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Original Contribution

Anal Intercourse Among Female Sex Workers in Côte d'Ivoire: Prevalence, Determinants, and Model-Based Estimates of the Population-Level Impact on HIV Transmission

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Current evidence suggests that anal intercourse (AI) during sex work is common in sub-Saharan Africa, but there have been few studies in which the contribution of heterosexual AI to human immunodeficiency virus (HIV) epidemics has been investigated. Using a respondent-driven sampling survey of female sex workers (FSWs; $n = 466$) in Abidjan, Côte d'Ivoire, in 2014, we estimated AI prevalence and frequency. Poisson regressions were used to identify AI determinants. Approximately 20% of FSWs engaged in AI during a normal week (95% confidence interval: 15, 26). Women who performed AI were generally younger, had been selling sex for longer, were born in Côte d'Ivoire, and reported higher sex-work income, more frequent sex in public places, and violence from clients than women not reporting AI. Condom use was lower, condom breakage/slippage more frequent, and use of water-based lubricants was less frequently reported for AI than for vaginal intercourse. Using a dynamic transmission model, we estimated that 22% (95% credible interval: 11, 37% of new HIV infections could have been averted among FSWs during 2000–2015 if AI had been substituted for vaginal intercourse. Despite representing a small fraction of all sex acts, AI is an underestimated source of HIV transmission. Increasing availability and uptake of condoms, lubricants, and pre-exposure prophylaxis for women engaging in AI could help mitigate HIV risk.

anal sex; HIV/AIDS; Côte d'Ivoire; female sex worker; mathematical model; respondent-driven sampling; West Africa

Abbreviations: AI, anal intercourse; CI, confidence interval; CrI, credible interval; FSW, female sex worker; HIV, human immunodeficiency virus; PAF, population attributable fraction; RDS, respondent-driven sampling; VI, vaginal intercourse.

Female sex workers (FSWs) share a disproportionately high burden of human immunodeficiency virus (HIV) infection worldwide (1). This results from an intertwined sets of behavioral, biological, and sociostructural factors that enhance their vulnerability to HIV acquisition (2). Although sex work intersects with injecting drug use in some settings, the primary mode of HIV acquisition and transmission for FSWs is thought to be vaginal intercourse (VI). Insertive and, particularly, receptive anal intercourse (AI) carry a well-recognized heightened risk of HIV transmission as compared with VI (3, 4), which does not substantially differ between male-female and male-male contacts (5, 6). Paradoxically, the role of heterosexual AI in HIV epidemics seems to have been minimized in prevention, assuming that AI contributes little to HIV transmission despite growing evidence that this behavior is quite common among heterosexual men and women of all ages (7–9). Emerging data also suggest that AI during sex work is ubiquitous and reported by FSWs across sub-Saharan Africa, with lifetime prevalence estimates of AI ranging from 6% to 41% (10).

Collecting reliable information on AI prevalence, frequency, and determinants is key to designing more effective HIV prevention efforts. Targeted interventions among high-risk populations, such as FSWs performing receptive AI, could be an effective way to further curb HIV transmission (11). Specifically, evidence suggests that condom use during AI is lower and breakage more frequent than during VI (3, 12–14). Studies have also associated substance abuse, sexual violence, and coercion with AI practices (10, 15–17). These factors could further enhance HIV transmission during AI; understanding these vulnerability patterns remains important to prevention efforts.

Although sex work is a recognized risk factor for HIV transmission, the specific population-level impact of heterosexual AI on HIV transmission, and particularly during sex work, has rarely been studied. Recent studies show that the contribution of sex work to overall HIV transmission in Côte d'Ivoire is important (18, 19). Yet, the specific effect of receptive and insertive AI performed by FSWs and clients, respectively, on population-level HIV transmission remains unknown. Even if only a small proportion of individuals practice AI during commercial sex, this effect could also extend beyond FSW-client partnerships through further sexual mixing of clients with women not engaging in sex work.

With the ultimate goal of improving HIV prevention strategies relative to FSWs, this paper addresses 2 separate objectives. First, a respondent-driven sampling (RDS) survey conducted among FSWs in Côte d'Ivoire was analyzed to estimate AI prevalence and frequency, and to identify the determinants of this practice. Second, the population-level impact of AI during sex work on HIV transmission was estimated for Côte d'Ivoire by using a dynamic transmission model. This will enable us to assess the contribution of AI to the HIV epidemic and help inform prevention activities.

METHODS

Study design and population

A cross-sectional RDS survey was conducted among FSWs in Abidjan, Côte d'Ivoire, during March–July 2014. The survey collected information on HIV prevalence, sexual behaviors, reproductive health, and engagement in HIV prevention and treatment services. The study design and recruitment procedure have been described elsewhere (20, 21). Briefly, RDS is a network-based technique used to sample hard-to-reach populations (22). The technique starts with a convenience sample of "seeds," who then recruit other members of this population, using a chain-referral procedure (23). Five seeds were selected in Abidjan and each participant could recruit a maximum of 3 FSWs until the target sample size ($n = 466$), based on convergence of HIV prevalence, was met. Eligibility criteria for participation were being assigned female gender at birth, being older than 18 years, reporting more than half of income from sex work, and having resided in Abidjan for the past 3 months.

Structured questionnaires were administered face to face by trained interviewers in French or English. With respect to sexual behaviors, participants were asked how many sexual partners they usually have (including clients and nonpaying partners) during a "normal week," the number of VI and AI acts performed, and frequency of condom use in the past year for VI and AI. Women were then asked the number of new clients, regular clients, and nonpaying partners with whom they had VI and AI during the past month. From this set of questions, we estimated AI prevalence and frequency during a normal week, and AI prevalence during the past month. AI prevalence during past year was indirectly derived from the question about condom use during AI over the past 12 months. If women had not practiced AI during the past year, this was recorded in the questionnaire by using the "not applicable" response option. Self-reports of clinical sexually transmitted infection diagnosis in the past 12 months were also collected.

Upon completion of the questionnaire, a trained nurse provided HIV counseling and testing. HIV status was determined using a testing algorithm composed of 3 rapid tests: Determine HIV-1/2 Ag/Ab Combo (Alere, Inc., Waltham, Massachusetts), HIV 1/2 STAT-PAK (Chembio Diagnostic Systems, Inc., Medford, New York), and Genie III (Bio-Rad Laboratories, Inc., Hercules, California) (20).

Statistical analyses

Descriptive statistics are presented as crude and adjusted estimates based on RDS sampling weights (i.e., RDS II) (24). Confidence intervals were calculated for crude and adjusted estimates by clustering the standard errors at the recruiter level.

To examine determinants of AI, univariate and multivariable Poisson regression models were used to estimate prevalence ratios. Weekly prevalence of AI was chosen as the outcome because it had no missing value and was directly measured in the questionnaire (AI during the past year was indirectly ascertained). Potential determinants of AI were considered that had few missing values, were accurately measured, and for which an association with AI was previously reported or was deemed plausible. These included age, time since first paid sex, weekly number of sexual partners, weekly income from sex work, education level, country of birth, marital status, religion, having sex with clients in public places, sharing of earnings with someone providing a service for sex work, drug consumption in the past year, excessive alcohol drinking, clients using violence or force in past year to have certain types of sexual intercourse, knowledge that AI carries the highest HIV risk, and consistent condom use for VI during past year. Clustering of participants by recruiter was taken into account by using generalized estimating equations and an exchangeable correlation structure (25). Continuous independent variables were entered in the model by using natural cubic splines with 2 degrees of freedom (26). Observations with missing values for the covariates ($n = 5$) were removed from the analyses.

The association between AI exposure and HIV prevalence or sexually transmitted infection was also examined for different exposure definitions. Given the lack of balance between covariates between those reporting and not reporting AI, nearest-neighbor matching on the Mahalanobis distance was applied (27). We matched on covariates based on our a priori knowledge of potential confounders. These included age, time since first paid sex, weekly number of sexual partners, weekly income from sex work, consistent condom use during the past year for VI, country of birth, marital status, performing sex work in public places, and excessive alcohol consumption. Results from unmatched and matched Poisson regressions are presented. All statistical analyses were performed using the R statistical software (R Foundation for Statistical Computing, Vienna, Austria) (28) and relevant analytic packages (29–32).

Modeling population-level effect of AI on HIV transmission

A previously described, age-stratified, dynamic model of HIV transmission was developed for Côte d'Ivoire and calibrated to local epidemiologic and programmatic data (33, 34). The model

Table 1. Characteristics of Surveyed Female Sex Workers (n = 466), Abidjan, Côte d'Ivoire, 2014

Characteristic	Crude Estimate	95% CI	RDS-Adjusted Estimate	95% CI
Sociodemographic characteristics				
Age, years	28	27, 28	27	26, 28
Country of birth, %				
Côte d'Ivoire	76	70, 81	80	74, 86
Nigeria	23	18, 29	18	13, 25
Other	2	1, 3	1	1, 3
Education, %				
No school/outside system/other	18	15, 22	20	15, 27
Some or completed primary	33	29, 38	39	32, 45
Incomplete secondary	43	38, 48	37	30, 43
Completed secondary or higher	6	5, 9	5	3, 8
Currently married	7	4, 10	7	4, 12
Religion[a], %				
Muslim	13	10, 17	13	8, 19
Christian	77	72, 81	78	70, 83
Other	10	8, 14	10	7, 14
Sex work characteristics				
Age at first paid sex, years	22	21,22	20	19, 21
Time since first paid sex, years	6	5, 7	7	6, 8
Has sex with clients in public places, %	18	15, 22	19	14, 25
No. of sexual partners per normal week[b]	31	27, 34	32	27, 36
No. of sex acts per normal week[c]				
VI	32	29, 35	32	28, 37
AI	1	1, 2	2	1, 3
Prevalence of AI[c], %				
During a normal week	19	15, 23	20	15, 26
During past month[d]	21	18, 26	24	18, 30
During past year[e]	22	18, 26	24	18, 30
Proportion of weekly sex acts that are AI	3	2, 4	4	2, 6
Proportion of weekly sex acts that are AI among FSWs who report weekly AI[f]	17	14, 21	21	15, 28
Knowledge that AI carries the highest HIV risk[g]	5	4, 8	6	4, 9
Condom use over past year[c], %				
VI				
Never	0	0, 2	0	0, 1
Almost never	1	0, 2	1	0, 5
Sometimes	8	6, 11	10	6, 14
Often	52	47, 56	57	50, 63
Always	39	34, 44	33	27, 39
AI[h]				
Never	32	24, 42	28	18, 41
Almost never	1	0, 7	1	0, 5
Sometimes	17	11, 26	12	7, 22
Often	21	14, 30	30	18, 45
Always	29	22, 38	29	19, 42

Table continues

Table 1. Continued

Characteristic	Crude Estimate	95% CI	RDS-Adjusted Estimate	95% CI
Average price charged per act (USD)[i]				
VI with condom[j]	8	7, 9	8	7, 10
VI without condom[k]	28	23, 33	25	19, 30
AI with condom[l]	25	17, 33	20	14, 26
AI without condom[m]	33	22, 43	27	19, 36

Abbreviations: AI, anal intercourse; CI, confidence interval; HIV, human immunodeficiency virus; RDS, respondent-driven sampling; VI, vaginal intercourse.

[a] Missing 1 value.

[b] Includes new clients, regular clients, and nonpaying partners with whom vaginal, anal, or oral intercourse was performed.

[c] With any partner types.

[d] Missing 14 values.

[e] One woman who did not report AI during the past year but who did so during a normal week was recoded as having performed AI during past year, because the question about AI during a normal week was directly asked.

[f] $n = 86$.

[g] Missing 1 value.

[h] $n = 100$ and there is 1 missing value.

[i] Exchange rate: 1 CFA = 0.002 USD.

[j] $n = 464$ and there is 1 missing value.

[k] $n = 178$ and there are 2 missing values.

[l] $n = 73$ and there is 1 missing value.

[m] $n = 53$ and there is 1 missing value.

represents an open population of sexually active individuals stratified by age (15–19, 20–24, 25–49, and 50–59 years). Behavioral heterogeneity is incorporated in the model through the following mutually exclusive groups: low-risk women, high-risk women (>1 partner per year), FSW not practicing AI, FSW practicing AI, low-risk men, high-risk men (>2 partners per year), clients of FSWs, bisexual men who have sex with men, and exclusive men who have sex with men.

In this model, the force of HIV infection depends on the number and type of sexual partners, and associated HIV prevalence, infectiousness (which varies by disease stage, antiretroviral therapy status, and viral suppression), sexual mixing between age and risk groups, the fraction of condom-protected sexual acts, and the uninfected partner's susceptibility. For the latter, we assumed that young women have higher risk of HIV acquisition (35, 36) and that insertive/receptive AI also increases susceptibility. Specifically, receptive AI increased risk of HIV transmission by a factor varying between 2 and 20 as compared with receptive VI, and insertive AI by a factor of 2 as compared with insertive VI (4). Based on the proportion of FSWs reporting AI during the past year in the RDS survey, women entering the sex trade are assumed to either engage in AI at a certain frequency or not until they retire from sex work (recruitment in or out of sex work is independent of age).

The model was parameterized after a comprehensive review of the scientific and gray literature. Because we modeled HIV transmission in Côte d'Ivoire from the 1970s onward, other FSW surveys were also used to parametrize and calibrate the model. The full list of model parameters can be found elsewhere (33). Uncertainty associated with the model's parameters was captured through the elicitation of prior distributions. The model was then calibrated to HIV prevalence and coverage of antiretroviral therapy, using a Bayesian framework with incremental mixture importance sampling (37). Additional information on sexual mixing patterns, the model's equations, the estimation of historical trends in condom use, HIV testing and antiretroviral therapy coverage, and selected model fits are presented elsewhere (33, 34).

The contribution of AI performed by FSWs with their partners on HIV transmission was estimated using the population attributable fraction (PAF) calculated over the 2000–2015 period. The PAF is the proportion of the cumulative number of new HIV infections occurring over a certain time that would not have been acquired had the risk factor (i.e., the excess risk of AI vs. VI) been removed. This was achieved by setting the relative risk of insertive/receptive AI versus VI to 1. In other words, we assumed that AI acts were substituted with VI acts. Two scenarios were investigated: First the impact of AI alone was considered; second, the PAF also took into account the reduced condom use during AI by increasing condom use to the same fraction as for VI.

Ethics

All women were informed about the study procedures and they provided written informed consent before the interview. The study was approved after ethical review by the Comité national d'éthique et de la recherche in Côte d'Ivoire, the Johns Hopkins School of Public Health Institutional Review Board in the United States, and the Imperial College Research Ethics Committee in the United Kingdom.

RESULTS

The 5 seeds recruited 593 women, of whom 466 met the eligibility criteria and consented to participate. The average age of

Table 2. Prevalence and Frequency of Vaginal or Anal Intercourse and Consistent Condom Use During the Past Month Among Female Sex Workers by Partner Type (n = 466), Abidjan, Côte d'Ivoire, 2014

Characteristic	Denominator for Survey Question	No. of Missing Values	Crude Estimate, %	95% CI	RDS-Adjusted Estimate, %	95% CI
With new clients						
Fraction reporting AI	462	5	12	9, 15	13	9, 18
Consistent condom use for VI	462	7	77	73, 81	75	68, 80
Consistent condom use for AI	55	0	49	36, 62	47	30, 65
Condom use at last VI or AI	462	6	87	84, 90	89	85, 93
With regular clients						
Fraction reporting AI	461	1	14	11, 18	13	10, 18
Consistent condom use for VI	461	3	67	62, 72	64	57, 70
Consistent condom use for AI	65	0	37	27, 49	36	22, 53
Condom use at last VI or AI	461	1	82	78, 85	80	73, 85
With nonpaying partners						
Fraction reporting AI	451	5	11	9, 14	14	10, 19
Consistent condom use for VI	451	36	5	4, 8	4	2, 7
Consistent condom use for AI	50	1	8	3, 20	5	1, 17
Condom use at last VI or AI	451	1	13	10, 17	13	9, 18

Abbreviations: AI, anal intercourse; CI, confidence interval; RDS, respondent-driven sampling; VI, vaginal intercourse.

participants was 27 years (range, 18–57 years). Most of the FSWs were born in Côte d'Ivoire, had some secondary education, and had been selling sex for an average of 6 years (Table 1).

RDS-adjusted estimates of prevalence and frequency of AI

Approximately 20% of FSWs reported performing AI during a normal week (95% confidence interval (CI): 15, 26; Table 1). This increased slightly to 24% (95% CI: 18, 30) if the recall period extended to the past month and 24% (95% CI: 18, 30) over the past 12 months, which suggests relative consistency of AI practice over the course of a year. Among all FSWs, the average frequency of AI was 1.9 (95% CI: 0.8, 2.9) acts per week compared with 32 (95% CI: 28, 37) VI acts per week, resulting in 4% (95% CI: 2, 6) of all sex acts being AI. If restricted to FSWs reporting weekly AI, the fraction of all sex acts that were AI reached 21% (95% CI: 15, 28). Knowledge that AI carries the highest sexual HIV risk was reported by only 6% of surveyed FSWs (95% CI: 4, 9).

Among FSWs who engaged in AI during past year, 82% (95% CI: 70, 90) reported often or always using a condom during VI, compared with 59% (95% CI: 46, 71) during AI (28% never used a condom during AI; 95% CI: 18, 41). Condom breakage/slippage during the past month was more frequently reported by women who had engaged in AI in the past month: 38% (95% CI: 25, 53) for those reporting AI compared with 21% (95% CI: 15, 29) for those not reporting it. This could be because use of appropriate water-based lubricants were less frequently reported for AI (9%; 95% CI: 5, 17) than for VI (27%; 95% CI: 21, 33). In Abidjan, the average price for VI protected by a condom was US $8 (95% CI: 7, 10) compared with an average price almost 3 times higher without condom ($25; 95% CI: 19, 30). Condom-protected AI was about twice as expensive as condom-protected VI ($20 USD; 95% CI: 14, 26). Condomless AI was the priciest ($27; 95% CI: 19, 36).

AI was commonly and similarly reported with all partner types: AI prevalence during the past month was 13% (95% CI: 9, 18) with new clients, 13% (95% CI: 10, 18) with regular clients, and 14% (95% CI: 10, 19) with nonpaying partners (Table 2). Consistent condom use for VI, however, varied markedly by partner type and was much lower during AI for new and regular clients, and similarly low with nonpaying partners (Table 2).

Determinants of AI during a normal week

In univariate analyses, most variables were associated with weekly AI prevalence (Table 3). After adjustment for potential confounders, results from the multivariable regression showed that AI prevalence declined with FSW age but increased with time since first paid sex (Web Table 1, available at https://academic.oup.com/aje). There was also a positive association between reports of weekly AI and income from sex work (Web Table 1). Women born outside of Côte d'Ivoire were 80% less likely to report AI than those born in the country (prevalence ratio = 0.20, 95% CI: 0.05, 0.86). Women who had sex with clients in public spaces (prevalence ratio = 2.20, 95% CI: 1.50, 3.24) and women reporting sexual violence from clients (prevalence ratio = 1.75, 95% CI: 1.20, 2.56) were more likely to report AI than those who did not report such experiences.

Associations among AI, HIV, and sexually transmitted infection

Women who reported performing AI during a normal week were less likely to test positive for HIV (5.7% HIV positive;

Table 3. Determinants of Anal Intercourse (During a Normal Week) Among Female Sex Workers[a] (n = 461), Abidjan, Côte d'Ivoire, 2014

Characteristic	PR	95% CI[b]	aPR[c]	95% CI[b]
Age[d]	(Splines)		(Splines)	
Time since first paid sex[d]	(Splines)		(Splines)	
Weekly no. of sex partners[d]	(Splines)		(Splines)	
Weekly income from sex work[d]	(Splines)		(Splines)	
Education				
No education	1.00	Referent	1.00	Referent
Some/completed primary	1.34	0.77, 2.35	0.96	0.57, 1.60
Secondary or higher	0.79	0.45, 1.38	0.89	0.54, 1.49
Foreign born	0.08	0.02, 0.30	0.20	0.05, 0.86
Currently married (vs. not or formerly married)	0.15	0.02, 1.18	0.20	0.03, 1.24
Religion				
Muslim	1.00	Referent	1.00	Referent
Christian	1.04	0.53, 2.05	1.17	0.61, 2.25
Other	1.60	0.70, 3.64	1.23	0.58, 2.61
Has sex with clients in public places	3.90	2.76, 5.52	2.20	1.50, 3.24
Share earnings with someone who provides a service for sex work	1.63	1.10, 2.42	0.97	0.63, 1.51
Consumed drugs in past year	2.38	1.51, 3.76	1.19	0.74, 1.92
Consumed >6 alcoholic drinks on 1 occasion every week	2.12	1.43, 3.14	0.96	0.63, 1.46
Clients used violence or force to have certain types of sexual intercourse (past year)	2.66	1.82, 3.90	1.75	1.20, 2.56
Knows that AI carries the highest HIV risk	1.51	0.76, 3.02	1.07	0.61, 1.89
Consistently used a condom for VI during past year	0.32	0.18, 0.56	0.61	0.35, 1.06

Abbreviations: aPR, adjusted prevalence ratio; CI, confidence interval; HIV, human immunodeficiency virus; PR, prevalence ratio.

[a] According to Poisson regression models with robust/clustered standard errors.

[b] Estimates were adjusted for clustering of standard errors by recruiter (respondent-driven sampling weights were not incorporated).

[c] Multivariable results are mutually adjusted for all variables listed in the table. A complete case analysis was used, and 5 observations with missing values were removed.

[d] Natural cubic splines with 2 degrees of freedom. Graphic representations of the splines are presented in Web Table 1.

95% CI: 1.9, 16.0) than those who did not perform AI (12.6% HIV positive; 95% CI: 8.4, 18.0). However, when looking at the association between HIV and exposure to AI over longer recall periods, the estimates became closer to the null value (Table 4). After matching on potential confounders to minimize imbalances, exposure to AI reported over the past month or past year was positively associated, albeit not significantly, with testing positive for HIV. AI was not associated with reports of having been diagnosed with a sexually transmitted infection, but all the effect size measures had large confidence intervals.

Population-level impact of AI performed by FSWs on HIV transmission

Selected model parameters, their prior distribution, and the posterior distributions are summarized in Table 5. The posterior median size of the FSW population was 1.6% (95% credible interval (CrI): 1.1, 2.2) of the female population aged 15–59 years. The posterior fraction of FSWs engaging in AI and the proportion of AI sex acts for this group had medians of 25% (95% CrI: 20, 29) and 21% (95% CrI: 15, 26), respectively. Finally, the posterior median of the relative risk of receptive AI, versus receptive VI, was 6.3 (95% CrI: 3.0, 11.1; it was fixed at 2 for insertive AI).

The fraction of new HIV infections due to AI among FSWs over the years 2000–2015 was estimated at 22% (95% CrI: 11, 37) when we assumed that condom use remained unchanged for these AI acts (Web Figure 1). Among clients, this PAF was estimated at 9% (95% CrI: 4, 16) for the same period. Overall, if all AI acts performed by FSWs were replaced by VI acts, a total of 4% (95% CrI: 2, 9) of new HIV infections would have been averted at the population level over the 2000–2015 period (Web Figure 1). Because condom use is lower for AI than for VI, PAF can also be computed by replacing all AI acts with VI acts and protecting them with a condom at the same rate as for VI acts. Doing so, the PAF estimates are slightly higher, with

Table 4. Associations Among Exposure to Anal Intercourse and HIV Prevalence and Reports of Sexually Transmitted Infection Diagnosis in the Past 12 Months in a Cross-Sectional Sample of Female Sex Workers, Abidjan, Côte d'Ivoire, 2014

Outcome and Anal Intercourse Frequency	Sample Size	Unmatched Regressions[a]				Matched Regressions[a,b]			
		Univariate		Multivariable[c]		Matched		aPR	95% CI
		PR	95% CI	aPR	95%CI	AI	No AI		
HIV prevalence									
AI during normal week	451	0.38	0.14, 1.01	0.46	0.23, 0.95	85	63	0.41	0.13, 1.25
AI during past month	438	0.51	0.22, 1.18	0.79	0.42, 1.48	94	69	1.18	0.48, 2.89
AI during past year	451	0.67	0.33, 1.35	0.77	0.42, 1.41	100	75	1.08	0.43, 2.70
Diagnosed with an STI[d] by a doctor or health worker in the past 12 months									
AI during normal week	462	1.28	0.82, 2.02	0.93	0.58, 1.49	84	63	1.07	0.58, 1.95
AI during past month	448	1.10	0.69, 1.76	0.79	0.48, 1.29	95	68	0.97	0.52, 1.79
AI during past year	462	1.09	0.70, 1.72	0.85	0.54, 1.34	99	75	0.99	0.54, 1.81

Abbreviations: AI. anal intercourse; aPR, adjusted prevalence ratio; CI, confidence interval; PR, prevalence ratio; STI, sexually transmitted infection.

[a] Poisson regression model with robust/clustered standard errors were used. Estimates were adjusted for clustering of standard errors by recruiter identification (respondent-driven sampling weights were not incorporated).

[b] Women who reported having AI were matched using a nearest-neighbor matching algorithm based on minimizing the Mahalanobis distance to the following covariates: age, time since first paid sex, weekly number of sexual partners, weekly income from sex work, consistent condom use during past year for VI, country of birth, marital status, having sex with clients in public places, and having consumed more than 6 alcoholic drinks on 1 occasion every week or more often.

[c] Multivariable models were adjusted for the following covariates: age (natural spline with 2 degrees of freedom), time since first paid sex (natural spline with 2 degrees of freedom), weekly number of sexual partners (natural spline with 2 degrees of freedom), weekly income from sex work (natural spline with 2 degrees of freedom), consistent condom use during past year for VI, country of birth (Côte d'Ivoire vs. other), marital status (married vs. other), having sex with clients in public spaces, and having consumed more than 6 alcoholic drinks on 1 occasion every week or more often.

[d] Includes syphilis, gonorrhea, chlamydia, herpes, human papillomavirus, hepatitis B, and hepatitis C, among others.

26% (95% CrI: 13, 41) of new HIV infections averted among FSWs, 11% (95% CrI: 6, 20) among clients of FSWs, and 6% (95% CrI: 3, 11) in the whole population.

DISCUSSION

As many as one-fifth of FSWs in Abidjan reported practicing AI weekly and approximately one-fourth did so during the past year. FSWs reported practicing AI with all partner types in relatively equal proportions. Among those practicing AI, anal sex accounted for about 21% of their weekly sex acts. This meant that about 22% of new HIV infections in FSWs may be due to AI and could have been averted if VI had been practiced instead. At the population level, even if FSWs constitute 1.6% (95% CrI: 1.1, 2.2) of the female population and only 3%–7% of all sex acts performed by FSWs are AI, we estimated that AI practiced during sex work could account for 4% (95% CrI: 2, 9) of all new HIV infections during 2000–2015. This estimate does not consider women not engaging in sex work who do engage in AI, and the figure should be considered conservative.

The prevalence of AI observed in this study is consistent with that reported in other studies of FSWs in sub-Saharan Africa (10). We found that women born outside of Côte d'Ivoire were less likely to report AI than those born in the country, but religion was not associated with AI prevalence. Our results also suggest that young women, those having sex in public spaces, and those who have been selling sex for longer were the most likely to practice AI, highlighting a heightened pattern of vulnerability. Sexual violence and coercion have often been associated with AI (10, 15, 17, 38) and FSWs reporting sexual violence by clients in Abidjan were 75% more likely to have engaged in AI. If AI is performed in a context of sexual violence, the HIV risk posed by this practice could be higher, because traumatic abrasions of the rectal mucosa can facilitate transmission (10, 39). On the other hand, AI was also reported by women who had higher weekly income and the price charged for AI was more than twice that of VI. Given such financial incentives, AI may not always be performed in a coercive context. Reflecting low awareness of HIV risk associated with AI, condom use was low, with 28% of women never using condom during AI.

In this cross-sectional sample of FSWs, we did not find any consistent associations between AI reports and HIV prevalence. First, AI practice was measured over short periods and our exposure measurements may not reflect this behavior at the time of HIV infection. Second, the lack of association could be due to unmeasured confounders. Third, there were strong covariate imbalances between women engaging in AI and those who did not. Matching was used to alleviate this issue, but the resulting matched sample sizes for these analyses were small, leading to wide confidence intervals. Findings from cross-sectional studies on the association between AI

Table 5. Main Parameters Used in the Mathematical Model, Elicited Prior Distributions, and Posterior Distributions After Model Calibration to Epidemiologic and Intervention Coverage Data in the Study of Female Sex Workers (n= 466), Abidjan, Côte d'Ivoire, 2014

Parameter	Prior Distribution[a]	Posterior Median	95% CrI	Reference for Prior Distributions
Demographic				
FSWs among women[b], %	U(0.8, 1.7)*U(1.0, 1.7)	1.6	1.1, 2.2	51–56
Clients of FSWs among men[c], %	<20	15	10, 19	
Annual turnover rate from FSWs to non-FSW	U(0.05, 0.20)	0.11	0.07, 0.18	Assumption
Behavioral, per year				
FSW partner change rate	U(216, 360)	284	225, 348	40, 42, 57, 58
Clients of FSW partner change rate	U(23,37)	31	24, 36	59
Clients of FSW partner change rate with women not working in the sex trade	U(1.0, 6.8)	5.4	3.6, 6.5	56, 60, 61
No. of sex acts per client-FSW partnership (per partnership per year)	U(1,4)	2.5	1.7, 3.4	61
HIV transmission probability per act				
Female-to-male	U(0.013, 0.141)	0.089	0.056, 0.128	5
Male-to-female	U(0.060, 0.109)	0.089	0.063, 0.106	5
Changes in HIV transmission probability				
RR of HIV acquisition for women 15–24 years old vs. those aged ≥25 years per act	U(1.25, 2.5)	2.0	1.5, 2.5	35, 36
RR of HIV transmission per act	T(9.2, 4.5, 18.8)			
During acute infection	T(0.5, 0.3, 0.8)	8.6	5.6, 12.6	5
For individuals receiving ART (detectable viral load)	T(0.04, 0.01, 0.27)	0.5	0.4, 0.7	Assumption
For individuals receiving ART (virally suppressed)	U(0.75, 0.94)	0.12	0.03, 0.22	62
When sex act is protected by a condom		0.83	0.77, 0.91	Based on 63
Condom use by FSWs with clients[d], %	U(57, 68)			
In 1991	U(85, 93)	62	58, 67	40
In 2014		88	86, 92	20, 57
AI parameters	U(18.3, 29.9)			
FSW who engage in AI, %	U(14.8, 27.6)	25	20, 29	Our analysis
Sex acts that are anal for FSWs that engage in AI, %	T(2, 10, 20)	21	15, 26	Our analysis
RR of HIV acquisition of receptive AI as compared with receptive VI, per act	2	6.3	3.0, 11.1	4
RR of HIV acquisition of insertive AI as compared with insertive VI, per act	T(0.75, 0.61, 0.92)	2		4
Relative reduction in proportion of protected sex acts for AI vs. VI[e]	U(0.8, 1.7)*U(1.0, 1.7)	0.75	0.66, 0.85	Our analysis

Abbreviations: AI, anal intercourse; ART, antiretroviral therapy; CrI, credible interval; FSW, female sex worker; HIV, human immunodeficiency virus; RR, relative risk; VI, vaginal intercourse.

[a] *T*(m,a,b), indicates a triangular distribution in which m is the mode, a is the minimum, and b is the maximum. *U*(a,b) indicates a uniform distribution in which a is the minimum and b is the maximum.

[b] The prior distribution for the size of the FSW population was parameterized by multiplying the size of the population of men who have sex with men by a uniform prior distribution for the ratio of FSWs to men who have sex with men to keep the size of the former larger than the latter.

[c] The proportion of clients of FSWs was indirectly estimated using the multiplier method, balancing the partner change rate reported by FSWs and by clients of FSWs. The proportion of clients of FSW was constrained to be less than 20%.

[d] Only selected years are presented. Full details can be found in Maheu-Giroux et al. (33).

[e] To predict condom use at past AI or VI act, we modeled the relationships between condom use at past VI and the frequency of condom use during past year (ordinal responses). We then predicted condom use at past sex act for AI and VI separately on the basis of the ordinal frequency responses, and calculated their ratio.

and HIV prevalence were also found to be inconsistent in a recent review (10). Prospective studies of the effect of sexual risk behaviors on HIV incidence are more appropriate to determine causality and there is, indeed, strong empirical evidence that AI enhances HIV risk (6). A recent meta-analysis of per-act probabilities of HIV transmission for unprotected receptive AI found them to be substantially higher than those of male-to-female VI (6).

Our results need to be interpreted in light of several limitations. First, estimating AI prevalence among FSWs is challenging for several reasons: The practice can be stigmatized, is often taboo, and the AI questions can be misunderstood. This can affect the accuracy of self-reports and AI can potentially be underestimated because of social desirability bias (6). Furthermore, AI could be underreported in face-to-face interviews such as the one conducted in this study (10). Second, these challenges are further compounded by difficulties related to selecting representative samples of FSWs, who constitute a hard-to-reach and marginalized population. This, along with the characteristics of the different survey instruments, could explain why FSWs in our sample generally reported higher numbers of sexual acts than in previous studies in Côte d'Ivoire (40–42). Third, the dynamic model used to assess the population-level impact of AI on HIV transmission assumed that AI behaviors are constant over time and do not change as long as the women are involved in sex work. Given the cross-sectional nature of this survey, disentangling cohort and period effects on AI prevalence would have been challenging. A sensitivity analysis examining the influence of different parameters on the PAF estimates nevertheless showed that the most important source of parameter uncertainty was the relative risk of receptive AI versus receptive VI, and not AI prevalence, frequency, or condom use during AI (Web Figure 2). Finally, our results do not account for other modes of HIV transmission, such as through blood exposures. This is unlikely to affect our PAF estimates, however, because injecting drug use is uncommon in Abidjan (43) and unsafe medical injections are now believed to account for a small proportion of incident HIV infections in sub-Saharan Africa (44–47). However, this assumption has been challenged in the past (48–50) and necessitates ongoing surveillance to assess prevalence of unsafe injections and ultimate parenteral HIV acquisition risk in Côte d'Ivoire.

The study's strengths include the detailed characterization of AI practice and quantification of the population-level of AI during sex work on HIV transmission. The high PAF observed for AI among FSWs suggests potential opportunities for further targeted interventions. Specifically, this study highlighted that, among FSWs in Côte d'Ivoire, condom use during AI and knowledge of HIV risk associated with AI are low.

In conclusion, AI is commonly practiced among FSWs and their partners in Côte d'Ivoire. Despite representing only a small fraction of total sex acts performed by FSWs, AI is an important and underappreciated factor for HIV acquisition and transmission in this group. More attention should be paid to this risk factor in product development and prevention. Transmission risk associated with AI could be mitigated through increased condom use and promotion of appropriate water-based lubricants to reduce condom breakage during AI. Given the important financial incentives associated with condomless AI and the context of violence and coercion associated with this practice, effecting these measures could prove challenging, however. In such instances, the use of pre-exposure prophylaxis for women engaging in AI could be considered.

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