set at 6.5% as observed in this setting.<sup>50</sup> ART was assumed to decrease infectiousness of HIV by 90% using data from observational studies, as it was believed that the efficacy from HPTN 052 was likely higher than in a nontrial setting.<sup>3,49,57</sup> This was also informed by using data on genital shedding of HIV-1 for women on ART from the Yerelon cohort (see **Figure S4, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>).<sup>58</sup> Lower efficacy estimates were considered in the sensitivity analysis. HIV-infected individuals on ART are assumed to progress through the same HIV progression compartments but with ART reducing the progression rate 4-fold when compared with ART-naïve individuals.<sup>52–55</sup> The impact on survival was varied in the sensitivity analysis due to a lack of data specific to Bobo-Dioulasso. We assumed that FSW and clients access ART at the same rate as the general population, based on similar CD4 counts at treatment initiation from several local surveys.<sup>39,59,60</sup> While on ART, patients are LTFU at a rate assumed to be independent of CD4<sup>+</sup> count and duration on ART and are returned to the untreated phase for the same CD4<sup>+</sup> count compartment as they were in at the time of ART

**TABLE 1.** Behavioral and Antiretroviral Intervention Parameters

Behavioral Model Parameters	Female/FSW	Male/Client	Source
Percentage of population FSW or clients	2.0% (1.0%–3.0%) = NSW	5%–39%	From <sup>34,35</sup> for FSW and from a mapping exercise of FSW in 2010. Derived estimate for clients
Ratio of clients to FSWs (F)	5–13		Range derived from surveys <sup>35–37</sup>
Percentage of FSW who have lower numbers of yearly clients (OSW)	75% (65–80)		Refs. 30,38
Average duration of sex work or buying sex in years (1/ $\sigma$ )			Derived as a range using <sup>38–41</sup>
OSW	3–6		
FTSW	5–10		
Clients		4–8	
Average number of clients per year			Derived as a range from <sup>39</sup>
OSW ( $c_{11}$ )	24–104		
FTSW ( $c_{12}$ )	312–2500		
Proportion of FSW reporting using condoms during last sex act with clients in Bobo-Dioulasso 1993	65%–80%		Derived from <sup>40,42,43</sup>
Yearly rate of increase in condom use with last commercial partner 1993–2010	0%–1.6%		Supplementary material from <sup>35,37–39,44</sup>
Percentage of general population currently having casual sex	1.0%–8.3%	5.5%–18.1%	Refs. 35,36,44
Frequency of casual partners per year amongst medium and high-risk groups ( $c_{ca}$ )	2–93	2–7	<sup>38</sup> Little data on the number of casual partners of FSW or females, calculated from male reports
Yearly rate of increase in condom use with last casual partner 1993–2010	1.5%–2.5%		Fit using data points in <sup>35,38,44</sup>
Percentage of population reporting condom use with main partner (generally married/cohabitating)	0.7%–9.7%		Range from surveys of general population <sup>35,44</sup>
Model ART intervention parameters			
Year ART introduced			
CD4 <sup>+</sup> count <200 or WHO stage 3 or 4	2004		Refs. 39,45,46
CD4 <sup>+</sup> count <350 or WHO Stage 3 or 4	2009		Refs. 47,48
Relative HIV transmission probability while on ART compared with the transmission probability if untreated ( $\Phi$ )	0.10		Using <sup>2,3,6</sup> but weighted lower due to evidence of lower viral suppression <sup>45</sup> and data from West Africa <sup>49</sup>
Rate of cessation of ART per year ( $\zeta$ )	6.5%		Derived as a range from <sup>50,51</sup>
With ART-factor reduction in HIV progression (K)	0.25		Refs. 52–55

cessation. Individuals can reinitiate ART at the same rate as they initiate ART.

### Model Calibration

Parameters with significant uncertainty were assessed in a quasi-Bayesian framework, whereby they were allowed to vary within a specified prior distribution reflecting the range of likely estimates.<sup>61</sup> Latin hypercube sampling was performed to randomly generate 750,000 parameter sets from these ranges. Each model run using these parameter sets was compared with existing data on HIV prevalence from cross-sectional surveys of OSW and FTSW and clients in 1994, overall FSW prevalence from surveys in 1990, 1999, and 2003, and from general population estimates in 2000 (see **Table S2, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). For all data used in fitting, the 95% confidence intervals were widened by adding a relative  $\pm 10\%$  to each because of uncertainty in the data source. Parameter sets were accepted as a fit (or

“posterior” distribution) if the predicted prevalence simultaneously fell within the widened 95% confidence intervals of each estimate. Data were not fit for time points after 2004; however, parameter sets were excluded if they showed an increase in HIV prevalence in the general population after 2004, to correspond with data from national surveys. The posterior parameter sets were used for all simulations and were used to calculate a median estimate for all outcomes.

### Population Attributable Fraction Calculations

The relative contribution of FTSW, OSW, and overall FSW populations to new infections in the whole population was calculated using bidirectional population attributable fractions (PAF). The transmission in commercial partnerships was set to 0 for either OSW or FTSW or both, and their clients for 5-year periods, done in separate simulations. The number of incident cases in the total population was averaged over each set of simulations and was then

compared with the number of new cases in the original model. The following equation was used:

$$PAF_{FSW} = (1 - \text{Incident Cases}_{noFSW} / \text{Incident Cases}_{original}) \times 100\%$$

### Simulations

Different interventions using ART were modeled beginning in 2014 and compared with the status quo (SQ) scenario of a yearly 25% recruitment onto ART of all eligible (CD4<sup>+</sup> count <350 cells/μL) HIV-infected individuals. The modeled interventions targeted all HIV-infected FSW, by typology (FTSW and OSW), or the entire population assuming increased eligibility and 80% recruitment onto ART per year. For scenarios targeting different subgroups, the ART recruitment rates for other subgroups were maintained at the level of the SQ scenario. The impact of each scenario was measured over 20 years in terms of percentage of HIA (%HIA) and efficiency as LYG per 100 additional person-years of ART (PYAs) among the entire population, compared with SQ. This time frame was selected to allow the accumulation of health benefits in terms of LYG and comparability to recent modeling analyses.<sup>15</sup>

For the scenario targeting all FSW, the contribution of each uncertainty parameter to the variation in %HIA over 20 years was estimated using linear regression analysis of covariance, where the percentage of the sum of squares attributable to each parameter was calculated to determine its impact on overall uncertainty.

### Sensitivity Analysis

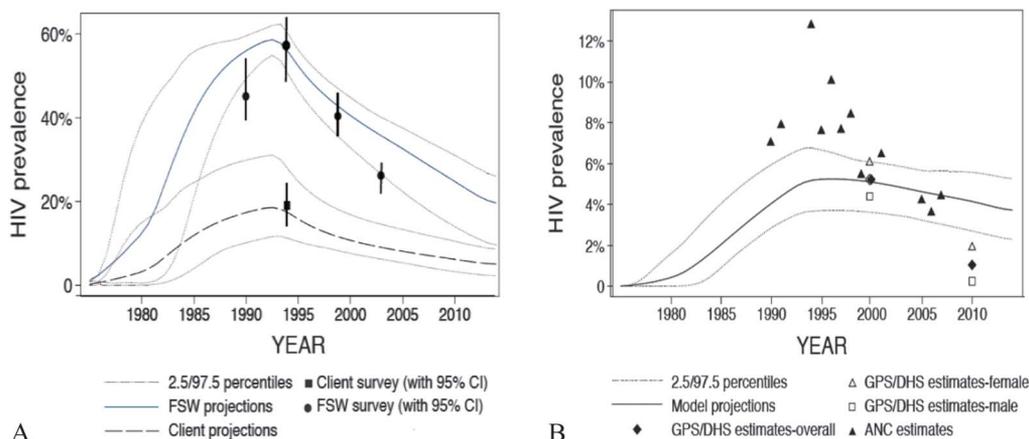
For the FSW-targeted ART scenario, the model was run for a number of univariate sensitivity analyses to assess how impact and efficiency would vary under different assumptions

for the extension in survival attributable to ART (3 or 5 fold decrease in progression) or double the yearly ART dropout rates (13%). Projections were compared with the SQ scenario, calibrated assuming the same change in parameters. We also examined scenarios assuming different efficacies of ART for reducing HIV infectivity, either based on an observational study from China (26% reduction)<sup>7</sup> or an alternative estimate (58% reduction) produced using data on genital HIV-1 RNA shedding from the Yerelon cohort (see **Figure S4, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>).<sup>58</sup>

Additionally, because there is evidence from our cohort and Benin that there can be poorer virological suppression in FSWs than the general population,<sup>45,62</sup> we considered a scenario where the efficacy of ART in reducing infectivity was lower in FSW (58% reduction) than for other subgroups (90% reduction). Finally, we considered how the impact and efficiency of targeting ART to FSW would vary if condom use had reached lower levels (70%) among FSWs by 2014. For these scenarios, we did not refit the model but allowed the epidemic to increase because of the lower levels of condom use.

### RESULTS

Of 750,000 iterations, there were 240 model fits to HIV prevalence data among FSWs and 24 fits to HIV prevalence data including the general population that also displayed a decreasing prevalence by 2010. Table S3 (see **Supplemental Digital Content**, <http://links.lww.com/QAI/A597>) compares the posterior ranges for the model fits to their respective prior ranges. The model projections of HIV prevalence over time suggest that the HIV epidemic in Bobo-Dioulasso increased rapidly among high-risk groups in the 1980s (Fig. 1A), during which rates of condom use were negligible, peaked in the early 1990s, and then gradually decreased. Similar trends are projected for the general population (Fig. 1B). The model



**FIGURE 1.** Model fit projections of HIV prevalence and data estimates for FSWs and their clients (A) and overall (B) populations. Note the different scales on the y-axis. The symbols and bars represent measured prevalence in (A) clients and sex workers and (B) the general population from surveys, ANC surveillance, and from the DHS 2010, limited to the Hauts-Bassin region and including rural areas. The lines represent median fits and 2.5% and 97.5% percentiles from the 24 fitted simulations. GPS, general population survey; DHS, demographic and health survey.

estimates that 34,259 (range, 25,512–40,127) HIV cases occurred in Bobo-Dioulasso since the onset of the epidemic to 2014. The model's posterior estimated condom use at last sex act was 87.1% (95% confidence interval [CI]: 82.5 to 95.0) in commercial partnerships, 35.4% (95% CI: 29.0 to 43.5) in casual partnerships, and 4.5% (95% CI: 3.5 to 5.5) in main partnerships by 2010 (see **Figure S3, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>).

In the absence of any prevention interventions, namely any increase in condom use, ART coverage, or male circumcision (MC; coverage estimated to be 90%), the model suggests that HIV prevalence would have been 10%–32% overall and 68%–82% in FSW in 2014 (see **Figure S5, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). Promotion of condom use averted 31%–53% of HIV infections during this period. The provision of ART since 2004 was estimated to have averted 2%–8% of cases and MC averted 36%–62%.

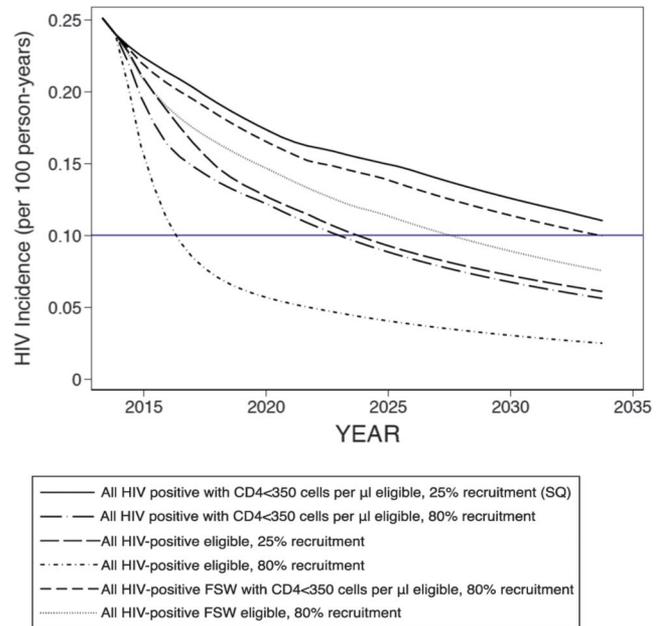
### PAF due to Commercial Sex

Model projections suggest that a large portion of incident HIV infections in this setting are attributable to commercial sex, with this being the greatest in 1985–1990 when 75%–88% of infections are attributable to FSW. This declined to 39% between 1995 and 2010, as condom use increased in commercial sex (see **Figure S6, Supplemental Digital Content**, <http://links.lww.com/QAI/A597>). Most incident infections are due to FTSW (PAF = 60%–70%) during the early phase of the epidemic, but the proportion approaches that of OSW by 2010 (PAF = 10%–20%), due to higher condom use in FTSW than OSW.

### Future Impact and Efficiency of ART Over 20 Years

The continuation of the SQ scenario will avert 35%–47% of infections compared with stopping ART over the next 20 years if condom use remains at 2010 levels, and local HIV elimination (defined as reducing HIV incidence to less than 1 infection per 1000 person-years) would be achieved by 2037 (Fig. 2). The most rapid decline in incidence is achieved by increasing recruitment of all HIV-infected individuals onto ART (54–71 %HIA compared with SQ) with local elimination being achieved by 2016. If FSW are targeted, with 80% of HIV-infected FSWs recruited each year, then a smaller impact (4–38 %HIA) is achieved, with local elimination occurring by 2027.

Figure 3 and Table S4 (see **Supplemental Digital Content**, <http://links.lww.com/QAI/A597>) present the impact and efficiency (LYG and HIA/100 PYA) of different ART scale-up scenarios. Although expanding ART recruitment to 80% of all HIV-infected individuals has the largest impact of all scenarios considered, it is much less efficient (55 LYG/100 PYA) than targeting all FSWs (98 LYG/100 PYA) or FTSW (251 LYG/100 PYA) at the same recruitment rate. Interestingly, targeting OSW was not substantially more efficient than targeting everyone.



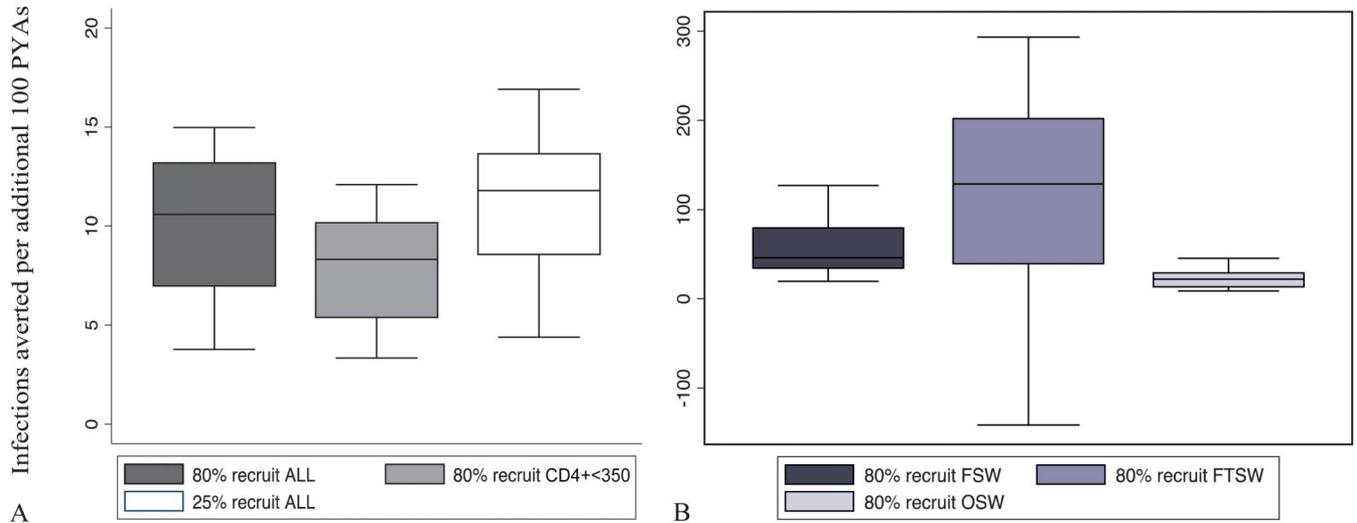
**FIGURE 2.** Projected overall annual HIV incidence rates for scenarios of eligibility and recruitment onto ART. The line represents the threshold for elimination (<1 case per 1000 person-years).

### Sensitivity Analysis

Figure 4 and Table S5 (see **Supplemental Digital Content**, <http://links.lww.com/QAI/A597>) present the effect of varying assumptions on the projected impact and efficiency of scaling up ART to 80% recruitment of infected FSWs each year. Assuming a reduced effect of ART on infectivity (58% vs. 90%) reduces the %HIA by two-thirds and LYG/100 PYAs by half, compared with the FSW recruitment scenario. If the efficacy of ART is reduced further to 26%, little impact is achieved. In the scenario with differential efficacy of ART in reducing infectivity among FSWs and the general population, impact is reduced by 57% and efficiency by 45%. Different assumptions for the efficacy of ART for increasing survival do not significantly change the estimated impact or efficiency of ART. Finally, increasing the rate of LTFU for all individuals on ART reduces the LYG but also reduces the years of ART after they have left sex work and therefore increases efficiency.

If we assume that commercial condom use (defined as condom use at last commercial sex act between a FSW and client) had reached lower levels in this setting, the incremental impact and efficiency of scaling up of ART among FSW increases. However, targeting ART to FSWs can no longer achieve elimination by 2034. Elimination is not achieved by 2034 for any targeted ART scenario with <82% commercial condom use or with <57% commercial condom use if targeting ART to all HIV-infected individuals.

Analysis of covariance determined that the largest proportion of variation in %HIA for the scenario where 80% of infected FSWs are recruited onto ART each year is due to uncertainty in the yearly number of clients for FTSW



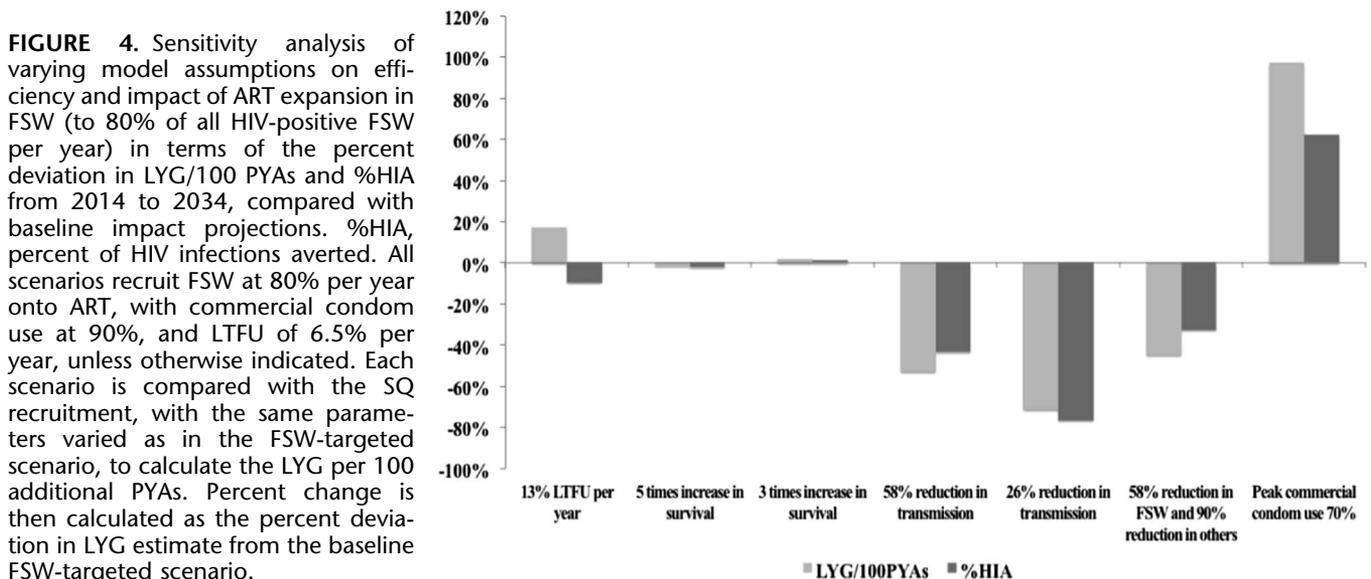
**FIGURE 3.** Efficiency of ART scenarios in averting new HIV infections compared with the SQ scenario. Note the different y-axis scales for A and B. Each box represents the median and range of modeled impacts for recruiting (A) 80% or 25% of all HIV-infected individuals or increasing recruitment to 80% of all subgroups with a CD4<sup>+</sup> count <350 cells per microliter or (B) 80% of all FSW, FTSW, or OSW regardless of CD4<sup>+</sup> count onto ART each year. Negative values are a result of fewer years predicted for ART for some parameter sets compared with the SQ, implying very good efficiency.

(14.4%), the cofactor increase in infectivity during acute infection (13.7%), and the rate of condom increase for casual partnerships from 1994 to 2010 (13.0%).

### DISCUSSION

Although models have considered the impact of targeting ART among FSW populations in Asia,<sup>15,24,25</sup> this is the first study to estimate the impact of targeting TasP to different typologies of FSWs in West Africa. Burkina Faso has a diminishing incidence of HIV, and although the prevalence in the general population was more than 3% in the 1990s, it now has a national prevalence close to 1%.<sup>26,48</sup> This decline is

mirrored in the FSW population in Bobo-Dioulasso where the prevalence has declined from 57.2% in 1994<sup>40</sup> to 20.4% in 2010.<sup>38</sup> This occurred within the context of expanded condom availability and syndromic management of STIs, both scaled up during the 1990s.<sup>28,63</sup> Our model attributes 40% of the historical reduction in HIV prevalence to the expansion in condom use, reflected in the decrease in HIV transmission attributable to FSWs, from more than 70% in the late 1980s to less than 50% of new infections after 1995. The model also suggests that HIV prevalence would have been much higher without the high coverage of MC, which is traditionally practiced in Burkina Faso, and that ART so far has had little impact on the epidemic because of low coverage rates.



Similar declines in HIV prevalence have been observed in many FSW populations in the region, some in countries directly targeting FSW with interventions combining STI and behavioral components<sup>64–66</sup> and others where the decline occurred independently of programmatic changes, possibly because of the natural history of the epidemic.<sup>67–70</sup>

Current and expanded ART provision in this setting could achieve considerable impact, with most HIV infections being averted when 80% of all HIV-infected individuals are recruited onto ART each year, resulting in rapid elimination. However, this strategy is considerably less efficient than targeting FTSW or all FSW and requires a much larger investment in ART (a 96% increase in provision over targeting FSW) and wide-scale HIV counseling and testing. Targeting FSW is more feasible, as most FSWs in Burkina Faso report having been tested for HIV in the past year (83% in 2010), whereas less than 30% of the general population report ever being tested.<sup>38,71</sup> However, FSWs can be difficult to reach, and care is therefore best offered within specialized clinics, where staff can provide multiple interventions in a non-judgmental environment.<sup>39,72</sup>

In our model, the efficiency of expanding ART to FSWs is higher if condom use is lower in commercial settings. However, in this heightened epidemic scenario, just scaling up ART among FSWs can no longer achieve elimination. This emphasizes the importance of achieving high levels of condom use among FSWs as a fundamental primary intervention for controlling HIV transmission,<sup>27</sup> and illustrates the importance of preventing behavioral risk compensation as has occurred in other populations, such as men who have sex with men.<sup>1,73</sup> Indeed, studies from South Africa have shown that diverting funds from other prevention activities can lead to an increase in incidence despite expanding ART coverage.<sup>74</sup> However, studies of African FSWs have shown that sexual risk taking in women on ART can be minimized if behavioral change programs are maintained.<sup>75–77</sup>

Even when assuming a more conservative efficacy of ART in reducing HIV infectivity, targeting ART towards FSW still prevents more infections than the current policy. Although targeting OSW reduces efficiency due to their lower PAF, it is likely that their inclusion would be easier to implement. Although survey data suggest few transitions from OSW to FTSW, it is likely that a FSW's client volume fluctuates and so the distinction between full and occasional sex work may be blurred and difficult to assess in the field.

### Limitations of the Model

Our modeling analysis had limitations. First, the model did not include the full heterogeneity of the sexually active subgroups or preferential like-with-like sexual mixing between individuals of the same sexual risk because of a paucity of data in this setting. This might be a contributing factor to the high HIV prevalence predicted in 2010. Furthermore, after 2000, there was little HIV prevalence data from Bobo-Dioulasso that could be used for model fitting, with the demographic and health survey aggregating data across the region. However, despite the higher prevalence predicted by our model in 2010 as compared with the demographic and health survey estimates,

this is consistent with surveillance data from antenatal clinics in Bobo-Dioulasso, where prevalence was 4.2% (95% CI: 3.9 to 4.5) in 2007.<sup>78</sup> Second, although the model assumed more conservative efficacy estimates for the impact of ART on HIV infectivity, our results should be considered cautiously because there are little data on the efficacy of ART in high-risk populations. Instead, data on genital shedding of HIV from FSWs in this setting was used to estimate the likely efficacy of ART, but this method has not been validated; nor is it not known if low levels of HIV-1 RNA detected in women on ART represents infectious virus. Third, we did not include the possible development of antiretroviral drug resistance in our model, which could diminish impact or increase future costs.<sup>15</sup> Finally, we allowed individuals lost to follow-up to be recruited back onto ART, and so our projections could be optimistic.

In conclusion, our modeling suggests that targeting ART to FSWs in concentrated epidemic settings, such as in Bobo-Dioulasso, could be a highly efficient strategy for reducing HIV transmission and supports intervening in high-risk groups early in younger epidemics. The success of such an intervention depends on continuing investment in condom promotion. However, it is important to acknowledge that targeting FSWs may require more investment in increasing access to care through dedicated clinics, including adherence support, than for the general population, which could reduce efficiency gains seen in this model.<sup>79</sup> Furthermore, structural and legal barriers to FSW gaining access to care are considerable in most countries, and addressing these will be imperative to see any real success of targeted TasP.<sup>19,72</sup>

### ACKNOWLEDGMENTS

*The authors wish to thank the women and the organizations of persons living with HIV/AIDS (“Yérelon,” “Espoir et Vie,” Centre “Solidarité Action Sociale” and “Espoir pour Demain”) who participated in this study and staff at Service d’Hygiène, Bobo-Dioulasso, Burkina Faso. The authors also want to thank Charlotte Huet, Dramane Kania, Diane Valea and Antoinette Kabore for their invaluable assistance.*

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## APPENDIX 1. Composition of the Yérelon Study Group

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