HIV risk and prevention among sex workers: a focus on structural determinants and interventions

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Copyright declaration

Declaration of originality

I declare that the work presented in this thesis is my own work. Contributions from others are appropriately acknowledged and I have appropriately cited all references to the published work of others. This thesis was supervised by Professor Marie-Claude Boily (Imperial College London), Dr Michael Pickles (Imperial College London), and Dr Kate Shannon (University of British Columbia).

Abstract

HIV disproportionately affects female sex workers (FSWs), so it is unlikely that an effective and sustained HIV response will be achieved without effective HIV prevention strategies and interventions for FSWs. Emerging evidence highlights the important role of structural factors, such as violence, in risk of HIV acquisition and transmission among FSWs, so structural prevention approaches will be crucial for an effective HIV response in FSWs. To inform the design and implementation of effective structural HIV prevention approaches for FSWs, it is essential to better understand the patterns and effects of structural HIV determinants, and the effectiveness of different types of structural interventions on reducing HIV transmission.

In this thesis, I investigate violence against FSWs, a key and pervasive structural determinant of HIV in the sex work context. I use a combination of statistical analysis and mathematical modelling to investigate the burden and determinants of violence against FSWs, to better understand the effects of violence against FSWs and contribution of violence against FSWs to HIV transmission, and to estimate the potential impact of violence interventions for FSWs on HIV transmission. The statistical analyses I conduct and the dynamic mathematical models of violence and HIV I develop and utilise in this thesis are focussed in two settings: Mombasa, Kenya and Vancouver, Canada. In Mombasa, Kenya, my statistical analyses focus specifically on young FSWs.

Taken together, the work and findings in this thesis, add to the limited literature on the burden and effects of violence among young FSWs, and extend the emerging field of modelling structural HIV determinants and structural HIV interventions in the sex work context. The findings have important implications for the HIV response among FSWs, and provide some insights for future modelling studies of violence and HIV.

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Abbreviations and acronyms

AESHA	An Evaluation of Sex Workers Health Access
AIDS	Acquired immune deficiency syndrome
AOR	Adjusted odds ratio
ART	Antiretroviral therapy
CCU	Consistent condom use
CI	Confidence interval
CrI	Credible interval
DBS	Dried blood spot
FSW	Female sex worker
HIV	Human immunodeficiency virus
HTC	HIV testing and counselling
ICU	Inconsistent condom use
IDU	Injection drug use
KASH	Keeping Alive Societies Hope
LHS	Latin Hypercube Sampling
MOT	Modes of Transmission
MSM	Men who have sex with men
ODE	Ordinary differential equation
OR	Odds ratio
PAF	Population attributable fraction
PR	Prevalence ratio
PRCC	Partial rank correlation coefficient
PrEP	Pre-exposure prophylaxis
PWID	People who inject drugs
RR	Relative risk
SSA	Sub-Saharan Africa
STI	Sexually transmitted infection
SWEAT	Sex Worker Education and Advocacy Task Force
TasP	Treatment as Prevention
UNAIDS	The Joint United Nations Programme on HIV/AIDS
WHO	World Health Organisation
YFSW	Young female sex worker

Relevant publications and presentations

A section of Chapter 1 is adapted from a systematic review paper published in *PLoS One.* The citation details for this article are shown below. This article is freely available online and is shown in Appendix A.

Mountain E, Mishra S, Vickerman P, Pickles M, Gilks C, et al. (2014) Antiretroviral Therapy Uptake, Attrition, Adherence and Outcomes among HIV-Infected Female Sex Workers: A Systematic Review and Meta-Analysis. PLoS ONE 9(9): e105645. doi:10.1371/journal.pone.0105645

The following conference and meeting presentations arose from work related to this thesis:

- Poster presentation: "Understanding the violence cycle and the impact of structural interventions on workplace violence perpetrated against female sex workers in Vancouver, Canada: Implications for HIV prevention". 8th IAS Conference on HIV Pathogenesis, Treatment and Prevention. Held in Vancouver, Canada, July 2015.
- Poster presentation: "Burden and determinants of violence and negative police interactions among young women who self-identify as sex workers in Mombasa, Kenya". 9th IAS Conference on HIV Pathogenesis, Treatment and Prevention. Held in Paris, France, July 2017.
- Oral presentation: "Violence and negative police interactions among young women who self-identify as sex workers: Early findings". Transitions study dissemination workshop. Held in Nairobi Kenya, January 2017.

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I gratefully thank Dr Marissa Becker (University of Manitoba) and Dr Sharmistha Mishra (University of Toronto) for sharing data from the Transitions study in Mombasa, Kenya with me, which I analysed in Chapters 3-5, and would also like to thank Dr Sharmistha Mishra for her technical assistance with STATA. Chapter 3 has been written up as a draft manuscript and so has benefited from the comments and review of co-authors. The co-authors of this draft manuscript include: Dr Mike Pickles, Professor Marie-Claude Boily, Parinita Bhattacharjee, Dr Marissa Becker, Dr Sharmistha Mishra, Dr Eve Cheuk, Helgar Musyoki, Dr Shajy Isac and Professor James Blanchard. I would like to thank the co-authors for their useful insights on the interpretations and implications of the results. I would also like to thank a number of the co-authors listed for their suggestions which helped refine my plan of analysis for the work presented in Chapter 4.

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Chapter 1: Introduction

1.1 Overview

The world has committed to embarking on a Fast-Track plan to end the HIV epidemic by 2030 [1,2]. Successes over the past 15 years, such as the global scale-up of antiretroviral therapy (ART) and a 48% decrease in AIDS-related death since 2005, have inspired confidence in the global community that this bold target can be achieved [1,3,4]. However, in 2016 there were still 1.8 million new HIV infections occurring worldwide [4], and the pace of decline in new HIV infections in recent years is too slow to achieve the Fast-Track target of fewer than 500,000 new HIV infections by 2020 [3].

In all settings, key populations, such as sex workers, men who have sex with men (MSM) and people who inject drugs (PWID) are disproportionately affected by HIV [5]. UNAIDS estimates suggest that as many as 50% of all new HIV infections worldwide occur in key populations [5]. Without addressing HIV in key populations, who are at high risk of acquiring and transmitting HIV, it is unlikely that an effective and sustained HIV response will be achieved [5]. The research in this thesis focuses on one of these key populations: female sex workers (FSWs).

Globally, FSWs suffer a disproportionate burden of HIV and in many HIV epidemics sex work plays a key role in HIV transmission [6]. Effective interventions for FSWs are therefore an essential component of HIV prevention programming [7]. In order to design and implement effective HIV prevention strategies for FSWs, it is critical to understand the factors that shape risk of HIV acquisition and transmission among FSWs. Emerging evidence indicates that structural factors, such as violence, are important determinants of HIV risk among FSWs [8,9]. As such, there is an increasing emphasis on incorporating structural approaches into HIV prevention for sex workers and on gaining a better understanding of the structural patterns that shape HIV risk [8-11].

Worldwide, FSWs experience high levels of violence from multiple perpetrators (e.g. clients, police, and intimate partners) [12,13]. These abuses heighten HIV risk among sex workers through multiple pathways, and undermine HIV prevention efforts [9,12,14,15]. Thus, addressing and preventing violence is a critical part of the HIV prevention response, as well as being essential for improving the safety and well-being of FSWs [11,12,15].

In this thesis, my overarching aims are to investigate the burden and determinants of violence against FSWs, better understand the effects and contribution of violence against FSWs to HIV transmission, and estimate the potential impact of violence interventions for FSWs on HIV transmission. In particular, this thesis will look in more detail at these issues in young female sex workers (YFSWs), who are a particularly vulnerable but understudied population. A key methodological approach used in addressing these aims will be mathematical modelling. Models will be developed to dynamically model violence against FSWs. The work in this thesis is set mainly in Mombasa, Kenya, and also in Vancouver, Canada. In undertaking this research, I hope to help improve our understanding of the epidemiology and effects of violence against FSWs and the potential impact of violence interventions, and in doing so help inform the design and implementation of structural HIV prevention approaches and interventions for FSWs. I also hope to provide useful insights for future model development, data collection, and methodological approaches for modelling structural determinants of HIV risk among FSWs.

In the rest of this chapter I introduce the key topics and concepts relevant to this thesis. I start with a broad overview of sex work, HIV epidemiology among FSWs, and HIV prevention, testing, and treatment among FSWs. I then introduce in greater detail structural HIV determinants and structural interventions in the sex work context, with a focus on violence against FSWs. Following this, I highlight specific vulnerabilities of YFSWs. Then, I review the role of mathematical modelling in examining the impact of HIV interventions for FSWs, and highlight the current state of the field in modelling structural determinants and structural interventions in the context of sex work. Lastly, I introduce the study settings in this thesis. I conclude this chapter with an outline of my thesis aims and chapter content.

1.2 Sex work

Sex work is often defined broadly as the exchange of sex for money, goods or other benefits [6,16-18]. Within this broad definition, there can be substantial variation in the practice of sex work within and between countries and communities, ranging from informal or intermittent sex in exchange for money or goods, to formal or commercial sex work where individuals are more likely to self-identify as sex workers and often have high client volumes [7,16-19]. Work environments are diverse, with some selling sex in formal sex work establishments (e.g. brothels or massage parlours) or entertainment venues (e.g. bars and night clubs), while others might solicit clients in public places (e.g. streets, parks) or via the internet or mobile phones [9,16]. Some sex workers may work independently, or work together in brothels, or work for a manager or pimp [9,16].

There is often inconsistency in definitions of sex work in the literature, and the distinctions between sex work, transactional sex and other financially-motivated relationships can be arbitrary and unclear [20,21]. Sometimes, transactional sex is considered separate to sex work, and is a term used to describe sex in exchange for money, goods or gifts where there is typically no explicit negotiation of the exchange and no self-identification as a sex worker, and sometimes transactional sex is a broad term used to describe a broad range of sex work including commercial sex work [21]. Even when, sex work and transactional sex work are considered to be distinct, the boundaries of these two categories are often blurred, and women may transition between transactional sex and formal sex work over time [20,21].

Nevertheless, categories of sex work and definitions of sex work are useful and necessary for research and operational purposes, to help with appraising the role of sex work in HIV epidemics, identifying priority groups in the HIV response, developing and designing targeted HIV interventions, and incorporating the needs of sex workers into HIV prevention programmes [21,22]. It is important that definitions of sex work are clear and context specific, useful for programmatic and research purposes, and used with knowledge of their limitations [17,22].

1.3 Epidemiology of HIV among FSWs

1.3.1 Burden of HIV

Since the beginning of the HIV epidemic, FSWs have been a key population disproportionately affected by HIV [7]. In many settings, HIV prevalence is much higher among FSWs than in the general population [6]. A systematic review and meta-analysis examining the burden of HIV among FSWs in 50 low and middle-income countries, estimated that FSWs had a pooled 13.9 (95% CI 10·0–18·1) times increased odds of living with HIV infection compared to women in the general population, and an overall pooled HIV prevalence of 11·8% (95% CI 11·6–12·0) [6]. There was substantial heterogeneity in estimates across regions [6]. In Sub-Saharan Africa (SSA), overall HIV prevalence among FSWs was 36.9% (95% CI: 36.2-37.5%) whilst in Eastern Europe, Latin American and the Caribbean, Asia, and Middle East and North Africa, overall HIV prevalence among FSWs was 10.9% (95% CI: 9.8-12.0%), 6.1% (95% CI: 5.7-6.6%), 5.2% (95% CI: 5.0-5.3%) and 1.7% (95% CI: 0.9-2.6%), respectively [6]. The odds ratio for HIV infection was highest for FSWs in Asia (29.2 [95% CI: 22.2-38.4]), followed by FSWs in SSA (12.4 [95% CI: 8.9-17.2]) and Latin American and the Caribbean (12.0 [95% CI: 7.3-19.7]) [6]. In a recent update to this systematic review, which included additional data for low and middle-income countries, and also expanded the search to include data on high-income countries, SSA remained the region with the highest HIV prevalence, with an overall HIV prevalence among FSWs of 29.3% (95%CI:25.0-33.8%) [23]. In high income countries, for which there was a paucity of data, the overall HIV prevalence among FSWs was 1.8% (95% CI: 0.8%-3.1%) [23]. Another more recent systematic review examined the prevalence of HIV among FSWs in the United States and estimated an overall prevalence of 17.3% (95% CI 13.5-21.9%); however there was a wide range in prevalence estimates (0.3-32%), spanning a 20 year period, with only 2 of the 14 studies identified being conducted in the last 10 years [24]. An earlier systematic review also examined HIV prevalence among FSWs in Europe, and found a low HIV prevalence (<1%) among FSWs who did not inject drugs [25].

1.3.2 Risk factors for HIV among FSWs

A variety of biological, behavioural and structural risk factors contribute to FSW's increased risk of HIV acquisition [6-8]. Biologically, for example, the high prevalence of sexually transmitted infections (STIs) and synergistic relations between HIV and STIs increase the risk of HIV acquisition among FSWs [6,8]. Behavioural factors at the individual level, such as duration of time in sex work, age of sex work initiation, injection drug use, and alcohol use, as well as behavioural factors at the partner-level, such as high number of sexual partners, more risky sexual exchanges e.g. anal sex, and inconsistent condom use, also help to shape HIV risk among FSWs [6,8]. Structural factors, which are factors that operate outside the control of the individual, such as stigma, gender inequality, physical and sexual violence, and sex work regulatory policies, can also directly or indirectly increase a FSW's risk of HIV acquisition [6,8,9]. Structural factors, which are the central focus of this thesis, are reviewed in greater detail in Section 1.5.

1.3.3 Contribution of sex work to HIV transmission

There are a number of different approaches to estimating the contribution of sex work to HIV transmission. Traditional approaches include the numerical proxy and the UNAIDS HIV modes of transmission (MOT) model, but these approaches are limited as they do not take into account chains of HIV transmission, and so can underestimate the contribution of sex work to HIV transmission [22]. Emerging approaches include estimating the population attribution fraction (PAF), which measures the fraction of HIV infections over a certain time period that are due to a given risk factor (e.g. sex work), from dynamic mathematical models [22]. Dynamic mathematical models can capture chains of HIV transmission, so this approach addresses some of the limitations of the traditional approaches [22]. There is a small, but growing body of model-based evidence that highlight the important role of sex work in HIV epidemics [22,26]. In a systematic review of mathematical modelling studies which aimed to identify modelling studies estimating the PAF of HIV infections due to high-risk groups, including FSWs, two of the studies, which were set in India, measured the PAF of sex work to HIV transmission [26]. In South India, the estimated 1-year PAF of sex work ranged between 86%-98% in males, and 12-42% in females [26,27]. In the same region, the PAF due to short-term client migration was estimated at 50% over 34 years in the total population [26,28]. Since this review, other modelling studies in India, Benin, Burkina Faso, and Cote D'Ivoire, have also estimated the contribution of sex work to HIV transmission [22,29-32]. A modelling study in Bangalore, India, estimated that 68% of new HIV infections were attributed to commercial sex work in 1986-1995 [31], and since then the PAF has declined as condom use has increased amongst key populations and HIV prevalence in the rest of the population has increased [31]. In Cotonou, Benin, it was estimated that between 1993 and 2008, sex work had contributed directly or indirectly to 93% (range: 84-98%) of all cumulative HIV infections [32]. In Bobo-Diolasso, Burkina Faso, it was estimated that 75-88% of HIV infections were attributable to commercial sex in 1985-1990, which declined to 39% in 1995-2010 as condom use increased among FSWs [29]. In Cote D'Ivoire, it was also estimated that FSWs contributed substantially to new HIV infections early in the HIV epidemic (PAF of 95% in 1976-1985), which has declined in more recent years, with FSWs estimated to contribute to 19% of HIV infections in 2005-2015 [30].

1.4 HIV prevention and treatment among FSWs

1.4.1 HIV prevention

Given the vulnerability and high burden of HIV among FSWs and the key role of sex work in HIV transmission, FSWs have been recognised as an important risk group to target for HIV prevention [7,11]. There are a number of different behavioral, biomedical and structural approaches to HIV prevention among FSWs [7,10,11]. Existing behavioural prevention strategies include promotion of condom use, control and treatment of STIs, peer-led education and HIV testing and counselling, and these prevention interventions are often core components of HIV programmes and large-scale, combination and structural interventions [7,10,11,33]. Existing structural approaches to HIV prevention, include community empowerment and prevention of violence; these approaches will be reviewed in greater detail in Section 1.6. In recent years, there has also been increasing interest in new biomedical ART-based HIV prevention approaches for FSWs [10,34-36]. Given the emerging evidence that HIV-infected individuals on ART are less likely to transmit HIV, there has been growing interest in Treatment as Prevention (TasP) for FSWs [10,34,35,37-39]. TasP is a strategy which involves expanding ART coverage among HIV-infected individuals to help reduce HIV transmission at a population-level [40]. In addition to reductions in infectiousness, early treatment initiation also has substantial health benefits for the HIV positive individual, so this strategy has benefits at both the individual and population-level [10,40]. There has also been interest in strategies that use ART to prevent HIV infection in FSWs, including oral pre-exposure prophylaxis (PrEP) and vaginal microbicides [10,34,35,40-43].

1.4.2 HIV treatment and the care cascade

By reducing HIV viral load and helping to restore immune function, ART substantially improves the longevity and quality of life for people living with HIV, and also reduces their infectiousness

[40]. For successful treatment and sustained viral suppression it is essential that HIV infected individuals engage and remain in the HIV care cascade [44]. The HIV care cascade is a series of stages starting with being HIV diagnosed through HIV testing, followed by linkage to and enrolment in HIV care after HIV diagnosis, retention in pre-ART care prior to ART initiation, initiation of ART once eligible for treatment, retention on treatment once ART is started, adherence to ART, and achievement of sustained viral suppression and immunological improvement [39,44-48]. Although, under the new WHO guidelines to treat all HIV positive individuals regardless of CD4 count, the “retention in pre-ART care” stage will cease to exist [49].

1.4.2.1 HIV testing

HIV testing and counselling (HTC) is an essential component of HIV programming worldwide, serving as the main entry point to HIV treatment and care for those who are HIV-infected [47,50]. For those who test negative, HTC is also an important opportunity to link those at risk of HIV to primary HIV prevention programmes and services, and also encourage re-testing [47]. The WHO recommends that FSWs voluntarily test for HIV every 6-12 months [47]. In a WHO review of 52 low and middle-income countries in 2010, the median percentage of FSWs who tested for HIV in the past 12 months and knew their test results was 49%, but there was wide variation across countries [51]. For example, in SSA where the median percentage of FSWs who tested for HIV in the past 12 months and knew their test results was 60%, estimates ranged between 0-95% across countries [51].

1.4.2.2 Linkage, enrolment and retention in HIV care

Among FSWs, there are very limited studies on linkage to and enrolment in HIV care after being HIV diagnosed [46,52-56]. In a study in Rwanda, 12-36 months after HIV diagnosis, 85% of HIV positive FSWs reported having enrolled in HIV care a median of 30 days after their diagnosis [52], while in a HIV self-testing trial in Zambia, 78% of FSWs reporting a positive HIV test at the 4 month follow-up visit reported that they had sought medical care following their positive test [53]. In a study of HIV-positive FSWs in the Dominican Republic, 92% reported ever receiving medical attention related to HIV (i.e. were linked to HIV care) [56], while in a cross-sectional study in Malawi, the majority (69%) of HIV-infected FSWs had a history of HIV care [54].

A few studies have reported broadly on current engagement and retention of FSWs in HIV care (i.e. not specific to either pre-ART or ART care) [56-62]. For instance, in a study of HIV-positive FSWs in the Dominican Republic, 85% reported attending HIV-related services in the last 6 months, and of those women 63% did not miss any HIV service appointments in that 6 months [56-58,62]. In a study in Mozambique, 83% of HIV positive FSWs reported being in HIV care [61], while in Miami, 76% of HIV positive FSWs reported that they were currently in HIV care [59].

1.4.2.3 HIV treatment

In a systematic review and meta-analysis we conducted in March 2014 to characterise the HIV treatment cascade stages among FSWs globally (Appendix A), we also found a paucity of data on ART uptake, ART attrition, adherence and treatment response (viral suppression and CD4 count improvement) among FSWs [39]. As of March 2014, only 39 studies, from fourteen different countries in Africa, Asia, North America, South America, and Central America and the Caribbean, reported information on these ART cascade stages among FSWs [39]. Of these studies, the majority provided estimates of either current ART use or median CD4 counts at and/or after ART initiation, with very few providing estimates of treatment attrition (e.g. treatment discontinuation or loss to follow-up on ART), adherence and viral suppression [39].

ART uptake among HIV-infected FSWs was particularly variable across the different studies and settings. Across 18 studies, the overall pooled estimate for current ART use among HIV positive FSWs was 38% (95%CI: 29%-48%) (Figure 1.1) [39]. Treatment discontinuation was reported for only one FSW study population in Kenya, increasing from 4% at 6 months to 10% at 12 months [39]. Loss to follow-up after ART initiation was reported in three FSW study populations in Kenya and Burkina Faso, with estimates ranging between 3-10% after varying times on ART [39]. Adherence to ART, which was reported in nine studies, was consistently high, ranging from 67% to 100%, across the varying time periods, adherence thresholds, recall periods and methods of assessment [39]. The fraction of FSWs on ART virally suppressed, which was reported in only 6 studies, ranged between 40%-82%, across varying time-periods and definitions of viral suppression (pooled estimated: 57% [95% CI: 46-68%]) [39].

Since this review, additional studies have reported quantitative estimates on the HIV treatment cascade stages among FSWs [34,54,56,59,60,63-75]. For example, in a study in the Dominican Republic, which reported on multiple stages of the HIV treatment cascade, most HIV positive FSWs had ever initiated ART (78%), and 72% were currently taking ART, of whom 79% reported 100% adherence in the past 4 days [56]. About a third (36%) also reported experiences with an ART interruption, and 48% of all HIV positive FSWs in the study had undetectable viral load [56]. In a study in Malawi, 52% of HIV positive FSWs reported current ART use and 45% were virally suppressed [54].

Population	Study-Period	n/N	Estimate (%) and 95% CI
Low and Middle Income			
Kenya 1 [49]	1993-2010 [a]	65/282	23.0 (18.3-28.4)*
Brazil 1 [47]	2003-2004	1/4	25.0 (0.6-80.6)
Burkina Faso 1 [37]	2003-2005	26/273	9.5 (6.3-13.6)
Burkina Faso 1 [57]	2007-2011	180/258	69.8 (63.8-75.3)*
India 1 [46]	2007	4/19	21.1 (6.1-45.6)*
El Salvador 1 [52]	2008	0/39	0.0 (0.0-9.0)*
Zimbabwe 1 [50]	2009	151/480	31.3 (27.1-35.6)*
India 3 [40]	2008-2009	17/35	48.6 (31.4-66.0)*
Kenya 2 [34]	2009	177/607	29.2 (25.6-33.0)*
India 2 [55]	2011	252/603	41.8 (37.8-45.8)*
Dominican Republic 1 [53]	2012-2013	194/268	72.4 (66.6-77.7)*
Kenya 2 [36]	NR	19/57	33.3 (21.4-47.1)
Subgroup (I^2 = 97.1%, N_p =9*)			**39.3 (27.2-52.9)**
High Income			
USA 1 [48]	1999-2000	0/2 [b]	0.0 (0.0-84.2)
		10/21 [c]	47.6 (25.7-70.2)*
Canada 3 [24]	2003	14/34	41.2 (24.7-59.3)*
Canada 2 [58]	2003-2013	31/43	72.1 (56.3-84.7)*
USA 2 [41]	2006-2010	8/46	17.4 (7.8-31.4)*
Russia 1 [59]	2007-2011	3/42	7.1 (1.5-19.5)*
Canada 1 [45]	2011	35/88	39.8 (29.5-50.8)*
Subgroup (I^2 = 86.9%, N_p =6*)			**35.3 (19.8-54.7)**
Overall (I^2 = 95.5%, p<0.001, N_p =15*)			**37.9 (28.5-48.4)**

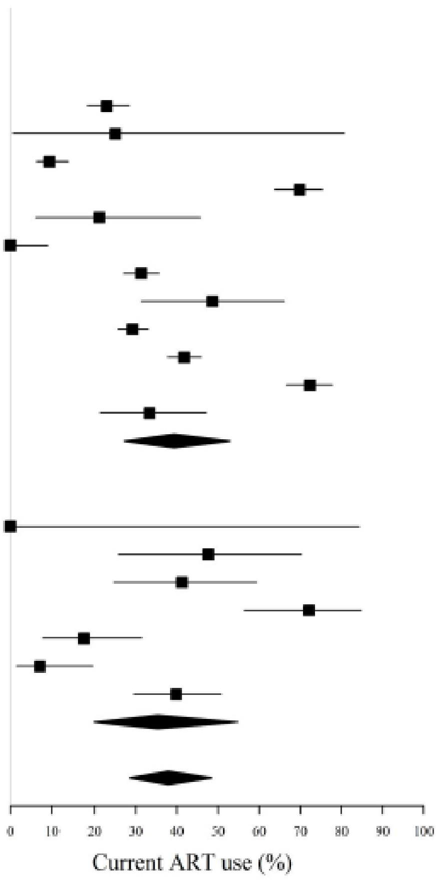


Figure 1.1 Forest plot of current ART use among HIV-infected FSWs in studies published up until March 2014 (from Mountain *et al* [39]). Study estimates are grouped by country income and ordered by study period. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall or subgroup estimates. Only study estimates with a known time period of data collection which were measured among at least 10 FSWs were used for pooling. I^2 and p-values are the measures of heterogeneity used. [a] ART was provided to FSWs in the Kenyan cohort from 2004, [b] Sample is 'active' FSWs, [c] Sample is 'active' and 'former' FSWs. ART = antiretroviral therapy, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N= sample size of FSWs available for each outcome, Np = number of independent study populations

1.5 Structural HIV determinants and violence against FSWs

1.5.1 Structural factors and HIV risk among FSWs

Early research on risk factors for HIV among FSWs tended to focus on the individual and partner-level biological and behavioural factors shaping FSWs HIV risk [8]. However, more recently there has been growing interest in understanding the structural factors that shape HIV risk, in order to better understand the heterogeneities in HIV epidemics among FSWs [8,9,76].

HIV structural factors are any physical, social, cultural, organizational, community, economic, legal, or policy aspects of the environment, that either directly or indirectly impede or facilitate an individual's HIV prevention behaviours [77,78]. A recent systematic review by Shannon and colleagues found a number of structural factors associated with HIV infection among FSWs, including migration and mobility, geographic residence, sex trafficking, physical and sexual violence from clients, police and managers, local policing practices, drug and alcohol use in the workplace, type of sex work venue, economic incentives from clients, and client demand for non-condom use [9]. Many of these structural factors were also found to be associated with decreased condom use among FSWs [9]. Other structural factors that were also found to be associated with decreased condom use among FSWs, included laws and policies governing sex work (e.g. enforcement of criminal sanctions), stigma, food insecurity, economic and residential insecurity, poverty, and historical gender-based violence [9]. Conversely, structural factors that were found to be protective against HIV infection or associated with higher rates of condom use, included community empowerment, supportive managerial and peer practices, as well as access to sexual health care and HIV prevention [9,79]. In some cases, structural factors were found to confer both HIV risk and HIV protection (e.g. migration and work environment), highlighting the complexity of the causal pathways between structural factors and HIV risk [8,9]. Studies among FSWs have also documented a number of structural-related barriers to accessing health services and engaging in the HIV care cascade, including stigma, discriminatory medical staff, economic and residential insecurities, violence and fear of violence or arrest, policing practices, and imprisonment [46,52,53,56,58,59,65,67,70,80-97]. Conversely, in a study in Swaziland, higher levels of social participation were associated with increased HIV testing among FSWs [98].

Given the wide range and complexity of structural factors, different conceptual frameworks have been proposed to try and classify structural factors and their impact on HIV risk, and help guide future research. Barnett and Whiteside proposed a framework where structural factors were organised based on their distance from HIV risk behaviour [77,99]. Sweat and Denison grouped structural elements into four levels: superstructural factors which affect nations, structural factors which affect smaller segments of the population, environmental factors which affect an individual's conditions and resources, and individual factors which affect an individual's experience of environmental factors [77,78,99]. Rhodes also described a risk environment framework, in which different physical, social, economic and policy environments can interact at the micro- and macro-levels, through a combination of susceptibility and vulnerability factors, to influence drug-related harm [8,100]. More recently, Latkin and colleagues proposed a dynamic social systems model for HIV-related behaviours that includes six structural dimensions (resources, science and technology, formal social control, informal social influences and control, social interconnectedness, and settings) which can operate at the macro, meso and micro levels [99]. Blanchard and Aral also presented a conceptual framework which incorporates the dynamic interactions between individual and societal factors, that together create structural patterns (e.g. mixing patterns and sexual networks), and which combined with individual characteristics and behaviours interact to influence HIV transmission dynamics [101].

Structural HIV determinants frameworks specific to FSWs have also been proposed [8,98,101,102]. For example, Blanchard and Aral also proposed a dynamic conceptual framework specific to FSWs, in which the macro-level societal context influences both the population size, socioeconomic and demographic characteristics of FSWs and their clients, as well as the organisation of sex work (e.g. locations and venues of sex work, how FSWs and clients connect, and who controls work conditions) [101]. Together, the organisation of sex work and individual characteristics of FSWs and their clients, result in structural patterns (e.g. network structure and mixing patterns) and aggregate properties (e.g. average client volume and condom use rates), which influence transmission dynamics and epidemic trajectories [101]. Shannon and colleagues also describe a conceptual framework in which structural determinants interact with individual and interpersonal behavioural and biological factors (e.g. drug use, duration in sex work, condom negotiation, STI co-infection) to influence HIV acquisition and transmission dynamics and epidemic trajectories [8]. This conceptual framework incorporates multiple levels of structural determinants, including macro structural factors (e.g. policies and laws governing sex work, stigma, mobility and migration), community organisation of sex work (e.g. community empowerment, sex work collectivization), and the physical, social, economic and policy features of the work environment (e.g. venue-based characteristics, managerial practices, local policing, ART use, and HIV testing), which are organised by their relative proximity to HIV transmission dynamics, and which can act dynamically and interactively to increase or reduce HIV risk among FSWs [8].

1.5.2 Violence and HIV among FSWs

1.5.2.1 Burden and determinants of violence against FSWs

Violence against FSWs, which has many negative consequences for FSW's physical, sexual, reproductive and mental health, including increased risk for HIV, is widespread across many sex work settings [12,13]. FSWs are often subject to many different forms of violence, including physical, sexual, and psychological violence (see Box 1.1), from a wide range of perpetrators, including clients, police, managers, co-workers, and intimate partners [11-13,103,104]. Workplace violence, which can include violence perpetrated by individuals such as clients, police, managers, pimps or co-workers, is often a ubiquitous feature of many sex work environments [11,13,15,105,106]. Other police abuses and policing strategies, such as arrest, raids, police crackdowns, extortion, harassment, and confiscation of condoms are also pervasive and have negative consequences for FSWs health and safety [9,107-109]. As outlined later in Section 1.11, the research in my thesis is focused on physical and sexual violence against FSWs, as well as policing abuses and strategies which can negatively impact FSWs safety and HIV risks. For the rest of this thesis, "violence against FSWs" will be used as a broad term encompassing the different types of physical, sexual and psychological violence, as well as negative policing practices.

Box 1.1 Examples of types of violence experienced by FSWs [11,103]
Physical violence: Physical assault (e.g. slapped, pushed, hit, kicked), battery, murder, physical restraint, robbery Sexual violence: Rape, gang rape, sexual harassment, coercion or intimidation into engaging in sex, subject to sex acts against one's will Psychological violence: Harassment and verbal abuse, threats, belittlement, humiliation

A few global reviews in recent years have examined the burden of violence against FSWs [12,13,108,109]. A systematic review by Deering *et al,* which examined the correlates of violence against FSWs, found a high prevalence of lifetime sexual workplace violence (ranging between 14% to 54%) and lifetime physical workplace violence (ranging between 19% to 67%) [13]. Sexual and physical workplace violence in the past year were similarly high, ranging between 19% to 44% and 15% to 31%, respectively [13]. Estimates of sexual and physical violence from intimate or non-paying partners in the past year ranged between 15% to 61% and 8% to 19%, respectively [13]. A systematic review by Footer *et al*, which examined the influence of policing practices on HIV and STI risk among sex workers, found that police arrest was very common in the studies included, with 6-45% of sex workers reporting that they had ever been arrested [108]. Sexual coercion by police was also reported by 3-37% of sex workers across the studies, while police extortion was reported by 12-28% of sex workers [108]. In a broader review of human rights violations against sex workers by Decker *et al*, police-perpetrated sexual violence was reported by 7-89% of sex workers in the studies identified, while quantitative estimates of police arrest and police extortion ranged between 4-75% and 12-100%, respectively [12]. Physical or sexual violence from clients was also reported by 8-76% of sex workers [12].

FSWs are particularly vulnerable to experiencing violence due to their stigmatised and marginalised position in society and the often criminalised nature of sex work [12,13,15,104,110,111]. Criminalisation of all or some aspects of sex work is the main policy approach to sex work globally, but other policy approaches including legalisation and decriminalisation also exist (see Box 1.2) [12,112].

In Deering *et al's* systematic review, numerous social, physical, policy, economic, interpersonal and individual factors were found to be correlated with elevated rates of physical and sexual violence among sex workers [13]. In particular, there was consistent evidence that policing practices (e.g. arrest, violence, coercion) were associated with increased rates of physical or sexual violence by clients [13]. For example in India, FSWs reported numerous police-related experiences, including police raids, having sex with or giving gifts to police to avoid trouble, and confiscation of condoms, all of which were associated with FSWs experiencing more client violence [113]. In Canada, police assault (including sexual or physical violence) was associated with increased odds of client violence [114]. Forced or coerced entry into sex work (sex trafficking), was found to be associated with increased sexual violence at sex work initiation among FSWs in Thailand, and increased physical or sexual violence in the first month of sex work among FSWs in India [115,116]. Other studies from India have also documented an increased risk of recent physical and sexual violence among FSWs trafficked into sex work [115-118]. Work environment also appeared to be an important risk factor for violence, with client or police violence highest amongst FSWs working outdoors, on the street, or in public places [13]. In addition, heavy alcohol consumption has been associated with increased sexual violence against sex workers [13,119]. For example, in Kenya, FSWs who were binge drinkers were more likely to experience sexual violence in the past year [120]. Similarly, in China, FSWs who were classified as heavy or hazardous drinkers were more likely to experience client sexual violence [121], whilst in Russia, FSWs reporting binge drinking in the past year were more likely to experience police sexual coercion [122]. Other factors that have also been found to be linked to risk of violence among FSWs include: drug use, gender and economic inequities, and voluntary migration [13]. Conversely, in Karnataka, FSWs that were members of a community group were found to be significantly less likely to report violence in the past 6 months [123]. Collective empowerment among FSWs in Karnataka was also strongly associated with reduced violence [124]. In Andhra Pradesh, FSWs living in areas with active community advocacy groups were found to report that police treat them more fairly than FSWs living in areas without active community advocacy groups [125].

Box 1.2 Policy approaches to sex work (adapted from [12,112])
Full criminalisation: All aspects of sex work, including selling sex, purchasing sex, and earning money from someone's sex work are illegal. Examples of settings where sex work is fully criminalised include China, India, South Korea, Russia, South Africa, Uganda, Zimbabwe, and most of the USA. Partial criminalisation: Some aspects of sex work are illegal (e.g. selling sex or buying sex, or activities related to sex work). Criminalisation of clients (also known as the end demand Swedish model), is the policy approach in a number of settings, including Sweden and Norway. Legalisation: Sex work is legal and permitted under specified conditions (e.g. licensed brothels or sex work zones). Legalisation is of often accompanied by compulsory registration and mandatory health checks. Examples of settings with a legal policy approach include the Netherlands, Nevada (USA), Tijuana (Mexico), and Senegal. Decriminalisation: All laws criminalising sex work are removed. Sex work is legal and regulated under occupational health and safety laws. Various international bodies now recommend decriminalisation of sex work, but so far only New Zealand and New South Wales in Australia operate under full decriminalisation.

1.5.2.2 Impact of violence on HIV

There are many possible mechanisms, both direct and indirect, through which violence against FSWs is hypothesised to heighten FSW's vulnerability to HIV and undermine HIV prevention efforts:

- Forced sex (i.e. rape) can directly increase risk of HIV infection, as the genital trauma (lacerations and tears) from forced sex can facilitate HIV transmission [12-15].
- Violence is associated with higher-risk sexual behaviours, such as anal sex, and if anal sex is forced this may confer an even higher risk of HIV transmission, due to both genital trauma and the increased risk of HIV transmission associated with anal intercourse [12-14,126].
- Forced or coerced sex is less likely to be protected with condoms [81,106,127], and condom breakage is more likely during sexual violence [104].
- Violence or fear or violence from clients and intimate partners can deter FSWs from negotiating condom use in order to prioritise their own safety [14,15,83,128].
- Through threats of violence and acts of violence, gatekeepers, such as managers and owners of sex work establishments, may force sex workers into taking on more clients

and foregoing condom use with clients [14,15,83,128].

- FSWs may be forced into sexual situations with more men than was arranged by a client [14].
- Sex workers may be forced or coerced into unpaid and unprotected sex by police to escape arrest or harassment, or to avoid prolonged detainment in prison [12,15,129].
- Condom confiscation by police can directly increase FSWs risk of HIV infection by prompting unprotected sex, and FSWs may be less likely to carry condoms to avoid arrest or extortion by police who use condoms as evidence against them [12,108]. Confiscation of drugs and injecting equipment is also associated with HIV infection among FSWs [12,108].
- Experiencing violence has a negative impact on sex workers physiological well-being, leading to anxiety, depression, loss of self-esteem and low self-efficacy, which can affect sex workers ability and willingness to negotiate condom use and access health services [15,59,91,106,128,130-134].
- Hostility and abuse from health care workers can impede and make sex workers reluctant to access health care services [15,90].
- Experiences of violence or fear of violence and arrest can deter and impede FSW's access to health services and engagement in the HIV care cascade (e.g. HIV testing, treatment and adherence) [12,58,66,67,70,81,82,91,135].
- When arrested and detained, sex workers may not be able to access and adhere to their medications, including ART [12,52,136].
- Police raids and crackdowns can lead to re-location of FSWs to unknown and unsafe areas, which may put FSWs at further risk of client violence [13,106,113]. This displacement of FSWs to remote areas may also lead to FSWs being unable to access HIV prevention and health care services [13,109,113,129,137].
- Survivors of violence are more likely to be re-victimised and experience additional violence [14,138].
- As sex work is often illegal, reporting experiences of violence to the police may be difficult, which can result in violence continuing [136].
- Men who perpetrate violence are more likely to engage in high risk behaviours and be infected with HIV or other STIs [14,81].

Two systematic reviews to date by Shannon *et al* and Footer *et al* have examined the quantitative evidence for the effects of violence on FSWs HIV risk and HIV-related outcomes [9,32,108]. In the systematic review by Shannon *et al*, which examined the effects of structural determinants on HIV prevalence, incidence and condom use among FSWs, a number of studies found that physical and sexual violence from clients, managers and police, and other policing practices (e.g. arrest, harassment, detainment, raids, incarceration) were associated with HIV infection, inconsistent condom use, condom use failure and condom breakage [9]. In the systematic review by Footer *et al*, the effects of policing on HIV and STI infection, condom use, syringe use, number of clients, and HIV/STI testing access among FSWs, were examined [108]. In the small number of studies identified (14 studies), being arrested by police was consistently associated with HIV infection and inconsistent condom use, and sexual coercion by police and extortion were also associated with current or recent HIV and STI infection and inconsistent condom use [108]. Quantitative data linking violence to reduced uptake of health services and poor HIV testing, care and treatment outcomes, although limited, has also begun to emerge in recent years [58,66,67,70,81,82,91,107,135]. Among FSWs in the Dominican Republic, violence from an intimate partner was significantly associated with not currently being on ART and missing an ART dose in the last 4 days, while violence from a client was significantly associated with never having received HIV care and ever interrupting ART [58]. Among FSWs in the Gambia, forced sex by a clients was negatively associated with receiving an STI test in the past year [91]. In a longitudinal analysis of sex workers in Vancouver, Canada, incarceration was associated with experiencing gaps in ART use over a 2.5 year period [67]. In the same cohort of FSWs, a greater density of displacement due to policing was associated with HIV treatment interruptions [66]. Studies in Cote d'Ivoire, Swaziland, and Cameroon, also found that experiences of violence were significantly associated with fear and avoidance of seeking health services among FSWs [70,82,107]. In a pooling booth survey of FSWs in South India, at the ecological level, FSWs who reported violence in the past year were significantly less likely to have accessed the HIV intervention program or to have ever visited the project sexual health clinic [81].

Taken together, these studies provide important quantitative evidence for the negative effects of violence on HIV risks and HIV related outcomes in different settings. However, there are still gaps in the literature. In particular, few studies have quantitatively examined the effects of police violence and law enforcement strategies on FSWs HIV risks, and there is a paucity of quantitative studies examining the effects of violence on uptake of health services, and engagement in the HIV care cascade. In addition few studies have conducted mediation analyses to explore the most likely and important pathways and mechanisms underlying the associations between violence and HIV infection among FSWs [104,139-141].

1.6 Structural interventions and addressing violence against FSWs

Broadly speaking, structural interventions are those that aim to promote HIV prevention and reduce HIV vulnerability by changing the structural context in which people live, and often involve one or a combination of legal, policy, social, community, organisational, cultural or economic actions or processes [77,142-144]. In the context of sex work, the main structural approaches to HIV prevention have included government policy initiatives, community mobilization, and interventions to address violence, and often these approaches are integrated together [10,11,145]. In some settings, micro-finance programmes, which are another type of structural intervention, have also been implemented among FSWs [146-149].

1.6.1 Government policy initiatives

The most notable government policy initiative that has been implemented is the 100% condom programme in Thailand [145,150]. This was a countrywide government led initiative that aimed to increase condom use through empowering FSWs to be able to refuse sex without a condom and through imposing sanctions on sex work establishments that did not follow the 100% condom rule [145,151]. This programme resulted in a rapid increase in condom use in sex work [145,151]. Since its conception in 1989, the 100% Condom Use Programme has been implemented in numerous other countries, including Cambodia, Philippines, Vietnam and China [151].

1.6.2 Community empowerment

Community empowerment (also known as community mobilisation) is a strategy that seeks to empower and mobilise FSWs to gain control of and change the structural barriers that impact their health, HIV risk and human rights [11,152,153]. In the WHO guidelines on HIV prevention for FSWs, community empowerment was recommended as a necessary component of HIV interventions, that should be the foundation for all HIV intervention and prevention approaches for sex workers [11]. Community mobilisation and empowerment approaches often involve numerous activities, such as advocacy with stakeholders who hold power and control, consciousness raising among FSWs about their rights, identifying and challenging barriers to HIV prevention, formation of FSW collectives and peer-groups, and establishment of community-led safe spaces (e.g. drop-in centres), and will also normally include more traditional elements, such as condom promotion, peer-led education, and HIV screening and treatment [11,79,123,143,154,155]. A recent systematic review found that community-based HIV prevention approaches for FSWs were associated with improved HIV outcomes in India, Brazil, and the Dominican Republic [79].

One of the earliest and most well-known community mobilization initiatives is the Sonagachi Project in Kolkata, India, which started as a peer-led condom education programme in the Sonagachi red-light district in 1992 but evolved into a community empowerment program [152,156,157]. A large FSW collective was formed, and through promoting group solidarity, fostering empowerment, creating political awareness, forming savings and business co-operatives, and increasing access to condoms and other social and material resources, this initiative led to significant increases in condom use among sex workers, from 3% in 1992 to 90% in 1999 [79,98,158,159]. The low rate of HIV infection in Kolkatta is also thought to be attributed to this programme [79,145]. To test the efficacy of the Sonagachi model, 2 other communities in West Bengal were randomly assigned to a Sonagachi replication intervention or a standard intervention [158]. Over a 15 month period, condom use significantly increased in the Sonagachi intervention community compared to the standard intervention control community [157,158].

Community mobilisation of sex workers is also a key component of Avahan, which is another large-scale HIV prevention programme in India [154,160]. When evaluated in Karnataka and Andhra Pradesh, these Avahan community mobilisation activities were found to have had positive effects on condom use and structural barriers [123,154,160-162]. Outside of India, in Brazil; a recent study has looked at the impact of *Encontros,* an intervention which included strategies to mobilise FSW communities, expand social networks, create community partnerships, and reduce stigma [163,164]. FSWs exposed to the *Encontros* intervention were found to have significantly higher odds of reporting consistent condom use with regular clients than FSWs not exposed to the *Econtros* interventions [163,164]. A study in the Dominican Republic also looked at the impact of two community solidarity interventions among FSWs, one with the addition of government policy on condom use and one without [165]. The community solidarity intervention without the addition of government policy was associated with significant increases in condom use with new clients, whilst the community solidarity intervention with the addition of government policy was associated with significant increases in condom use with both clients and regular partners and was also associated with a decrease in STI prevalence [165]. *Abriendo Puertas*, a multi-level intervention in the Dominican Republic, which included community mobilisation activities, stigma reduction, and sensitivity training for HIV clinical care providers, was also found to significantly improve HIV outcomes (condom use and ART adherence) in pre-post intervention surveys [165]. An integrated individual community, and structural intervention in China, which included structural components such as, community solidarity, collective commitment, multisectoral government community partnership coordination, and stigma and discrimination reduction, also showed a positive impact on reducing HIV and STI risks (e.g. improved rates of condom use with different types of partners) [150].

1.6.3 Addressing and preventing violence against FSWs

Given that FSWs experience a high burden of violence and that violence is an important risk factor for HIV among FSWs, it is essential that violence against FSWs is addressed and incorporated into HIV prevention for FSWs, to improve both the health, safety and well-being of FSWs. In the recent WHO guidelines on HIV prevention among FSWs, it was recommended that violence against FSWs should be addressed and prevented, and that antidiscrimination and right-respecting laws should be established in order to protect against violence, discrimination, and other violations of rights faced by sex workers [7].

One of the key strategies suggested by the WHO to try to address violence against FSWs is community empowerment [11]. Community empowerment can provide a mechanism for FSWs to engage in their problems, such as violence, and then mobilise and advocate for changes to behaviours of groups and institutions that perpetrate violence and deny them their rights [11]. In India, collective empowerment, being a member in a community group, and living in an area with active community advocacy groups, have all been shown to be associated with either reduced violence or fairer treatment from police [101,123,125].

Promoting the safety and security of sex workers, building sex workers' knowledge of their rights in relation to sex work and violence, and providing legal, health and other supportive services for sex workers, have also been suggested as key strategies to reducing violence [11]. For example, SWEAT (Sex Worker Education and Advocacy Task Force), an organisation in South Africa, has developed a list of safety tips for sex workers, organises community meetings to help raise awareness among sex workers of their rights, refers sex workers to lawyers if legal services are needed, and also provides counselling for those who have reported incidents of abuse [11,15]. In Scotland, sharing lists and descriptions of violence perpetrators, known as the Ugly Mugs Scheme, provides an early warning system for sex workers about violent clients [166]. In Kenya, the sex worker project KASH (Keeping Alive Societies' Hope) has set up a phone hotline for sex workers in order to provide immediate support and response to violence [11]. Advocating for legal and policy reforms, such as decriminalisation of sex work, and working with police to reduce police harassment and violence and raise their awareness about sex workers' rights and laws, have also been suggested as important violence reduction strategies [11,12,15].

In India, numerous strategies to try and reduce violence against FSWs have been incorporated into the Avahan HIV prevention programme [81,123,128,167-169]. For example, in Karnataka, one of the states where Avahan operates, interventions include policy-level advocacy, in which co-ordination committees with various stakeholders have been established to work in partnership with the HIV prevention programme and to provide a platform for sex workers to raise concerns, such as harassment and violence, with government officials and police [81]. Partnerships with police heads have been created to try to reduce police violence [81,128], and HIV/AIDS awareness and sex worker sensitisation training has also been provided to journalists [81]. Volunteer human rights lawyers have also been brought together, to provide sex workers with legal literacy and the ability to bring perpetrators of violence to justice [81]. These human rights lawyers also deliver legal empowerment workshops to many FSWs [81,128]. Crisis management teams have also been set up to try and provide immediate responses to any violent attacks, sexual assaults, or wrongful arrests against FSWs [81,128]. Community mobilization efforts also include activities which focus on addressing feelings of powerlessness and isolation, and advocacy against violence, wrongful arrest, stigma and discrimination [81,123]. Integrated bio-behavioural surveys in Karnataka, indicate that these violence reduction interventions have led to significant reductions in the proportion of FSWs reporting experiences of violence [81]. Similar police interventions implemented as part of Avahan in Andhra Pradesh, also led to a significant decline in negative police interactions with FSWs [168].

There are now numerous positive examples of police practice and partnerships between police and sex workers, including in Kisumu, Kenya, where KASH has helped foster partnerships with police [109,170]. In Kenya, a brief alcohol reduction intervention was also found to significantly reduce the odds of FSWs reporting experiences of different types of violence [171,172].

1.7 Vulnerabilities of young female sex workers

Studies suggest that YFSWs may be more vulnerable to HIV than older FSWs for reasons such as reduced ability to negotiate condom use, increased use of drugs and alcohol use, and susceptibility to violence [173-175]. Furthermore, adolescents are often more vulnerable to manipulation and exploitation or abuse by older people, which can potentially increase risk of HIV infection [173-175], and for young women there are a number of biological mechanisms that are thought to increase their risk of HIV acquisition [173,176]. Stigma, discrimination and criminalisation of sex work can also be barriers to YFSWs uptake of health services, which may contribute to YFSW's heightened risk of HIV infection [173,175]. In addition to criminalisation of sex work, laws classifying sex work among people under 18 years of age as sexual exploitation, make it particular difficult for young women under 18 who sell sex to access health services compared to older sex workers [173-175]. Despite their unique vulnerabilities, YFSWs are an under-researched population, whose needs are often not adequately addressed in the HIV prevention response [173,175,177,178]. To address the specific needs of YFSWs, and for an effective HIV response in YFSWs, it is important that studies are conducted to better understand the dual epidemics of HIV and violence in this at risk population.

1.8 Mathematical modelling approaches for evaluating the impact of interventions in the sex work context

Determining the effectiveness of HIV interventions and their impact on reducing HIV transmission is essential for guiding HIV prevention approaches for FSWs. However, evaluating interventions, especially complex structural and combination interventions is challenging, and often conducting randomised controlled trials, the gold standard for evaluating efficacy of interventions, is not possible [77,128,179,180]. Mathematical models are useful tools that are increasingly being used to estimate the impact of HIV interventions and guide policy decisions [181-184]. By simulating "what-if" scenarios, mathematical models can help assess the impact of any one or combination of behavioural, biological and structural interventions on population-level HIV transmission [26,185].

Two recent reviews have identified a growing number of mathematical modelling studies that have assessed the impact of FSW focussed interventions on HIV transmission among FSWs and the wider community [26,181]. Mishra *et al* systematically searched for modelling studies published between 1986 and 2011 that evaluated the impact of focused interventions among high-risk groups, including FSWs [26]. The modelling studies identified evaluated a wide range of interventions, including condom use, syndromic STI management, periodic presumptive treatment for STIs, ART use, PrEP, and vaginal microbicides, and demonstrated that interventions focused on FSWs could be effective in both high and low prevalence epidemic settings [26]. However, there was also considerable variation in estimated impact across models [26]. In low-prevalence epidemic settings, sex worker interventions in the absence of risk compensation were estimated to avert 6-97% of HIV infections in the total population (i.e. FSWs, clients and general population), and in high-prevalence epidemic settings, sex worker interventions in the absence of risk compensation were estimated to avert 7-40% of HIV infections in the total population (i.e. FSWs, clients and general population) [26]. Boily and Shubber's review of modelling studies among key populations published between 2012 and 2013 found that, across a number of models, targeting interventions to higher-risk individuals was often found to be more efficient [181]. Models assessing FSW focused interventions were limited, but indicated that increasing ART coverage or reducing violence could avert HIV infections among FSWs, other high-risk groups and the general population [181,186,187]. Since these two reviews, other mathematical models have suggested that maximising FSWs access to care and treatment (e.g. increased HIV screening, improved linkage to and retention in pre-ART care, scale-up of ART, early ART initiation), targeting the most active FSWs for condom and STI interventions, PrEP prioritised to FSWs, community empowerment, elimination of violence, promotion of safe work environments, and decriminaisation of sex work, could be effective at reducing HIV transmission [9,29,31,155,184,188,189]. Section 1.9 will describe in further detail the existing studies which have modelled the potential impact of structural interventions among FSWs.

1.9 Modelling structural HIV determinants and structural HIV interventions in the sex work context

In addition to estimating the impact of interventions, mathematical models have been utilised to explore complex and heterogeneous HIV transmission dynamics, estimate HIV incidence, and understand the contribution of different sexual behaviours and risk factors to HIV epidemics, [26,181,190,191]. As mathematical models allow you to study multiple, complex, interacting dynamics through time, mathematical modelling could also be a potentially useful tool in helping to understand structural HIV determinants and the impact of structural interventions among FSWs. However, to date, very few mathematical models of HIV transmission among FSWs have incorporated structural factors or assessed the impact of structural HIV interventions [9,155,186,189].

A recent modelling study conducted by Shannon and colleagues, which examined the potential impact that structural changes could have on HIV infections among FSWs and their clients, was the first and is the only study to date to directly incorporate structural factors into dynamical HIV transmission models in the context of sex work [9]. In this study a deterministic compartmental model was used to simulate sexual HIV transmission among FSWs and their clients in three different settings (Vancouver, Canada; Mombasa, Kenya; and Bellary, India) [9]. For each setting modelled, the FSW population was stratified by structural determinants that were important in shaping HIV risk to FSWs in each setting [9]. The main structural determinants considered across all settings were work environment and different forms of violence, and two settings additionally considered community empowerment (community collectivization and peer-led outreach) [9]. The model considered the associations between structural factors (e.g. higher rates of violence in some work environments), and the impact of these structural factors on different partner level risks (e.g. condom use), and individual behavioural (e.g. duration of sex work) and biological (e.g. STI co-infection rates) factors in each setting [9]. In two of the study settings (Canada and Kenya), it was estimated that reducing or eliminating sexual violence and its short-term and long-term negative impacts on condom use could substantially avert HIV infections by 17-20% in the next 10 years, and in Kenya, modest coverage of peer-led outreach could avert 20% of HIV infections in the next decade [9]. Across all settings, decriminalisation of sex work had the largest impact, averting 33-46% of HIV infections in the next 10 years [9].

Three other modelling studies have also indirectly evaluated the impact of structural interventions on HIV transmission among FSWs [155,186,189]. Vassall *et al* examined the added impact of adding community empowerment interventions to core HIV prevention services for FSWs delivered as part of Avahan for FSWs in two districts in Karnataka, India (Bellary and Belgaum) [189]. In this study, an exposure analysis was first conducted to estimate the incremental change in condom use with clients related to exposure to the community empowerment intervention, and then these effect estimates were used to parameterise in the model the fraction of increases in condom use with clients associated with the community empowerment intervention [189]. It was estimated that the community empowerment intervention had averted 1257 and 2775 HIV infections over a seven year period in Belgaum and Bellary, respectively, which represented 31% and 39% respectively of the total impact of *Avahan* over this period, respectively [189]. Another modelling study by Wirtz and colleagues, also indirectly evaluated the impact of scaling up coverage of community empowerment among FSWs in four countries (Kenya, Thailand, Brazil and Ukraine), using the Goals model (a deterministic model which projects HIV prevalence and incidence) and an impact matrix which translates changes in coverage of the community empowerment intervention to changes in levels of inconsistent condom use in the model [155]. The impact of expanding the community empowerment intervention from the baseline coverage (5% in Kenya and Ukraine, and 10% in Thailand and Brazil) was examined. Over a 5-year period, scaling-up the coverage of community empowerment interventions to optimistic levels (65% in Kenya and Ukraine and 75% in Thailand and Brazil), was estimated to avert 220 infection among sex workers in Thailand (8% reduction), 1830 in Brazil (10% reduction), 2220 in Ukraine (12% reduction) and 10,800 in Kenya (12% reduction) [155]. Decker *et al* also used the Goals model to estimate the impact of a hypothetical decrease in prevalence of violence against FSWs on HIV transmission in Kenya and Ukraine. Reducing physical and sexual violence among FSWs was estimated to avert 21,000 and 4,700 infections among FSWs and adults over 5 years, in Kenya and Ukraine, respectively, through reducing unprotected vaginal and anal sex

[186].

Despite the importance of structural factors for HIV among FSWs, very few mathematical modelling studies to date in the sex work context have incorporated structural HIV determinants or evaluated structural interventions [9,155,186,189]. Only one study to date has modelled structural factors for FSWs dynamically [9]. Modelling structural factors dynamically is important, as it allows changes in structural factors over time, recurrence of exposure to structural factors, and interactions between structural factors to be captured. All the modelling studies to date have examined the impact of structural changes and interventions on HIV epidemics, but no studies have utilised dynamic models to try and understand the dynamics and contribution of different structural factors to HIV transmission in the sex work context. Given the emerging state of this field, it is important to explore how different types of structural factors could be dynamically modelled, and what types of research questions such models can be used to address, and also determine what data is important to collect to inform and improve the predictions of these models.

1.10 Study settings

The work in this thesis is set mainly in Mombasa, Kenya, and also in Vancouver, in British Columbia, Canada. These two settings have different types of HIV epidemics. Vancouver provides a key example of a HIV epidemic concentrated among key populations [9]. Similar to other high-income countries, and elsewhere in North America, the beginning of the Vancouver HIV epidemic in the 1980s was characterised by a high incidence of HIV among men who have sex with men (MSM) [192]. In the mid-1990s there was then a shift in HIV trends, with a rapid rise in HIV incidence among injecting drug users (IDUs) and street-based FSWs [192]. Mombasa, like the rest of Kenya, has a high HIV prevalence in the general population, but there is also a concentration of very high HIV prevalence among key populations, including FSWs [9]. HIV prevalence was 7.4% in the general population in Mombasa in 2014, and over the years, women in Mombasa have consistently had a higher prevalence than men [193]. Mapping estimates suggest that there are about 9000 FSWs in Mombasa [194]. HIV prevalence among FSWs in Mombasa ranged between about 30-35% in 2005-2006 [120,195,196]. More recent studies suggest that this may have reduced but is still high at about 20% [60,197].

There have been successful efforts in recent years to scale up ART access in both Kenya and British Columbia, Canada among the general population [66,67,198-200]. Data on HIV treatment and care for FSWs is limited in both settings (Figure 1.1) [39]. Alongside ART scale-up, there has also been improved coverage of syringe distribution and other harm reduction in British Columbia among the general population and PWID, which have all contributed to reductions in

HIV incidence [9,67]. In addition to scaling up ART coverage, Kenya has made substantial progress towards achieving other goals and targets set out in the Kenya AIDS Strategic Framework [200]. For example, the country achieved 20% reduction in new HIV infections among adults between 2013 and 2015 and 50% reductions in new HIV infections among children in the same time period [200]. However, the contribution of young people to adult new HIV infections has increased from 29% in 2013 to 51% in 2015 [200]. Young people, along with key populations, such as FSWs, have been identified as priority populations in the Kenyan HIV response [201,202]. Key populations, including FSWs, were first prioritised in the 2009-2013 Kenya National AIDS Strategic Framework, and since then there has been considerable expansion in key population programmes, although prior to this, key populations were not a focus of the Kenya HIV response [203].

In both settings, sex work is criminalised, and as will be described in further detail in later chapters, there is a heavy burden of violence among FSWs in both settings, from numerous perpetrators, including clients, intimate partners and police [9].

1.11 Thesis aims and chapter content

1.11.1 Thesis aims

There is increasing evidence to highlight the important role of structural factors in HIV risk and transmission among FSWs. To achieve an effective HIV response among FSWs, it is essential that structural interventions are incorporated into HIV prevention programmes for FSWs. In order to inform the design and implementation of effective structural HIV prevention approaches and interventions for FSWs, we need context specific data to better understand i) the patterns of structural factors, ii) the effect of structural factors on HIV risk, and ii) the effectiveness of different types of structural interventions on reducing HIV transmission at a population-level.

Responding to these needs, the aims of my thesis are to 1) investigate the burden and determinants of violence against FSWs (a key structural determinant of HIV risk), 2) better understand the effects and contribution of violence against FSWs to HIV transmission, and 3) estimate the potential impact of violence interventions for FSWs on HIV transmission.

The next four chapters will address these aims using a combination of mathematical modelling and statistical analysis: Chapters 2 and 3 address the first aim, Chapters 4 and 5 address the second aim, and Chapters 2 and 5 address the third aim. The analyses undertaken are focussed in two settings: Vancouver, Canada (Chapter 2) and Mombasa, Kenya (Chapters 3, 4 and 5). The statistical analyses in Chapters 3 and 4 are focussed on YFSWs.

1.11.2 Content of thesis and chapter organisation

In Chapter 2, I develop a new dynamic mathematical model to simulate experiences of workplace violence among FSWs in Vancouver, Canada. I utilise this model to characterise the dynamics of workplace violence, estimate incidence of workplace violence, and estimate the impact of violence-related structural interventions on both workplace violence and inconsistent condom use among FSWs in Vancouver. This analysis builds on the prior modelling work undertaken by Shannon *et al*, which was introduced in Section 1.9, and utilises data from a prospective cohort of sex workers in Vancouver, Canada, known as AESHA ("An Evaluation of Sex Workers Health Access"). To date, very few mathematical models of HIV transmission among FSWs have incorporated structural factors or assessed the impact of structural HIV interventions (see Section 1.9), so this analysis addresses an important gap in the literature, and will provide insights for future model development, data collection, and methodological approaches for modelling structural determinants of HIV risk among FSWs.

In Chapters 3, 4 and 5, I focus on violence against FSWs in Mombasa, Kenya, with a focus on YFSWs. In Chapter 3, I examine the burden and determinants of violence (physical violence, sexual violence, and police assault or arrest) among YFSWs in Mombasa, Kenya. I analyse data from the Transitions study, which is a cross-sectional study of young women in Mombasa, Kenya, that included participants who self-identified as sex workers. Following on from this analysis, in Chapter 4, I examine whether there is a relationship between these experiences of violence and HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection. I also explore the pathways underlying the associations found between violence and HIV infection. YFSWs are often at even greater risk of violence and HIV than older FSWs, but are a particularly under-researched population (see Section 1.7). Thus, the analyses conducted in Chapter 3 and 4 address an important gap in the literature on violence and HIV for YFSWs. In Chapter 5 I utilise the findings from the data analyses in Chapter 3 and 4, to develop, parameterise and calibrate a dynamic model of violence against FSWs and HIV transmission among FSWs and their clients in Mombasa, Kenya. I use this model to explore the contribution of violence against FSWs to HIV transmission and the potential impact of violence prevention on HIV transmission among FSWs and their clients in Mombasa, Kenya.

In Chapter 6, I provide a broad overview and synthesis of the key findings, strengths, limitations and implications of the work in this thesis; and discuss future directions of research. I also provide a framework for guiding future modelling studies of structural HIV determinants, and discuss the types of data needed for such modelling studies.

1.12 References

1. UNAIDS. Global AIDS Update 2016. UNAIDS, Geneva, Switzerland: 2016.
2. UNAIDS. Fast-Track Ending The AIDS Epidemic By 2030. UNAIDS, Geneva, Switzerland: 2014.
3. UNAIDS. UNAIDS Data 2017. UNAIDS, Geneva, Switzerland: 2017.
4. UNAIDS. Fact Sheet July 2017. UNAIDS: 2017.
5. WHO. Policy Brief: Consolidated guidelines on HIV prevention, diagnosis, treatment and care for key populations, 2016 update. Geneva: WHO: 2017.
6. Baral S, Beyrer C, Muessig K, et al. Burden of HIV among female sex workers in low-income and middle-income countries: a systematic review and meta-analysis. The Lancet infectious diseases. 2012 Jul;12(7):538-49
7. WHO. Prevention and treatment of HIV and other sexually transmitted infections for sex workers in low- and middle-income countries: recommendations for a public health approach. WHO, Geneva, Switzerland. 2012
8. Shannon K, Goldenberg SM, Deering KN, Strathdee SA. HIV infection among female sex workers in concentrated and high prevalence epidemics: why a structural determinants framework is needed. Current Opinion in Hiv and Aids. 2014 Mar;9(2):174-82
9. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
10. Bekker LG, Johnson L, Cowan F, et al. Combination HIV prevention for female sex workers: What is the evidence? The Lancet. 2015 03 Jan;385(9962):72-87
11. WHO. Implementing Comprehensive HIV/STI Programmes with Sex Workers Practical Approaches from Collaborative Interventions. WHO, Geneva, Switzerland. 2013
12. Decker MR, Crago AL, Chu SKH, et al. Human rights violations against sex workers: Burden and effect on HIV. Lancet. 2015 10 Jan;385(9963):186-99
13. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
14. Dunkle KL, Decker MR. Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups. Am J Reprod Immunol. 2013 Feb;69:20-6
15. WHO. Violence against sex workers and HIV prevention. WHO Information Bulletin Series. 2005;Number 3
16. Harcourt C, Donovan B. The many faces of sex work. Sex Transm Infect. 2005 Jun 1;81(3):201-6
17. UNAIDS. Sex work and HIV/AIDS: UNAIDS Technical Update. UNAIDS, Geneva, Switzerland: 2002.
18. Vandepitte J, Lyerla R, Dallabetta G, Crabbe F, Alary M, Buve A. Estimates of the number of female sex workers in different regions of the world. Sex Transm Infect. 2006 Jun 1;82:III18-III25
19. UNAIDS. UNAIDS guidance note on HIV and sex work. UNAIDS, 2012.
20. Jewkes R, Morrell R, Sikweyiya Y, Dunkle K, Penn-Kekana L. Transactional relationships and sex with a woman in prostitution: prevalence and patterns in a representative sample of South African men. BMC public health. 2012;12:325
21. McMillan K, Worth H, Rawstorne P. Usage of the Terms Prostitution, Sex Work, Transactional Sex, and Survival Sex: Their Utility in HIV Prevention Research. Arch Sex Behav. 2018 Jan 5
22. Mishra S, Boily MC, Schwartz S, et al. Data and methods to characterize the role of sex work and to inform sex work programs in generalized HIV epidemics: evidence to challenge assumptions. Annals of Epidemiology. 2016 01 Aug;26(8):557-69
23. Beyrer C, Crago AL, Bekker LG, et al. An action agenda for HIV and sex workers. The Lancet. 2015 17 Jan;385(9964):287-301

24. Paz-Bailey G, Noble M, Salo K, Tregear SJ. Prevalence of HIV Among U.S. Female Sex Workers: Systematic Review and Meta-analysis. Aids Behav. 2016 01 Oct;20(10):2318-31
25. Platt L, Grenfell P, Bonell C, et al. Risk of sexually transmitted infections and violence among indoor-working female sex workers in London: The effect of migration from Eastern Europe. Sex Transm Infect. 2011 August;87(5):377-84
26. Mishra S, Steen R, Gerbase A, Lo Y-R, Boily M-C. Impact of High-Risk Sex and Focused Interventions in Heterosexual HIV Epidemics: A Systematic Review of Mathematical Models. Plos One. 2012 Nov 30;7(11)
27. Vickerman P, Foss AM, Pickles M, et al. To what extent is the HIV epidemic in southern India driven by commercial sex? A modelling analysis. AIDS. 2010 Oct 23;24(16):2563-72
28. Deering KN, Vickerman P, Moses S, Ramesh BM, Blanchard JF, Boily MC. The impact of out-migrants and out-migration on the HIV/AIDS epidemic: a case study from south-west India. AIDS. 2008 Dec;22 Suppl 5:S165-81
29. Low A, Nagot N, Konate I, et al. Potential impact of existing interventions and of antiretroviral use in female sex workers on transmission of HIV in Burkina Faso: a modeling study. Journal of acquired immune deficiency syndromes (1999). 2015 01 Mar;68:S180-S8
30. Maheu-Giroux M, Vesga JF, Diabate S, et al. Changing Dynamics of HIV Transmission in Cote d'Ivoire: Modeling Who Acquired and Transmitted Infections and Estimating the Impact of Past HIV Interventions (1976-2015). J Acquir Immune Defic Syndr. 2017 15 Aug;75(5):517-27
31. Mitchell KM, Prudden HJ, Washington R, et al. Potential impact of pre-exposure prophylaxis for female sex workers and men who have sex with men in Bangalore, India: A mathematical modelling study: A. Journal of the International AIDS Society. 2016 January;19 (1) (no pagination)(20942)
32. Williams JR, Alary M, Lowndes CM, et al. Positive impact of increases in condom use among female sex workers and clients in a medium HIV prevalence epidemic: modelling results from Project SIDA1/2/3 in Cotonou, Benin. PloS one. 2014;9(7):e102643
33. Chersich MF, Luchters S, Ntaganira I, et al. Priority interventions to reduce HIV transmission in sex work settings in sub-Saharan Africa and delivery of these services. Journal of the International Aids Society. 2013 Mar 4;16
34. Eakle R, Gomez GB, Naicker N, et al. HIV pre-exposure prophylaxis and early antiretroviral treatment among female sex workers in South Africa: Results from a prospective observational demonstration project. PLoS Med. 2017 Nov;14(11):e1002444
35. Gomez GB, Eakle R, Mbogua J, Akpomiemie G, Venter WD, Rees H. Treatment And Prevention for female Sex workers in South Africa: protocol for the TAPS Demonstration Project. BMJ open. 2016 Sep 26;6(9):e011595
36. Hargreaves JR, Fearon E, Davey C, Phillips A, Cambiano V, Cowan FM. Statistical design and analysis plan for an impact evaluation of an HIV treatment and prevention intervention for female sex workers in Zimbabwe: A study protocol for a cluster randomised controlled trial. Trials. 2016 January 05;17 (1) (no pagination)(6)
37. Alary M, Lowndes CM, Van de Perre P, et al. Scale-up of combination prevention and antiretroviral therapy for female sex workers in West Africa: time for action. AIDS. 2013 Jun 1;27(9):1369-74
38. Delva W, Eaton JW, Meng F, et al. HIV treatment as prevention: optimising the impact of expanded HIV treatment programmes. PLoS Med. 2012;9(7):e1001258
39. Mountain E, Mishra S, Vickerman P, Pickles M, Gilks C, Boily MC. Antiretroviral therapy uptake, attrition, adherence and outcomes among hiv-infected female sex workers: A systematic review and meta-analysis. PLoS ONE. 2014 02 Oct;9 (9) (no pagination) (e105645)

40. WHO. Antiretroviral Treatment as Prevention (TasP) of HIV and TB: 2012 update. WHO, Geneva, Switzerland: 2012.
41. Mutua G, Sanders E, Mugo P, et al. Safety and Adherence to Intermittent Pre-Exposure Prophylaxis (PrEP) for HIV-1 in African Men Who Have Sex with Men and Female Sex Workers. Plos One. 2012 Apr 12;7(4)
42. Obiero J, Mwethera PG, Hussey GD, Wiysonge CS. Vaginal microbicides for reducing the risk of sexual acquisition of HIV infection in women: systematic review and meta-analysis. Bmc Infectious Diseases. 2012 Nov 6;12
43. Ye L, Wei S, Zou Y, et al. HIV Pre-Exposure Prophylaxis Interest among Female Sex Workers in Guangxi, China. Plos One. 2014 Jan 22;9(1)
44. Gardner EM, McLees MP, Steiner JF, Del Rio C, Burman WJ. The spectrum of engagement in HIV care and its relevance to test-and-treat strategies for prevention of HIV infection. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America. 2011 Mar 15;52(6):793-800
45. Kay ES, Batey DS, Mugavero MJ. The HIV treatment cascade and care continuum: updates, goals, and recommendations for the future. AIDS Research and Therapy. 2016;13
46. Mountain E, Pickles M, Mishra S, Vickerman P, Alary M, Boily MC. The HIV care cascade and antiretroviral therapy in female sex workers: Implications for HIV prevention. Expert Review of Anti-Infective Therapy. 2014 01 Oct;12(10):1203-19
47. WHO. Consolidated guidelines on general HIV care and the use of antiretroviral drugs for treating and preventing HIV infection: recommendations for a public health approach. WHO, Geneva, Switzerland: 2013.
48. Rosen S, Fox MP. Retention in HIV care between testing and treatment in sub-Saharan Africa: a systematic review. PLoS Med. 2011 Jul;8(7):e1001056
49. Fox MP, Rosen S. A new cascade of HIV care for the era of "treat all". PLoS Medicine. 2017;14 (4) (no pagination) (e1002268)
50. WHO. Consolidated guidelines on HIV prevention, diagnosis, treatment and care for key populations. WHO, Geneva, Switzerland: 2014.
51. WHO. Global HIV/AIDS response: epidemic update and health sector progress towards universal access: progress report 2011. WHO, Geneva, Switzerland: 2011.
52. Braunstein SL, Ingabire CM, Geubbels E, et al. High burden of prevalent and recently acquired HIV among female sex workers and female HIV voluntary testing center clients in Kigali, Rwanda. PLoS One. 2011;6(9):e24321
53. Chanda MM, Ortblad KF, Mwale M, et al. HIV self-testing among female sex workers in Zambia: A cluster randomized controlled trial. PLoS Med. 2017 Nov;14(11):e1002442
54. Lancaster KE, Powers KA, Lungu T, et al. The HIV care continuum among female sex workers: A key population in Lilongwe, Malawi. PLoS ONE. 2016 01 Jan;11 (1) (no pagination) (e0147662)
55. Smith LR, Patterson TL, Magis-Rodriguez C, et al. Engagement in the HIV Care Continuum among Key Populations in Tijuana, Mexico. Aids Behav. 2016 01 May;20(5):1017-25
56. Zulliger R, Barrington C, Donastorg Y, Perez M, Kerrigan D. High drop-off along the HIV care continuum and ART interruption among female sex workers in the dominican Republic. J Acquir Immune Defic Syndr. 2015 01 Jun;69(2):216-22
57. Kerrigan D, Barrington C, Donastorg Y, Perez M, Galai N. Abriendo Puertas: Feasibility and Effectiveness a Multi-Level Intervention to Improve HIV Outcomes Among Female Sex Workers Living with HIV in the Dominican Republic. Aids Behav. 2016 01 Sep;20(9):1919-27
58. Mendoza C, Barrington C, Donastorg Y, et al. Violence from a sexual partner is significantly associated with poor HIV care and treatment outcomes among female sex workers in the Dominican Republic. J Acquir Immune Defic Syndr. 2017 01 Mar;74(3):273-8

59. Surratt HL, O'Grady CL, Kurtz SP, Buttram ME, Levi-Minzi MA. HIV testing and engagement in care among highly vulnerable female sex workers: implications for treatment as prevention models. Journal of health care for the poor and underserved. 2014 01 Aug;25(3):1360-78
60. Lafort Y, Greener R, Roy A, et al. HIV prevention and care-seeking behaviour among female sex workers in four cities in India, Kenya, Mozambique and South Africa. Tropical Medicine and International Health. 2016 01 Oct;21(10):1293-303
61. Lafort Y, Lessitala F, Candrinho B, et al. Barriers to HIV and sexual and reproductive health care for female sex workers in Tete, Mozambique: results from a cross-sectional survey and focus group discussions. BMC public health. 2016 20 Jul;16:608
62. Zulliger R, Maulsby C, Barrington C, et al. Retention in HIV care among female sex workers in the Dominican Republic: implications for research, policy and programming. Aids Behav. 2015 01 Apr;19(4):715-22
63. Bhattacharjee P, McClarty LM, Musyoki H, et al. Monitoring HIV Prevention Programme Outcomes among Key Populations in Kenya: Findings from a National Survey. PLoS ONE. 2015;10(8):e0137007
64. Cowan FM, Davey CB, Fearon E, et al. The HIV care cascade among female sex workers in Zimbabwe: Results of a population-based survey from the sisters antiretroviral therapy programme for prevention of HIV, an integrated response (SAPPH-IRe) trial. J Acquir Immune Defic Syndr. 2017 01 Apr;74(4):375-82
65. Duff P, Goldenberg S, Deering K, et al. Barriers to Viral Suppression among Female Sex Workers: Role of Structural and Intimate Partner Dynamics. J Acquir Immune Defic Syndr. 2016 01 Sep;73(1):83-90
66. Goldenberg SM, Deering K, Amram O, et al. Community mapping of sex work criminalization and violence: impacts on HIV treatment interruptions among marginalized women living with HIV in Vancouver, Canada. Int J STD AIDS. 2017 01 Sep;28(10):1001-9
67. Goldenberg SM, Montaner J, Duff P, et al. Structural Barriers to Antiretroviral Therapy Among Sex Workers Living with HIV: Findings of a Longitudinal Study in Vancouver, Canada. Aids Behav. 2016 May;20(5):977-86
68. Holland CE, Papworth E, Billong SC, et al. Antiretroviral treatment coverage for men who have sex with men and female sex workers living with HIV in Cameroon. J Acquir Immune Defic Syndr. 2015 01 Mar;68:S232-S40
69. Lancaster KE, Lungu T, Mmodzi P, et al. The association between substance use and sub-optimal HIV treatment engagement among HIV-infected female sex workers in Lilongwe, Malawi. AIDS Care. 2017 01 Feb;29(2):197-203
70. Lyons CE, Grosso A, Drame FM, et al. Physical and sexual violence affecting female sex workers in Abidjan, cote d'ivoire: Prevalence, and the relationship with the work environment, HIV, and access to health services. J Acquir Immune Defic Syndr. 2017;75(1):9-17
71. Mayanja Y, Kamacooko O, Bagiire D, Namale G, Kaleebu P, Seeley J. 'Test and Treat' Among Women at High Risk for HIV-infection in Kampala, Uganda: Antiretroviral Therapy Initiation and Associated Factors. Aids Behav. 2017 Nov 10
72. Muth S, Len A, Evans JL, et al. HIV treatment cascade among female entertainment and sex workers in Cambodia: impact of amphetamine use and an HIV prevention program. Addiction science & clinical practice. 2017 Sep 5;12(1):20
73. Schwartz SR, Papworth E, Ky-Zerbo O, et al. Safer conception needs for HIV prevention among female sex workers in Burkina Faso and Togo. Infectious Diseases in Obstetrics and Gynecology. 2014;2014 (no pagination) (296245)
74. Vuylsteke B, Semde G, Auld AF, et al. Retention and risk factors for loss to follow-up of female and male sex workers on antiretroviral treatment in ivory coast: A retrospective cohort analysis. J Acquir Immune Defic Syndr. 2015 01 Mar;68:S99-S106

75. Wilson KS, Deya R, Masese L, et al. Prevalence and correlates of intimate partner violence in HIV-positive women engaged in transactional sex in Mombasa, Kenya. Int J STD AIDS. 2016 Nov;27(13):1194-203
76. Blanchard JF, O'Neil J, Ramesh BM, Bhattacharjee P, Orchard T, Moses S. Understanding the social and cultural contexts of female sex workers in Karnataka, India: implications for prevention of HIV infection. The Journal of infectious diseases. 2005 Feb 1;191 Suppl 1:S139-46
77. Gupta GR, Parkhurst JO, Ogden JA, Aggleton P, Mahal A. HIV prevention 4 - Structural approaches to HIV prevention. Lancet. 2008 Aug-Sep;372(9640):764-75
78. Sumartojo E. Structural factors in HIV prevention: concepts, examples, and implications for research. Aids. 2000 Jun;14:S3-S10
79. Kerrigan DL, Fonner VA, Stromdahl S, Kennedy CE. Community Empowerment Among Female Sex Workers is an Effective HIV Prevention Intervention: A Systematic Review of the Peer-Reviewed Evidence from Low- and Middle-Income Countries. Aids Behav. 2013 Jul;17(6):1926-40
80. Anderson S, Shannon K, Li J, et al. Condoms and sexual health education as evidence: impact of criminalization of in-call venues and managers on migrant sex workers access to HIV/STI prevention in a Canadian setting. BMC Int Health Hum Rights. 2016 17 Nov;16(1):1-10
81. Beattie TSH, Bhattacharjee P, Ramesh BM, et al. Violence against female sex workers in Karnataka state, south India: impact on health, and reductions in violence following an intervention program. BMC Public Health. 2010 Aug 11;10
82. Berger BO, Grosso A, Adams D, et al. The Prevalence and Correlates of Physical and Sexual Violence Affecting Female Sex Workers in Swaziland. J Interpers Violence. 2016 Feb 12;12:12
83. Burke VM, Nakyanjo N, Ddaaki W, et al. HIV self-testing values and preferences among sex workers, fishermen, and mainland community members in Rakai, Uganda: A qualitative study. PLoS ONE. 2017 August;12 (8) (no pagination) (e0183280)
84. Hong Y, Zhang C, Li X, et al. HIV testing behaviors among female sex workers in Southwest China. Aids Behav. 2012 Jan;16(1):44-52
85. Kakchapati S, Paudel T, Maharjan M, Lim A. Systematic differences in HIV, syphilis and risk behaviors among street based and establishment based female sex workers in Kathmandu Valley of Nepal. Nepal Journal of Epidemiology. 2016;6(4):620-30
86. King EJ, Maman S. Structural barriers to receiving health care services for female sex workers in Russia. Qualitative health research. 2013 Aug;23(8):1079-88
87. Lyons T, Krusi A, Pierre L, Kerr T, Small W, Shannon K. Negotiating Violence in the Context of Transphobia and Criminalization: The Experiences of Trans Sex Workers in Vancouver, Canada. Qual Health Res. 2017 Jan;27(2):182-90
88. Nakanwagi S, Matovu JK, Kintu BN, Kaharuza F, Wanyenze RK. Facilitators and Barriers to Linkage to HIV Care among Female Sex Workers Receiving HIV Testing Services at a Community-Based Organization in Periurban Uganda: A Qualitative Study. Journal of sexually transmitted diseases. 2016;2016:7673014
89. Ngo AD, Ratliff EA, McCurdy SA, Ross MW, Markham C, Pham HTB. Health-seeking behaviour for sexually transmitted infections and HIV testing among female sex workers in Vietnam. AIDS Care. 2007 August;19(7):878-87
90. Scorgie F, Nakato D, Harper E, et al. 'We are despised in the hospitals': sex workers' experiences of accessing health care in four African countries. Cult Health Sex. 2013;15(4):450-65
91. Sherwood JA, Grosso A, Decker MR, et al. Sexual violence against female sex workers in The Gambia: a cross-sectional examination of the associations between victimization and reproductive, sexual and mental health. BMC Public Health. 2015;15:270
92. Socias ME, Shoveller J, Bean C, Nguyen P, Montaner J, Shannon K. Universal Coverage without Universal Access: Institutional Barriers to Health Care among Women Sex Workers in Vancouver, Canada. PLoS One. 2016;11(5):e0155828

93. Wang Y, Li B, Pan J, et al. Factors associated with utilization of a free HIV VCT clinic by female sex workers in Jinan City, Northern China. Aids Behav. 2011 May;15(4):702-10
94. Wang Y, Li B, Zheng J, et al. Factors related to female sex workers' Willingness to utilize VCT service: A qualitative study in Jinan City, Northern China. Aids Behav. 2009 October;13(5):866-72
95. Zeng H, Zhao Y, Meng S, et al. Exploring HIV prevention strategies among street-based female sex workers in Chongqing, China. International Journal of Environmental Research and Public Health. 2015 16 Jan;12(1):855-70
96. Zulliger R, Kennedy C, Barrington C, Perez M, Donastorg Y, Kerrigan D. A multi-level examination of the experiences of female sex workers living with HIV along the continuum of care in the Dominican Republic. Global Public Health. 2017 27 Jun:1-15
97. Nyblade L, Reddy A, Mbote D, et al. The relationship between health worker stigma and uptake of HIV counseling and testing and utilization of non-HIV health services: the experience of male and female sex workers in Kenya. AIDS Care. 2017 Nov;29(11):1364-72
98. Fonner VA, Kerrigan D, Mnisi Z, Ketende S, Kennedy CE, Baral S. Social Cohesion, Social Participation, and HIV Related Risk among Female Sex Workers in Swaziland. Plos One. 2014 Jan 31;9(1)
99. Latkin C, Weeks MR, Glasman L, Galletly C, Albarracin D. A Dynamic Social Systems Model for Considering Structural Factors in HIV Prevention and Detection. Aids Behav. 2010 Dec;14:S222-S38
100. Rhodes. The ‘risk environment’: a framework for understanding and reducing drug-related harm. Int J Drug Policy. 2002;13:85-94
101. Blanchard JF, Aral SO. Emergent properties and structural patterns in sexually transmitted infection and HIV research. Sex Transm Infect. 2010 Dec;86:4-9
102. Overs C, Loff B. The tide cannot be turned without us: sex workers and the global response to HIV. J Int AIDS Soc. 2013;16(1):18459
103. Choudhury SM, Anglade D, Park K. From Violence to Sex Work: Agency, Escaping Violence, and HIV Risk Among Establishment-Based Female Sex Workers in Tijuana, Mexico. Janac-Journal of the Association of Nurses in Aids Care. 2013 Jul-Aug;24(4):368-82
104. Tounkara FK, Diabate S, Guedou FA, et al. Violence, condom breakage, and HIV infection among female sex workers in Benin, West Africa. Sex Transm Dis. 2014 2014-May;41(5):312-8
105. Krusi A, Chettiar J, Ridgway A, Abbott J, Strathdee SA, Shannon K. Negotiating safety and sexual risk reduction with clients in unsanctioned safer indoor sex work environments: a qualitative study. Am J Public Health. 2012 Jun;102(6):1154-9
106. Rhodes T, Simic M, Baros S, Platt L, Zikic B. Police violence and sexual risk among female and transvestite sex workers in Serbia: qualitative study. BMJ (Clinical research ed). 2008;337:a811
107. Decker MR, Lyons C, Billong SC, et al. Gender-based violence against female sex workers in Cameroon: prevalence and associations with sexual HIV risk and access to health services and justice. Sex Transm Infect. 2016 Jun 8;8:8
108. Footer KH, Silberzahn BE, Tormohlen KN, Sherman SG. Policing practices as a structural determinant for HIV among sex workers: a systematic review of empirical findings. J Int AIDS Soc. 2016;19(4 Suppl 3):20883
109. Tenni B, Carpenter J, Thomson N. Arresting HIV: Fostering Partnerships between Sex Workers and Police to Reduce HIV Risk and Promote Professionalization within Policing Institutions: A Realist Review. PLoS ONE [Electronic Resource]. 2015;10(10):e0134900
110. Bungay V, Halpin M, Halpin PF, Johnston C, Patrick DM. Violence in the Massage Parlor Industry: Experiences of Canadian-Born and Immigrant Women. Health Care Women Int. 2012 2012;33(3):262-84
111. WHO. WHO Multi-country Study on Women's Health and Domestic Violence against Women. WHO, Geneva, Switzerland. 2005

112. Krusi A, Pacey K, Bird L, et al. Criminalisation of clients: Reproducing vulnerabilities for violence and poor health among street-based sex workers in Canada - A qualitative study. BMJ open. 2014;4(6)
113. Erausquin JT, Reed E, Blankenship KM. Police-Related Experiences and HIV Risk Among Female Sex Workers in Andhra Pradesh, India. J Infect Dis. 2011 Dec 1;204:S1223-S8
114. Shannon K, Kerr T, Strathdee SA, Shoveller J, Montaner JS, Tyndall MW. Prevalence and structural correlates of gender based violence among a prospective cohort of female sex workers. BMJ. 2009 Aug 11;339
115. Decker MR, McCauley HL, Phuengsamran D, Janyam S, Silverman JG. Sex trafficking, sexual risk, sexually transmitted infection and reproductive health among female sex workers in Thailand. Journal of Epidemiology and Community Health. 2011 Apr;65(4):334-9
116. Silverman JG, Raj A, Cheng DM, et al. Sex Trafficking and Initiation-Related Violence, Alcohol Use, and HIV Risk Among HIV-Infected Female Sex Workers in Mumbai, India. J Infect Dis. 2011 Dec 1;204:S1229-S34
117. George A, Sabarwal S. Sex trafficking, physical and sexual violence, and HIV risk among young female sex workers in Andhra Pradesh, India. International Journal of Gynecology & Obstetrics. 2013 Feb;120(2):119-23
118. Gupta J, Reed E, Kershaw T, Blankenship KM. History of sex trafficking, recent experiences of violence, and HIV vulnerability among female sex workers in coastal Andhra Pradesh, India. International Journal of Gynecology & Obstetrics. 2011 Aug;114(2):101-5
119. Li Q, Li X, Stanton B. Alcohol Use Among Female Sex Workers and Male Clients: An Integrative Review of Global Literature. Alcohol and Alcoholism. 2010 Mar-Apr;45(2):188-99
120. Chersich MF, Luchters SMF, Malonza IM, Mwarogo P, King'ola N, Temmerman M. Heavy episodic drinking among Kenyan female sex workers is associated with unsafe sex, sexual violence and sexually transmitted infections. Int J STD AIDS. 2007 Nov;18(11):764-9
121. Zhang C, Li X, Stanton B, et al. Alcohol use and client-perpetrated sexual violence against female sex workers in China. Psychol Health Med. 2013 May 1;18(3):330-42
122. Odinokova V, Rusakova M, Urada LA, Silverman JG, Raj A. Police sexual coercion and its association with risky sex work and substance use behaviors among female sex workers in St. Petersburg and Orenburg, Russia. Int J Drug Policy. 2014 Jan;25(1):96-104
123. Bhattacharjee P, Prakash R, Pillai P, et al. Understanding the role of peer group membership in reducing HIV-related risk and vulnerability among female sex workers in Karnataka, India. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2013 Jun 20;25:S46-S54
124. Blanchard AK, Mohan HL, Shahmanesh M, et al. Community mobilization, empowerment and HIV prevention among female sex workers in south India. Bmc Public Health. 2013 Mar 16;13
125. Punyam S, Pullikalu RS, Mishra RM, et al. Community advocacy groups as a means to address the social environment of female sex workers: a case study in Andhra Pradesh, India. Journal of Epidemiology and Community Health. 2012 Oct;66:II87-II94
126. Baggaley RF, Dimitrov D, Owen BN, et al. Heterosexual Anal Intercourse: A Neglected Risk Factor for HIV? Am J Reprod Immunol. 2013 Feb;69:95-105
127. Deering KN, Bhattacharjee P, Mohan HL, et al. Violence and HIV Risk Among Female Sex Workers in Southern India. Sex Transm Dis. 2013 Feb;40(2):168-74
128. Gurnani V, Beattie TS, Bhattacharjee P, et al. An integrated structural intervention to reduce vulnerability to HIV and sexually transmitted infections among female sex workers in Karnataka state, south India. Bmc Public Health. 2011 Oct 2;11
129. Shannon K, Csete J. Violence, condom negotiation, and HIV/STI risk among sex workers. JAMA - Journal of the American Medical Association. 2010 04 Aug;304(5):573-4

130. Hong Y, Zhang C, Li X, Liu W, Zhou Y. Partner Violence and Psychosocial Distress among Female Sex Workers in China. Plos One. 2013 Apr 23;8(4)
131. Yuen WWY, Tran L, Wong CKH, Holroyd E, Tang CSK, Wong WCW. Psychological health and HIV transmission among female sex workers: a systematic review and meta-analysis. AIDS Care. 2016 02 Jul;28(7):816-24
132. Zhang C, Li X, Chen Y, et al. Alcohol and Other Drug Use, Partner Violence, and Mental Health Problems Among Female Sex Workers in Southwest China. Health Care Women Int. 2014 Jan 1;35(1):60-73
133. Patel SK, Ganju D, Prabhakar P, Adhikary R. Relationship between mobility, violence and major depression among female sex workers: a cross-sectional study in southern India. BMJ open. 2016;6(9):e011439
134. Zhang L, Li X, Wang B, et al. Violence, stigma and mental health among female sex workers in China: A structural equation modeling. Women Health. 2017 Jul;57(6):685-704
135. Zhang C, Li X, Hong Y, Chen Y, Liu W, Zhou Y. Partner violence and HIV risk among female sex workers in China. Aids Behav. 2012 May;16(4):1020-30
136. Wanyenze RK, Musinguzi G, Kiguli J, et al. "when they know that you are a sex worker, you will be the last person to be treated": Perceptions and experiences of female sex workers in accessing HIV services in Uganda. BMC Int Health Hum Rights. 2017 05 May;17 (1) (no pagination)(11)
137. Decker MR, Wirtz AL, Moguilnyi V, et al. Female Sex Workers in Three Cities in Russia: HIV Prevalence, Risk Factors and Experience with Targeted HIV Prevention. Aids Behav. 2014 Mar;18(3):562-72
138. Pack AP, L'Engle K, Mwarogo P, Kingola N. Intimate partner violence against female sex workers in Mombasa, Kenya. Cult Health Sex. 2013 Dec 11;11:11
139. Beattie TS, Bhattacharjee P, Isac S, et al. Declines in violence and police arrest among female sex workers in Karnataka state, south India, following a comprehensive HIV prevention programme. Journal of the International AIDS Society. 2015 16 Oct;18 (1) (no pagination)(20079)
140. Ulibarri MD, Strathdee SA, Ulloa EC, et al. Injection Drug Use as a Mediator Between Client-perpetrated Abuse and HIV Status Among Female Sex Workers in Two Mexico-US Border Cities. Aids Behav. 2011 Jan;15(1):179-85
141. Decker MR, Wirtz AL, Baral SD, et al. Injection drug use, sexual risk, violence and STI/HIV among Moscow female sex workers. Sex Transm Infect. 2012 Jun;88(4):278-83
142. Abdul-Quader AS, Collins C. Identification of structural Interventions for HIV/AIDS Prevention: The Concept Mapping Exercise. Public Health Rep. 2011 November/December;126(6):777-8
143. Blankenship KM, Friedman SR, Dworkin S, Mantell JE. Structural interventions: Concepts, challenges and opportunities for research. Journal of Urban Health. 2006 January;83(1):59-72
144. Dean HD, Fenton KA. Addressing social determinants of health in the prevention and control of HIV/AIDS, viral hepatitis, sexually transmitted infections, and tuberculosis. Public Health Rep. 2010 Jul-Aug;125:1-5
145. Shahmanesh M, Patel V, Mabey D, Cowan F. Effectiveness of interventions for the prevention of HIV and other sexually transmitted infections in female sex workers in resource poor setting: a systematic review. Tropical Medicine & International Health. 2008 May;13(5):659-79
146. Odek WO, Busza J, Morris CN, Cleland J, Ngugi EN, Ferguson AG. Effects of Micro-Enterprise Services on HIV Risk Behaviour Among Female Sex Workers in Kenya's Urban Slums. Aids Behav. 2009 Jun;13(3):449-61
147. Sherman SG, German D, Cheng Y, Marks M, Bailey-Kloche M. The evaluation of the JEWEL project: An innovative economic enhancement and HIV prevention intervention study targeting drug using women involved in prostitution. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2006 Jan;18(1):1-11

148. Sherman SG, Srikrishnan AK, Rivett KA, Liu S-H, Solomon S, Celentano DD. Acceptability of a Microenterprise Intervention Among Female Sex Workers in Chennai, India. Aids Behav. 2010 Jun;14(3):649-57
149. Tsai LC, Witte SS, Aira T, Altantsetseg B, Riedel M. Piloting a Savings-Led Microfinance Intervention with Women Engaging in Sex Work in Mongolia: Further Innovation for HIV Risk Reduction. The open women's health journal. 2011 Dec 30;5:26-32
150. Kang D, Tao X, Liao M, et al. An integrated individual, community, and structural intervention to reduce HIV/STI risks among female sex workers in China. Bmc Public Health. 2013 Aug 4;13
151. Rojanapithayakorn W. The 100% condom use programme in Asia. Reprod Health Matters. 2006 Nov;14(28):41-52
152. Ghose T, Swendeman D, George S, Chowdhury D. Mobilizing collective identity to reduce HIV risk among sex workers in Sonagachi, India: The boundaries, consciousness, negotiation framework. Social Science & Medicine. 2008 Jul;67(2):311-20
153. Wariki WMV, Ota E, Mori R, Koyanagi A, Hori N, Shibuya K. Behavioral interventions to reduce the transmission of HIV infection among sex workers and their clients in low- and middle-income countries. Cochrane Database of Systematic Reviews. 2012 2012(2)
154. Erausquin JT, Biradavolu M, Reed E, Burroway R, Blankenship KM. Trends in condom use among female sex workers in Andhra Pradesh, India: the impact of a community mobilisation intervention. Journal of Epidemiology and Community Health. 2012 Oct;66:II49-II54
155. Wirtz AL, Pretorius C, Beyrer C, et al. Epidemic Impacts of a Community Empowerment Intervention for HIV Prevention among Female Sex Workers in Generalized and Concentrated Epidemics. Plos One. 2014 Feb 6;9(2)
156. Halli SS, Ramesh BM, O'Neil J, Moses S, Blanchard JF. The role of collectives in STI and HIV/AIDS prevention among female sex workers in Karnataka, India. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2006 Oct;18(7):739-49
157. Swendeman D, Basu I, Das S, Jana S, Rotheram-Borus MJ. Empowering sex workers in India to reduce vulnerability to HIV and sexually transmitted diseases. Social Science & Medicine. 2009 Oct;69(8):1157-66
158. Basu I, Jana S, Rotheram-Borus MJ, et al. HIV prevention among sex workers in India. Jaids-Journal of Acquired Immune Deficiency Syndromes. 2004 Jul 1;36(3):845-52
159. Wechsberg WM, Luseno WK, Lam WKK, Parry CDH, Morojele NK. Substance use, sexual risk, and violence: HIV prevention intervention with sex workers in Pretoria. Aids Behav. 2006 Mar;10(2):131-7
160. Saggurti N, Mishra RM, Proddutoor L, et al. Community collectivization and its association with consistent condom use and STI treatment-seeking behaviors among female sex workers and high-risk men who have sex with men/transgenders in Andhra Pradesh, India. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2013 Jun 20;25:S55-S66
161. Kuhlmann AS, Galavotti C, Hastings P, Narayanan P, Saggurti N. Investing in Communities: Evaluating the Added Value of Community Mobilization on HIV Prevention Outcomes Among FSWs in India. Aids Behav. 2014 Apr;18(4):752-66
162. Reza-Paul S, Beattie T, Syed HUR, et al. Declines in risk behaviour and sexually transmitted infection prevalence following a community-led HIV preventive intervention among female sex workers in Mysore, India. Aids. 2008 Dec;22:S91-S100
163. Lippman SA, Chinaglia M, Donini AA, Diaz J, Reingold A, Kerrigan DL. Findings From Encontros: A Multilevel STI/HIV Intervention to Increase Condom Use, Reduce STI, and Change the Social Environment Among Sex Workers in Brazil. Sex Transm Dis. 2012 Mar;39(3):209-16
164. Lippman SA, Donini A, Diaz J, Chinaglia M, Reingold A, Kerrigan D. Social-Environmental Factors and Protective Sexual Behavior Among Sex Workers: The Encontros Intervention in Brazil. Am J Public Health. 2010 2010;100:S216-S23

165. Kerrigan D, Moreno L, Rosario S, et al. Environmental-structural interventions to reduce HIV/STI risk among female sex workers in the Dominican republic. Am J Public Health. 2006 Jan;96(1):120-5
166. TAMPEP. Work Safe in Sex Work - A European Manual on Good Practices in Work with and for Sex Workers. TAMPEP International Foundation. 2009
167. Beattie TS, Mohan HL, Bhattacharjee P, et al. Community mobilization and empowerment of female sex workers in Karnataka State, South India: associations with HIV and sexually transmitted infection risk. Am J Public Health. 2014 Aug;104(8):1516-25
168. Erausquin JT, Reed E, Blankenship KM. Change over Time in Police Interactions and HIV Risk Behavior Among Female Sex Workers in Andhra Pradesh, India. Aids Behav. 2015 Jun;19(6):1108-15
169. Reza-Paul S, Lorway R, O'Brien N, et al. Sex worker-led structural interventions in India: a case study on addressing violence in HIV prevention through the Ashodaya Samithi collective in Mysore. Indian Journal of Medical Research. 2012 Jan;135(1):98-106
170. Crofts N, Patterson D. Police must join the fast track to end AIDS by 2030. Journal of the International AIDS Society. 2016 18 Jul;19 (Supplement 3) (no pagination) (21153)
171. L'Engle KL, Mwarogo P, Kingola N, Sinkele W, Weiner DH. A randomized controlled trial of a brief intervention to reduce alcohol use among female sex workers in Mombasa, Kenya. J Acquir Immune Defic Syndr. 2014 Dec 1;67(4):446-53
172. Parcesepe AM, KL LE, Martin SL, et al. The impact of an alcohol harm reduction intervention on interpersonal violence and engagement in sex work among female sex workers in Mombasa, Kenya: Results from a randomized controlled trial. Drug Alcohol Depend. 2016 Apr 1;161:21-8
173. FHI. Young People Most at Risk of HIV: A Meeting Report and Discussion Paper from the Interagency Youth Working Group, U.S. Agency for International Development, the Joint United Nations Programme on HIV/AIDS (UNAIDS) Inter-Agency Task Team on HIV and Young People, and FHI. 2010.
174. Pettifor A, Nguyen NL, Celum C, Cowan FM, Go V, Hightow-Weidman L. Tailored combination prevention packages and PrEP for young key populations. J Int AIDS Soc. 2015;18(2 Suppl 1):19434
175. WHO. HIV and young people who sell sex: A technical brief. 2014.
176. Dellar RC, Dlamini S, Karim QA. Adolescent girls and young women: key populations for HIV epidemic control. J Int AIDS Soc. 2015;18(2 Suppl 1):19408
177. Baggaley R, Armstrong A, Dodd Z, Ngoksin E, Krug A. Young key populations and HIV: A special emphasis and consideration in the new WHO Consolidated Guidelines on HIV Prevention, Diagnosis, Treatment and Care for Key Populations. Journal of the International AIDS Society. 2015;18(2 Supplement 1):85-8
178. Cowan FM, Delany-Moretlwe S. Promise and pitfalls of pre-exposure prophylaxis for female sex workers. Current Opinion in HIV and AIDS. 2016 01 Jan;11(1):27-34
179. Beattie TSH, Bradley JE, Vanta UD, Lowndes CM, Alary M. Vulnerability re-assessed: The changing face of sex work in Guntur district, Andhra Pradesh. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2013 Mar 1;25(3):378-84
180. Laga M, Rugg D, Peersman G, Ainsworth M. Evaluating HIV prevention effectiveness: the perfect as the enemy of the good. Aids. 2012 Apr 24;26(7):779-83
181. Boily M-C, Shubber Z. Modelling in concentrated epidemics: informing epidemic trajectories and assessing prevention approaches. Current Opinion in Hiv and Aids. 2014 Mar;9(2):134-49
182. Eaton J, Menzies N, Stover J, et al. Health benefits, costs, and cost-effectiveness of earlier eligibility for adult antiretroviral therapy and expanded treatment coverage: a combined analysis of 12 mathematical models. Lancet Glob Health 2014;2: e23-34
183. Eaton JW, Johnson LF, Salomon JA, et al. HIV treatment as prevention: systematic comparison of mathematical models of the potential impact of antiretroviral therapy on HIV incidence in South Africa. PLoS Med. 2012;9(7):e1001245

184. Steen R, Hontelez JAC, Veraart A, White RG, de Vlas SJ. Looking upstream to prevent HIV transmission: can interventions with sex workers alter the course of HIV epidemics in Africa as they did in Asia? Aids. 2014 Mar 27;28(6):891-9
185. Keeling MJ, Danon L. Mathematical modelling of infectious diseases. British Medical Bulletin. 2009 Dec;92(1):33-42
186. Decker MR, Wirtz AL, Pretorius C, et al. Estimating the Impact of Reducing Violence Against Female Sex Workers on HIV Epidemics in Kenya and Ukraine: A Policy Modeling Exercise. Am J Reprod Immunol. 2013 Feb;69:122-32
187. Kato M, Granich R, Duc Bui D, et al. The potential impact of expanding antiretroviral therapy and combination prevention in Vietnam: Towards elimination of HIV transmission. Journal of acquired immune deficiency syndromes (1999). 2013 May 24
188. Mishra S, Mountain E, Pickles M, et al. Exploring the population-level impact of antiretroviral treatment: the influence of baseline intervention context. Aids. 2014 Jan;28:S61-S72
189. Vassall A, Chandrashekar S, Pickles M, et al. Community mobilisation and empowerment interventions as part of HIV prevention for female sex workers in southern india: A cost-effectiveness analysis. PLoS ONE. 2014;9 (10) (no pagination)(e110562)
190. Boily MC, Masse B. Mathematical models of disease transmission: A precious tool for the study of sexually transmitted diseases. Canadian Journal of Public Health. 1997 July/August;88(4):255-65
191. Garnett GP, Cousens S, Hallett TB, Steketee R, Walker N. Mathematical models in the evaluation of health programmes. The Lancet. 2011 August 6-12;378(9790):515-25
192. McInnes CW, Druyts E, Harvard SS, et al. HIV/AIDS in Vancouver, British Columbia: a growing epidemic. Harm Reduct J. 2009 Mar 5;6:5
193. NACC and NASCOP. Kenya HIV County Profiles. 2016.
194. Odek WO, Githuka GN, Avery L, et al. Estimating the size of the female sex worker population in Kenya to inform HIV prevention programming. PLoS ONE. 2014 03 Mar;9 (3) (no pagination)(e89180)
195. Luchters S, Chersich MF, Rinyiru A, et al. Impact of five years of peer-mediated interventions on sexual behavior and sexually transmitted infections among female sex workers in Mombasa, Kenya. BMC Public Health. 2008;8 (no pagination) (143)
196. Luchters SMF, Broeck DV, Chersich MF, et al. Association of HIV infection with distribution and viral load of HPV types in Kenya: A survey with 820 female sex workers. BMC Infectious Diseases. 2010 26 Jan;10 (no pagination) (18)
197. Bengtson AM, L'Engle K, Mwarogo P, King'ola N. Levels of alcohol use and history of HIV testing among female sex workers in Mombasa, Kenya. AIDS Care. 2014;26(12):1619-24
198. Montaner JS, Lima VD, Harrigan PR, et al. Expansion of HAART coverage is associated with sustained decreases in HIV/AIDS morbidity, mortality and HIV transmission: the "HIV Treatment as Prevention" experience in a Canadian setting. PLoS One. 2014;9(2):e87872
199. Nosyk B, Montaner JSG, Colley G, et al. The cascade of HIV care in British Columbia, Canada, 1996-2011: a population-based retrospective cohort study. The Lancet infectious diseases. 2014 Jan;14(1):40-9
200. NACC. Kenya AIDS Response Progress Report 2016.
201. NACC. Kenya AIDS strategic framework 2014/2015 - 2018/2019. National AIDS Control Council, Nairobi, Kenya.
202. NACC. Kenya’s Fast-track Plan to end HIV and AIDS among Adolescents and Young People. Nairobi, Kenya: 2015.
203. National AIDS & STI Control Programme, Ministry of Health, Kenya. Reaching the unreached - The Evolution of Kenya’s HIV/AIDS Prevention Programme for Key Populations. 2016.

Chapter 2: Modelling experiences of police harassment and client violence among sex workers in Vancouver, Canada and their impact on condom use

2.1 Overview

In this chapter I develop a dynamic mathematical model to simulate experiences of workplace violence among FSWs in Vancouver, Canada. My objectives are to use the model to characterise the dynamics of workplace violence, estimate incidence of workplace violence, and estimate the impact of violence-related structural interventions on both workplace violence and inconsistent condom use among FSWs in Vancouver. A large cohort of sex workers in Vancouver, known as AESHA, was the primary data source for guiding the development of the model structure, informing model parameters, and calibrating and validating the model. Dr Kate Shannon (University of British Columbia) shared the AESHA data for this chapter. Statistical analyses to generate the aggregate-level AESHA data used in this modelling analysis, were conducted by Melissa Braschel (University of British Columbia).

2.2 Background and rationale

As highlighted in Chapter 1, FSWs continue to experience high rates of workplace violence (e.g. violence perpetrated by clients, police, managers, pimps or madams), facilitated by criminalisation of sex work and stigma [1-3]. Police harassment (e.g. verbal threats, raids, arrest, coercion and assault) and client physical or sexual violence, which are among the most ubiquitous forms of workplace violence against FSWs in many settings, are important structural determinants of HIV risk among FSWs, associated with inconsistent condom use, client condom refusal, condom use failure, and HIV and STI infection [3,4]. Although workplace violence is widespread, empirical data highlight the heterogeneity in risk of violence among FSWs [2]. For example, a recent systematic review found that work environments of FSWs (i.e. places of solicitation and servicing clients) are particularly influential in shaping risk of violence, with studies from Canada, Britain and Russia documenting that FSWs working on the streets or in public places were at highest risk of experiencing client or police violence [2,5-7]. Individual drug and alcohol use were also found to be associated with elevated rates of workplace violence in a number of settings [2]. Additionally, a number of studies have found an independent link between negative policing practices (e.g. arrest, violence and coercion), and increased rates of client physical and sexual violence [2,8-11], which highlights the complex interactions between different types of violence.

Given the emerging studies documenting the negative impact of workplace violence on HIV risk among FSWs, it will be crucial to incorporate structural approaches that address workplace violence into HIV prevention for FSWs [3,12,13]. To inform the development of structural interventions to reduce violence against FSWs, it is essential to understand the dynamics and patterns of violence against FSWs, and estimating incidence of violence could also be helpful for monitoring trends in the burden of violence before and after structural changes and interventions. Investigating the potential impact that different types of structural interventions could have on HIV risk and transmission is also crucial for informing structural HIV prevention approaches, and given the complex interacting nature of structural factors (e.g. the relationship between different types of workplace violence, such as the influence of police harassment on increasing client violence [2]), it is also important to consider and examine what impact structural interventions could have on other structural conditions (e.g. to what extent could reducing police harassment help to reduce client violence?).

As previously discussed in Chapter 1, mathematical models can help to understand the dynamics of structural determinants and predict the potential impact of structural interventions. In the absence of longitudinal data, models can be utilised to provide estimates of incidence of structural determinants using cross-sectional prevalence data, which could potentially be useful given that longitudinal studies are not often able to be conducted. A recent study by Shannon and colleagues was the first to directly incorporate structural factors, including workplace violence against FSWs, into a HIV transmission model for FSWs [3]. This novel model was utilised to explore the impact of structural changes (e.g. violence elimination) on HIV transmission in three settings, including Vancouver, Canada [3]. Outside the sex work context, there are also limited studies in other key populations that have dynamically modelled structural HIV determinants [14]. In a recent study by Altice and colleagues, a dynamic model of incarceration and HIV transmission among PWID was developed and utilised to estimate the contribution of incarceration to HIV transmission and the potential impact of prison-based interventions on HIV transmission among PWID [14]. In the same study, calibration of the incarceration model component to data on prevalence of incarceration among PWID and the mean number of times previously incarcerated, was used to estimate incarceration and re-incarceration rates, average time spent in prison, and PWID exit rates; and calibration of the HIV transmission model to HIV prevalence data among PWID in different stages of incarceration was used to estimate the HIV transmission risk among PWID in different stages of incarceration [14]. However, there are no comparable studies in the sex work context that have been utilised to gain insights into the dynamics of violence, or other structural HIV determinants. In addition, no studies have explored whether dynamic models can be utilised to provide estimates of incidence of violence, or investigated what impact structural interventions may have on the mediating factors on the pathway between violence and risk of HIV acquisitions and transmission (e.g. condom use), and other structural conditions (e.g. to what extent might client violence be reduced if police harassment was eliminated?).

In this Chapter, I build on the prior modelling work by Shannon and colleagues [3] to begin to explore and address some of these unanswered research questions in the emerging field of modelling structural determinants of HIV among FSWs. My work is focused in the Vancouver setting, where there is a heavy burden of different types of workplace violence, including police harassment, client physical violence and client sexual violence; and police harassment increases risk for client violence [2,3]. My aim is to develop, parameterise and calibrate a new dynamic model of workplace violence experiences among FSWs in Vancouver, using data from a large cohort of FSWs in Vancouver, and utilise it to:

1) Investigate the dynamics of workplace violence among FSWs in Vancouver
2) Estimate incidence of workplace violence among FSWs and validate these estimates against empirical estimates from Vancouver
3) Estimate the potential impact of violence-related structural interventions on:
    a. Levels of workplace violence among FSWs
    b. Levels of inconsistent condom use (ICU) with clients among FSWs
4) Explore the sensitivity of model results to model assumptions and parameters

The new model developed in this chapter generalises the structure of the Shannon *et al* model, to provide a more flexible and representative framework for understanding the dynamics of workplace violence, and estimating incidence of violence. By estimating incidence of violence using cross-sectional prevalence data, and validating these estimates against empirical incidence estimates, I aim to determine if dynamic models of violence can be useful in estimating incidence when only cross-sectional data is available. I do not explicitly model HIV transmission, testing, or treatment among FSWs. Instead, this study focuses on the relationship between workplace violence and a key mediating interpersonal partner-level HIV risk factor: ICU with clients. Overall, from this study I hope to gain useful insights for future model development, data collection, and methodological approaches for modelling structural determinants of HIV risk among FSWs.

2.3 Methods

The methods is split into the following five sections: i) study setting and primary data source, ii) violence model, iii) incorporating condom use into the violence model, iv) modelling structural interventions, and v) plan of analysis.

2.3.1 Study setting and primary data source

2.3.1.1 Study setting

This setting for this study is Vancouver, Canada, which has a HIV epidemic concentrated in key populations, including FSWs (see Chapter 1, Section 1.10). In Vancouver, where most aspects of the sex work industry have historically been criminalised, there is a high prevalence of workplace violence, especially among street-based FSWs and those who use illicit drugs [3,11,15,16]. Police harassment is particularly common; 62% of FSWs report ever experiencing police harassment in their lifetime, and 40% report experiencing police harassment in the past 6 months [3]. A high proportion of FSWs also report ever experiencing client physical violence and client sexual violence in their lifetime (51% and 47%, respectively), while recently experiencing client physical violence and client sexual violence in the past 6 months is reported by 17% and 15% of FSWs, respectively [3]. These experiences of workplace violence have many negative consequences for FSWs HIV/STI prevention (e.g. has a sustained negative effect on condom use with clients) and safety (e.g. recent police harassment reduces FSWs ability to screen clients and displaces them to more isolated areas, which increases their risk for experiencing client violence) [3,11,15,17]. In 2013, a Supreme Court ruling deemed that three laws that prohibited running a bawdy house, public solicitation, and living on the avails of prostitution were unconstitutional on the grounds that these laws increased risk of harm to FSWs and thus violated their rights to security of the person [15,18]. However, under new legislation introduced by the government in 2014 (Bill C-36: The Protection of Exploited Persons and Communities Act), which criminalises the purchasing of sex like the Nordic model introduced by Sweden in 2009, sex workers and service providers report that they continue to experience the same negative impacts on their safety that led to the Supreme Court ruling [15,19].

2.3.1.2 Primary data source

A large open prospective cohort of sex workers in Vancouver, Canada, known as AESHA ("An Evaluation of Sex Workers Health Access"), was the primary data source for guiding the development of the model structure, informing model parameters, and calibrating and validating the model. AESHA, which initiated recruitment in 2010, was developed through substantial community collaborations with sex work agencies, and continues to be guided and monitored by a Community Advisory Board with representatives from over 15 agencies [20]. Time-location sampling is used to recruit participants from outdoor (e.g., streets, alleys) and indoor (e.g., massage parlours, micro-brothels, other in-call locations) sex work locations [20]. Outdoor solicitation locations and indoor sex worker venues were identified through community mapping, and continue to be updated by outreach teams. Online recruitment is also used to reach sex workers working through online solicitation spaces. Eligibility for the study includes being a woman (trans inclusive), having exchanged sex for money within the last 30 days and providing written informed consent. Participants complete a questionnaire, administered by a trained interviewer, at baseline (i.e. when enrolled) and on a bi-annual basis thereafter, which elicits responses on socio-demographics, sex work and drug use patterns, work environments, violence, and policing experiences [21,22]. The study holds ethical approval through Providence Health

Care/University of British Columbia Research Ethics Board. To be consistent with the terminology used throughout the rest of this thesis, the women sex workers in this cohort will be referred to as female sex workers (FSWs). Melissa Braschel, the AESHA statistician, provided the aggregate-level data from AESHA that was utilised in this chapter (further details in Sections 2.3.2.3 and 2.3.5.2). Secondary analyses that I conducted on this aggregate-level data (further details in Section 2.3.2.3) were approved by the Imperial College Research Ethics Committee, United Kingdom.

2.3.2 Violence model

In the following sections I describe the development, structure, parameterisation, and calibration of the dynamic violence model used in this chapter.

2.3.2.1 Model development

The violence model developed in this chapter, builds on prior work by Shannon and colleagues [3], and was guided by data on experiences of workplace violence among FSWs in the AESHA cohort (Figure 2.1). The new model includes the same essential components as in the Shannon *et al* model, namely: three types of workplace violence (police harassment, client physical violence and client sexual violence), stratification of the FSW population by work environment and injecting drug use, and inclusion of between-violence dynamics. However, the model also includes three key new features, which together provide a more flexible and representative framework for understanding the dynamics of violence, and estimating incidence of violence. The three key new features are as follows:

1) *Distinguishing between recent and non-recent experiences of client sexual violence* The structural component of the Shannon *et al* model distinguished between recent and non-recent experiences of police harassment and client physical violence, and allowed FSWs to flow between these states, but client sexual violence was represented as a single compartment which FSWs permanently remain in, which was done to reflect the greater severity of sexual violence and larger increase in inconsistent condom use if ever exposed to sexual violence. The new model, which also distinguishes between recent and non-recent experiences of police harassment and client physical violence, additionally distinguishes between recent and non-recent experiences of client sexual violence, with FSWs allowed to flow between all these states of violence (i.e. FSWs do not remain permanently in any compartment). This was done to better reflect that FSWs may continue to experience police harassment and client physical violence after an experience of client sexual violence. By

allowing FSWs to move in and out of each state, rather than being forced to stay in one compartment, incidence of violence can be calculated.

2) *Client sexual violence can occur prior to experiencing client physical violence*

The Shannon *et al* model assumes that client physical violence necessarily preceded client sexual violence. The new model relaxes this assumption, allowing FSWs to experience client sexual violence prior to experiencing client physical violence. This was done to better reflect data suggesting that some FSWs have experienced client sexual violence but not client physical violence (Figure 2.1). However, based on AESHA data, to take into account that client sexual violence may be more likely to occur with and following client physical violence, rates of experiencing client sexual violence in the model are higher for FSWs who have recently experienced client physical violence.

3) *Concurrent experience of different types of workplace violence*

In the Shannon *et al* model there are only six states of violence experience which are represented by separate compartments: never experienced workplace violence, recent police harassment, non-recent police harassment, recent client physical violence, non-recent client physical violence, and ever client sexual violence. In the new model, there are three states for each type of workplace violence (never experienced violence, recently experienced violence and non-recently experienced violence), and each compartment represents a different combination of violence states across the three types of workplace violence. This more complex model structure was developed to better reflect that FSWs can experience multiple types of workplace violence in a given time-period (Figure 2.1), and means that the model can more easily be fitted and cross-validated to additional empirical estimates on the proportion of FSWs who have experienced multiple types of workplace violence.

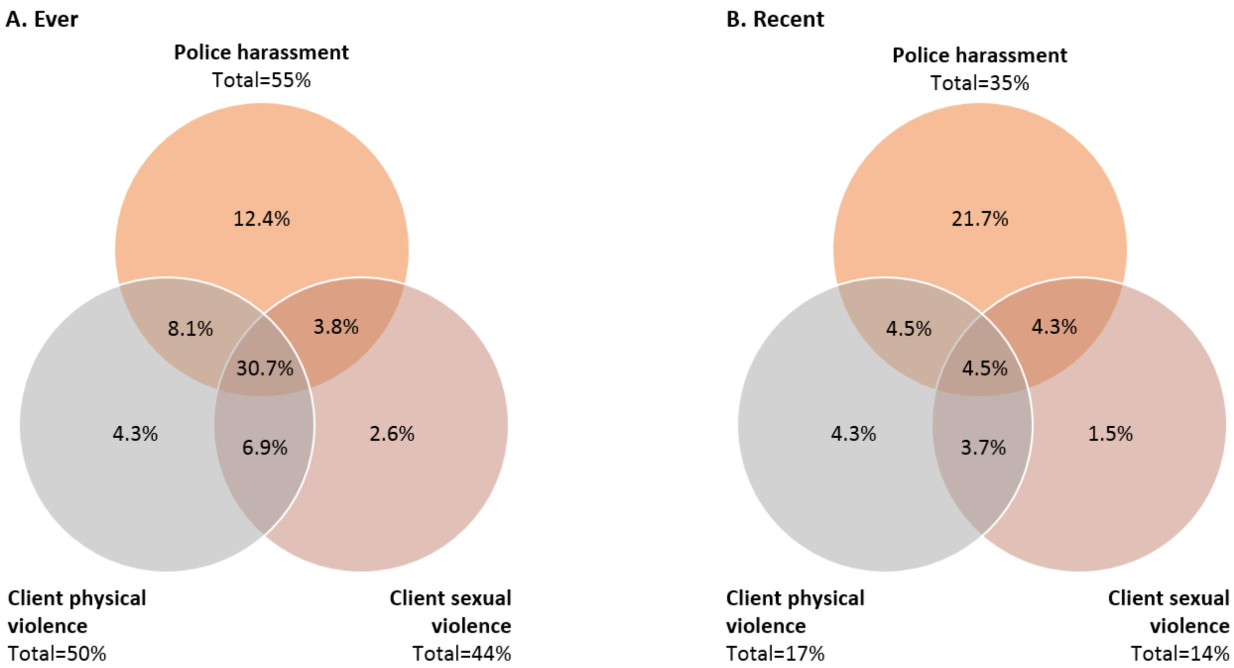


Figure 2.1 Experiences of workplace violence among FSWs in Vancouver, Canada. Proportion of FSWs who have (A) ever experienced police harassment, client physical violence and client sexual violence, and (B) recently experienced police harassment, client physical violence and client sexual violence in the last 6 months. Figure shows baseline data (2010-2014) from 753 FSWs enrolled in AESHA, an open prospective cohort of sex workers in Vancouver, Canada. These data were provided by Melissa Braschel, the AESHA statistician. FSWs, female sex workers; AESHA, An Evaluation of Sex Workers Health Access.

2.3.2.2 Model structure

A flowchart of the new model structure, representing the dynamics of the following three types of workplace violence: police harassment (excluding arrest and sexual violence), client physical violence and client sexual violence, is shown in Figure 2.2. Each compartment represents a different state of each of the three types of violence, and the arrows represent the flow of FSWs between them. Based on AESHA data survey items, each type of violence has three possible states: never experienced violence, recently experienced violence (within the last 6 months), and previously but not recently experienced violence. FSWs in the model are also stratified by their work environment (either outdoor/public space [e.g. street, alley, parks, public bathroom, or vehicle], informal-indoor [e.g. bar, hotel, sauna, nightclub], or brothel/quasi-brothel [e.g. managed indoor space/brothel, massage/beauty parlour, micro-brothel]) and injecting drug use (ever injection drug use [ever IDU] or never injection drug use [non IDU]), which results in 6 different FSW sub-groups.

The model represents an open and stable population over time. FSWs enter and exit the modelled population through initiation and cessation of sex work. Duration in sex work is specific to each work environment and injecting drug use status. All new FSWs initiate sex work with no prior experience of workplace violence (i.e. enter the never experienced police harassment/client physical violence/client sexual violence compartment), with a fixed proportion starting sex work in each work environment and injecting status. For simplicity, it is assumed that FSWs remain in their given work environment and injecting drug use status for their duration in sex work. Following sex work debut, FSWs can repeatedly experience each type of violence over time. The rates of experiencing violence (for the first time and recurrently after a previous experience) depend on FSWs work environment and injecting drug use status. To capture interactions between different types of workplace violence, the rates at which FSWs experience one type of workplace violence may also be increased (by a multiplicative rate ratio) if they have already experienced another type of workplace violence. Specifically, FSWs who have recently experienced police harassment are at increased risk of experiencing recent client physical violence and client sexual violence, and FSWs who have recently experienced client physical violence are at increased risk of experiencing recent client sexual violence [2,3]. A combination of AESHA data, review of existing literature [3], and discussion with experts in Vancouver (Dr Kate Shannon and Dr Kathleen Deering) informed the inclusion of these specific violence interactions.

Model equations

The new violence model is defined by a set of ordinary differential equations (ODEs), which are solved through numerical integration. The model equations, which are shown in the appendix (see Text B1 in Appendix B), were coded in Matlab and solved numerically using the ode15s solver, with outputs validated using the ode45 solver.

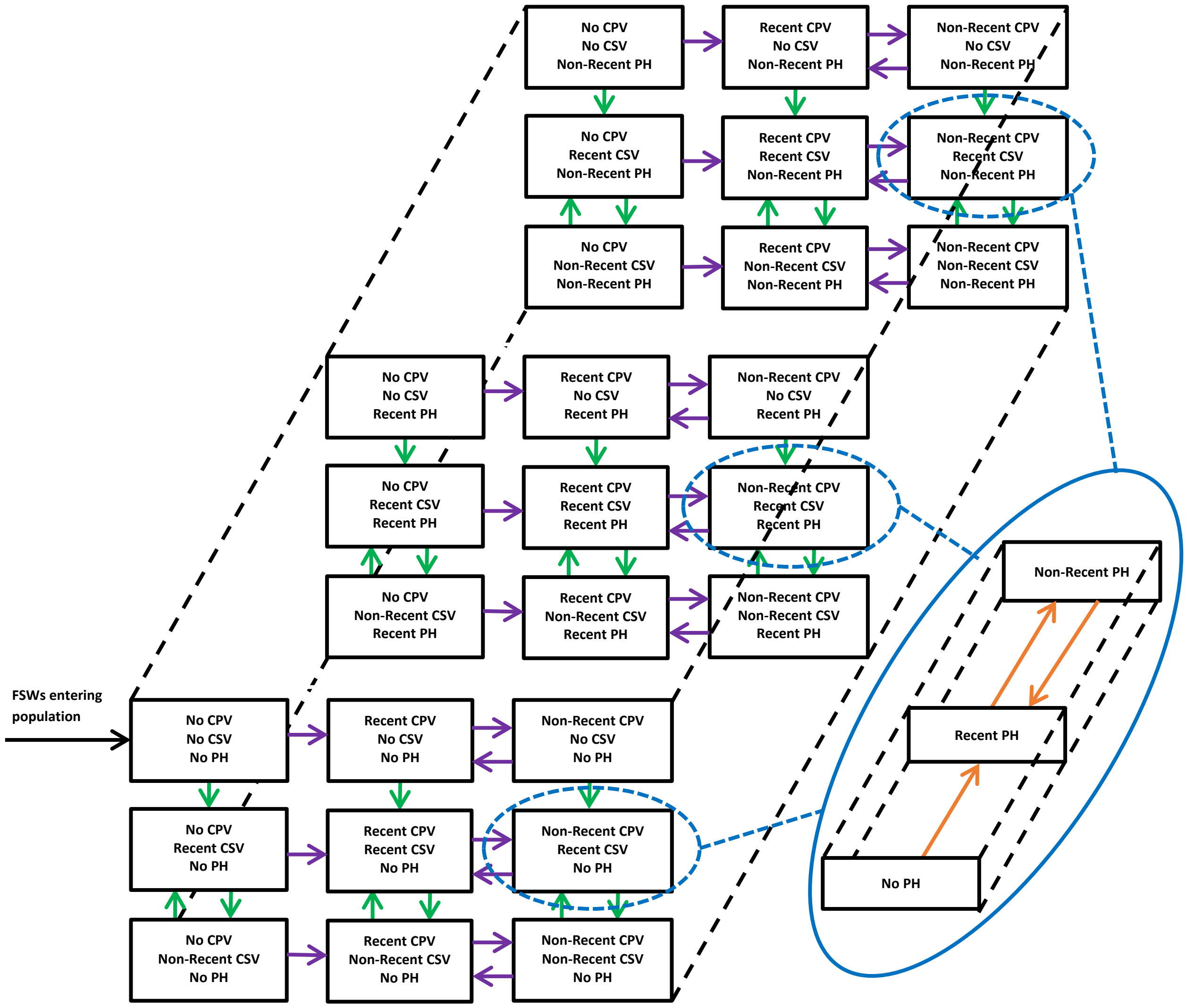


Figure 2.2 Model structure for each FSW sub-group. The flowchart represents the dynamic and iterative experiences of workplace violence among FSWs during their time in sex work. The model describes progression through three different states of violence experience (none, recent or non-recent) for three types of workplace violence: police harassment (PH), orange arrows; client physical violence (CPV), purple arrows; and client sexual violence (CSV), green arrows. All FSWs enter the model with no prior experience of workplace violence. Note that ceasing being a FSW, which can occur in each state, is not shown on this diagram for simplicity. FSW, female sex worker.

2.3.2.3 Model parameterisation

Table 2.1 describes the parameters in the violence model and gives their values (if a fixed parameter) or prior ranges (if a calibrated parameter). The fixed parameters were varied in a sensitivity analysis, which is described later (Section 2.3.5.4). The majority of parameter values were based on baseline survey data (2010-2014) from AESHA for 753 FSWs in the cohort. Melissa Braschel, the AESHA statistician, provided descriptive statistics on the proportion of FSWs in each sub-group, the years in sex work among FSWs in each sub-group, and the proportion of FSWs experiencing each type of workplace violence recently and ever (all FSWs and by sub-group), and also provided estimates of the relative risk of experiencing one type of violence among FSWs who have recently experienced another type of workplace violence, which were used to inform the fixed and prior parameter ranges. The definitions of workplace violence based on the AESHA survey items are given in Table 2.2.

To inform the prior parameter ranges of some parameters, further analysis of the aggregate-level AESHA data was required. First, as the years in sex work is reported by active FSWs and on average would be half the actual lifetime duration in sex work, the data on the duration of sex work was adjusted by a two-fold factor to give the prior range of lifetime duration in sex work. Second, a system of ODEs simplifying the full violence model component to represent the dynamics for just one type of violence and one FSW sub-group at a time, was used to generate prior ranges for the first-time and repeat violence rates for each type of violence among each sub-group of FSWs. The equilibrium prevalence of violence in this simplified system of equations, which assumed a constant population size and no violence interactions, was derived and matched to the AESHA prevalence data. To take into account that this simple system of ODEs ignore interactions between the different types of violence, the lower limit of the prior ranges for each violence rate was widened to zero. Other sources of data for informing model parameterisation are shown in Table 2.1.

Table 2.1 Parameter values and prior ranges for the violence model

Parameter	Symbol	Type of parameter	Value or Prior Range	Source
FSW population size in Vancouver city in 2013	N_{tot}	Fixed	1500	Shannon *et al* 2014 [3]
% of FSWs in each sub-group (ρ_{mn})				AESHA survey data
Non-IDU, outdoor-based	ρ_{11}	Fixed	12.0	
Non-IDU, informal indoor-based	ρ_{12}	Fixed	8.0	
Non-IDU, brothel-based	ρ_{13}	Fixed	29.0	
Ever-IDU outdoor-based	ρ_{21}	Fixed	30.0	
Ever-IDU, informal indoor-based	ρ_{22}	Fixed	18.0	
Ever-IDU, brothel-based	ρ_{23}	Fixed	3.0	
Lifetime duration selling sex (years) in each sub-group (κ_{mn})				Based on AESHA survey data (see Section 2.3.2.3 for further details) Note: $1/\kappa_{mn}$ = annual rate of turnover (ε_{mn})
Non-IDU, outdoor-based	κ_{11}	Calibrated	16.5-23.3	
Non-IDU, informal indoor-based	κ_{12}	Calibrated	16.8-27.1	
Non-IDU, brothel-based	κ_{13}	Calibrated	6.4-8.0	
Ever-IDU outdoor-based	κ_{21}	Calibrated	28.1-32.2	
Ever-IDU, informal indoor-based	κ_{22}	Calibrated	32.2-39.7	
Ever-IDU, brothel-based	κ_{23}	Calibrated	23.7-39.4	
Rate (per year) that FSWs experience police harassment for the first time by sub-group (α_{mn}^{PH})				Based on AESHA survey data (see Section 2.3.2.3 for further details)
Non-IDU, outdoor-based	α_{11}^{PH}	Calibrated	0-0.134	
Non-IDU, informal indoor-based	α_{12}^{PH}	Calibrated	0-0.066	
Non-IDU, brothel-based	α_{13}^{PH}	Calibrated	0-0.038	
Ever-IDU outdoor-based	α_{21}^{PH}	Calibrated	0-0.157	
Ever-IDU, informal indoor-based	α_{22}^{PH}	Calibrated	0-0.132	
Ever-IDU, brothel-based	α_{23}^{PH}	Calibrated	0-0.252	
Rate (per year) that FSWs experience client physical violence for the first time by sub-group (α_{mn}^{CPV})				Based on AESHA survey data (see section 2.3.2.3 for further details)
Non-IDU, outdoor-based	α_{11}^{CPV}	Calibrated	0-0.084	
Non-IDU, informal indoor-based	α_{12}^{CPV}	Calibrated	0-0.069	
Non-IDU, brothel-based	α_{13}^{CPV}	Calibrated	0-0.027	
Ever-IDU outdoor-based	α_{21}^{CPV}	Calibrated	0-0.122	
Ever-IDU, informal indoor-based	α_{22}^{CPV}	Calibrated	0-0.096	
Ever-IDU, brothel-based	α_{23}^{CPV}	Calibrated	0-0.256	
Rate (per year) that FSWs experience client sexual violence for the first time by sub-group (α_{mn}^{CSV})				Based on AESHA survey data (see section 2.3.2.3 for further details)
Non-IDU, outdoor-based	α_{11}^{CSV}	Calibrated	0-0.060	
Non-IDU, informal indoor-based	α_{12}^{CSV}	Calibrated	0-0.066	
Non-IDU, brothel-based	α_{13}^{CSV}	Calibrated	0-0.024	
Ever-IDU outdoor-based	α_{21}^{CSV}	Calibrated	0-0.076	
Ever-IDU, informal indoor-based	α_{22}^{CSV}	Calibrated	0-0.073	
Ever-IDU, brothel-based	α_{23}^{CSV}	Calibrated	0-0.119	
Rate (per year) that FSWs re-experience police harassment if previously experienced police harassment by sub-group (ν_{mn}^{PH})				Based on AESHA survey data (see section 2.3.2.3 for further details)
Non-IDU, outdoor-based	ν_{11}^{PH}	Calibrated	0-7.950	
Non-IDU, informal indoor-based	ν_{12}^{PH}	Calibrated	0-4.493	
Non-IDU, brothel-based	ν_{13}^{PH}	Calibrated	0-12.497	
Ever-IDU outdoor-based	ν_{21}^{PH}	Calibrated	0-4.438	
Ever-IDU, informal indoor-based	ν_{22}^{PH}	Calibrated	0-3.963	
Ever-IDU, brothel-based	ν_{23}^{PH}	Calibrated	0-14.758	
Rate (per year) that FSWs re-experience client physical violence if previously experienced client physical violence by sub-group (ν_{mn}^{CPV})				Based on AESHA survey data (see section 2.3.2.3 for further details)
Non-IDU, outdoor-based	ν_{11}^{CPV}	Calibrated	0-1.856	

Non-IDU, informal indoor-based	ν_{12}^{CPV}	Calibrated	0-1.614	
Non-IDU, brothel-based	ν_{13}^{CPV}	Calibrated	0-8.168	
Ever-IDU outdoor-based	ν_{21}^{CPV}	Calibrated	0-1.349	
Ever-IDU, informal indoor-based	ν_{22}^{CPV}	Calibrated	0-1.260	
Ever-IDU, brothel-based	ν_{23}^{CPV}	Calibrated	0-1.858	
Rate (per year) that FSWs re-experience client sexual violence if previously experienced client sexual violence by sub-group (ν_{mn}^{CSV})				Based on AESHA survey data (see section 2.3.2.3 for further details)
Non-IDU, outdoor-based	ν_{11}^{CSV}	Calibrated	0-2.185	
Non-IDU, informal indoor-based	ν_{12}^{CSV}	Calibrated	0-1.755	
Non-IDU, brothel-based	ν_{13}^{CSV}	Calibrated	0-3.913	
Ever-IDU outdoor-based	ν_{21}^{CSV}	Calibrated	0-1.446	
Ever-IDU, informal indoor-based	ν_{22}^{CSV}	Calibrated	0-0.994	
Ever-IDU, brothel-based	ν_{23}^{CSV}	Calibrated	0-2.629	
Multiplier (relative risk ratio) for increased rate of first-time and repeat client physical violence if recently experienced police harassment	$RR^{PHtoCPV}$	Calibrated	1.2-2.3	AESHA survey data
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced police harassment	$RR^{PHtoCSV}$	Calibrated	1.6-3.4	AESHA survey data
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced client physical violence	$RR^{CPVtoCSV}$	Calibrated	4.1-8.1	AESHA survey data
Time to non-recent police harassment or client physical violence or client sexual violence from recent police harassment, client physical violence or client sexual violence (years)	θ	Fixed	0.5	Timescale from AESHA survey item (experienced violence in last 6 months) Note: 1/θ = rate of transition from recent to non-recent violence states (ε)

Note: parameter symbol subscript *m* = injecting drug status (1= non-IDU, 2 = ever-IDU); parameter symbol subscript *n* = work environment (1= outdoor-based, 2 = informal indoor-based, 3 = brothel-based).

Table 2.2 Definitions of violence

Type of workplace violence	Definition
Police harassment (without arrest or sexual violence)	Experienced any of the following encounters with police while working: told to move on, police raid, threated with arrest/detainment/fine, searched, followed, picked up and driven elsewhere to work, verbally harassed, detained, delayed/held against will without arrest, physically assaulted, drugs/drug use equipment taken, other property taken
Client physical violence	Experienced any of the following from clients: physically assaulted/beaten, abducted/kidnapped, strangled, locked/ trapped in car, thrown out of a moving car, or assaulted with a weapon
Client sexual violence	Experienced any of the following from clients: forced to have sex without a condom, attempted sexual assault, or raped

2.3.2.4 Model calibration

To take into account uncertainty in the model parameters, model calibration was done in a Bayesian framework, using Latin Hypercube Sampling (LHS) combined with a target fitting method, to obtain multiple parameter sets that simultaneously fit to data on prevalence of violence [23,24]. The model calibration involved four steps:

1) LHS was used to randomly select a large number of parameter sets from the prior parameter ranges given in Table 2.1. Each prior parameter range was assigned a uniform prior distribution for this sampling process.
2) The model was initialised with all FSWs having never experienced any violence and then run with each parameter set for 100 years in order to reach equilibrium prevalence of each type of violence. To check that equilibrium prevalence was reached I used an equilibrium tolerance criterion which examined the relative difference in prevalence of violence at 100 years and the previous year. The tolerance criterion was set to 0.00025 which was guided by early model simulations in which I visually verified that equilibrium prevalence of violence was reached by 100 years.
3) A parameter set was accepted as a posterior parameter set for further analysis, if the model run projections of workplace violence prevalence at equilibrium simultaneously lay within the 95% confidence intervals of the following workplace violence prevalence data: prevalence of client sexual violence among all FSWs (ever and recently), prevalence of client physical violence among all FSWs (ever and recently), and prevalence of police harassment among all FSWs (ever and recently) (Table 2.3). The process was repeated to obtain 100 model fits that agreed with the fitting violence prevalence outcomes.

The model fit was cross-validated by comparing the model predictions on prevalence of each type of violence among each FSW sub-group (ever and recently), and prevalence of experiencing multiple different types of violence (ever and recently) to additional observed data (see Table B1 in Appendix B).

The best fitting parameter set, which was determined using a least squares method (i.e. minimum squared deviation between the observed prevalence data and model prevalence output), was used in sensitivity analyses for the fixed parameters (see Section 2.3.5.4).

Table 2.3 Prevalence data used in model fitting

	% (95% CI)	Source
Experienced police harassment		
Ever	55.0% (51.3-58.6%)	AESHA survey data[2]
Recently[1]	34.5% (31.1-38.0%)	AESHA survey data[2]
Experienced client physical violence		
Ever	50.3% (46.7-54.0%)	AESHA survey data[2]
Recently[1]	16.7% (14.1-19.6%)	AESHA survey data[2]
Experienced client sexual violence		
Ever	44.4% (40.8-48.0%)	AESHA survey data[2]
Recently[1]	14.2% (11.8-16.9%)	AESHA survey data[2]

[1] In the last 6 months
[2] Baseline data from 753 participants enrolled between 2010 and 2014

2.3.3 Incorporating condom use into the violence model

Inconsistent condom use (ICU) was incorporated into the violence model in order to evaluate the potential impact of violence-related structural interventions on reducing levels of ICU among FSWs in Vancouver. This was done by linking the workplace violence model to an ICU matrix, representing the fraction of FSWs using condoms inconsistently (henceforth referred to as ICU prevalence) for each compartment of the violence model. The following sub-sections provide details on the generation of the ICU matrix, and how information from the ICU matrix and violence model were combined to generate the overall prevalence of ICU in the model, which is a key outcome of interest. Following this, I describe the sampling of the parameters used in generating the ICU matrix.

ICU matrix

The ICU matrix was generated using available data on i) the baseline prevalence of ICU for each work environment, ii) the relative risk ratio for ICU associated with injecting drug use, and iii) the relative risk ratio for ICU associated with violence (Table 2.4), as follows:

1) *Baseline ICU prevalence*: each work environment compartment was assigned its specific baseline ICU prevalence (i.e. ICU_{B1} or ICU_{B2} or ICU_{B3}).
2) *Condom use associated with IDU*: the baseline ICU prevalence of each work environment was multiplied by a relative risk ratio associated with a history of ever injecting drugs (RR_{IDU}).
3) *Condom use associated with violence:* the ICU prevalence associated with each work environment and IDU state was further multiplied by a relative risk ratio associated with experience of violence. Data suggested an increased risk of ICU associated with recent experience of police harassment ($RR_{R\text{-}PH}$), with recent or non-recent experience of client physical violence ($RR_{R\text{-}CPV}$ or $RR_{NR\text{-}CPV}$, respectively), and with ever experiencing sexual violence ($RR_{E\text{-}CSV}$). For compartments representing experience of multiple types of

workplace violence, the ICU prevalence was only multiplied further by the highest relative risk ratio. This conservatively assumes that effects of violence on ICU do not compound each other. The influence of this assumption will be assessed in sensitivity analyses (see Section 2.3.5.4).

Linking the ICU matrix to the violence model to generate the ICU outcome

The overall prevalence of ICU, one of the key model outputs of interest, can easily be derived as the sum of each ICU matrix value weighted by the relevant proportion of FSWs in the corresponding violence model compartment.

Sampling parameter values for the ICU matrix

Table 2.4 gives the prior ranges of the ICU parameters used in generating the ICU matrix. LHS was used to randomly sample from these ICU parameter prior ranges, to create 100 ICU parameter sets (one for each of the existing 100 model fits).

Table 2.4 ICU parameters and prior ranges

Parameter	Symbol	Prior Range	Source
ICU in 2013 if:			Shannon *et al* 2014 [3]
Non-IDU, outdoor-based FSWs	ICU_{B1}	9.7-26.1%	
Non-IDU, informal indoor-based FSWs	ICU_{B2}	10.3-32.9%	
Non-IDU, brothel-based FSWs	ICU_{B2}	1.7-7.3%	
Relative risk (RR) for ICU if ever-IDU FSW	RR_{IDU}	0.9-2.0	Shannon *et al* 2014 [3]
RR for ICU due to the following workplace violence experiences:			Shannon *et al* 2014 [3]
Recent police harassment	$RR_{R\text{-}PH}$	1.0-2.0	
Recent client physical violence	$RR_{R\text{-}CPV}$	1.1-3.8	
Non-recent client physical violence	$RR_{NR\text{-}CPV}$	1.0-2.2	
Ever client sexual violence	$RR_{E\text{-}CSV}$	1.6-5.1	

2.3.4 Modelling structural interventions

There are five structural interventions implemented in the model, which focus on the elimination of different types of violence and the elimination of ICU associated with past (i.e. non-recent) experiences of violence (see Table 2.5 for further details). These structural interventions assume a perfect and instantaneous intervention, where violence or the excess risk of ICU due to non-recent violence is eliminated immediately following implementation of the intervention. Interventions are implemented when the equilibrium prevalence of workplace violence has been reached. Each of the five interventions affects ICU (see Table 2.5), and due to the interactions between police harassment and client violence, eliminating police harassment (Intervention 1) also affects client violence. The outcomes of interest are the reduction in prevalence of client violence (Intervention 1 only), and the reduction in average prevalence of ICU (all Interventions) (see Section 2.3.5.3 for further details).

Table 2.5 Structural interventions modelled

Intervention	Intervention detail	Assumptions	Effect on condom use and violence
1) Eliminate police harassment	Eliminate future experiences of police harassment by turning rates of first-time and repeat police harassment to zero	Assumes that police harassment is eliminated immediately	FSWs will no longer be experiencing excess risk of ICU or increased risk of client violence due to recent police harassment
2) Eliminate client violence	Eliminate future experiences of client violence by turning rates of first-time and repeat client physical violence and client sexual violence to zero	Assumes that client violence is eliminated immediately	FSWs will no longer be experiencing excess risk of ICU due to recent client physical and client sexual violence
3) Eliminate client violence and eliminate ICU associated with previous exposure to client violence	Eliminate future experiences of client violence by turning rates of first-time and repeat client physical violence and client sexual violence to zero. Eliminate excess risk of ICU due to non-recent client violence by switching the RR of ICU for non-recent client violence to one.	Assumes that client violence and excess risk of ICU due to non-recent client violence is eliminated immediately	FSWs will no longer be experiencing excess risk of ICU due to recent and non-recent client violence
4) Eliminate workplace violence	Eliminate future experiences of police harassment and client violence by turning rates of first-time and repeat police harassment and client physical violence and client sexual violence to zero	Assumes that police harassment and client violence is eliminated immediately	FSWs will no longer be experiencing excess risk of ICU due to recent police harassment, client physical violence and client sexual violence
5) Eliminate workplace violence and eliminate ICU associated with previous exposure to workplace	Eliminate future experiences of police harassment and client violence by turning rates of first-time and repeat police harassment and client physical violence and client sexual violence to zero. Eliminate excess risk of ICU due to non-recent client violence by switching the RR of ICU for non-recent client violence to one.	Assumes that police harassment, client violence and excess risk of ICU due to non-recent client violence is eliminated immediately	FSWs will no longer be experiencing excess risk of ICU due to recent and non-recent police harassment and client violence

2.3.5 Analysis Plan

The base case (i.e. posterior parameter sets) is used to predict relevant model outcomes to address the different chapter objectives. Model outputs from the 100 posterior parameter sets, are reported as the median and 95% credible interval (CrI) (i.e. 2.5th and 97.5th percentiles).

2.3.5.1 Characterising the dynamics of violence

The posterior parameter sets that fit the data provide a posterior range and distribution for each calibrated parameter, and thus give model estimates for the rates of first-time and repeat workplace violence, and the multipliers (relative risk ratios) for rates of first-time and repeat workplace violence if FSWs have recently experienced another type of violence.

2.3.5.2 Estimating incidence of violence and external validation

Model estimates

Each model fit is used to estimate incidence rates (per 100 person year) of i) first-time (FT) and ii) first-time and repeat (FTR) (i.e. all) exposure to police harassment, client physical violence, and client sexual violence overall, and by sub-group, work environment and injecting drug use.

In the model, FT incidence rates at equilibrium were estimated by dividing the cumulative number of FT violence events in one year by the total number of FSWs who have never experienced violence at the start of the year, and multiplying by 100. FTR incidence rates at equilibrium were estimated by dividing the cumulative number of FTR violence events in one year by the total number of FSWs, and multiplying by 100.

External validation to empirical data

The model estimates of violence incidence rates were then compared to empirical incidence rates of violence estimated from AESHA cohort data. Melissa Braschel, the AESHA statistician, carried out analyses to estimate incidence of workplace violence from AESHA cohort data. These incidence estimates, were based on baseline and follow-up interviews conducted between 2010 and 2014, which matches the time-period of baseline data used to parameterise and calibrate the model. Further details on how incidence rates of workplace were derived from AESHA cohort data are provided in the appendix (see Text B2 in Appendix B).

2.3.5.3 Evaluating the impact of structural interventions

The impact of each of the five structural interventions modelled (see Table 2.5) was quantified in terms of the reduction in prevalence of recent client physical violence and recent client sexual violence (evaluated for Intervention 1: Elimination of police harassment), and the reduction in average prevalence of ICU (evaluated for Interventions 1 to 5), compared to the baseline scenario without any structural intervention. These outcomes are calculated after 5 years of each intervention, among all FSWs, and by sub-group.

The relative reduction in prevalence of recent client violence due to elimination of police harassment (Intervention 1), was calculated by subtracting the prevalence of client violence after implementation of the intervention from the prevalence of client violence at the start of the intervention and dividing this by prevalence of client violence at the start of the intervention.

The relative reduction in average ICU due to each of the five interventions was calculated by subtracting the average prevalence of ICU after 5 years of the intervention from the average prevalence of ICU at the start of the intervention and dividing this by the average prevalence of ICU at the start of the intervention.

2.3.5.4 Sensitivity analyses

A number of sensitivity analyses were conducted to explore the influence of model parameters and assumptions on model outcomes:

1) *Influence of parameter uncertainty*: Partial rank correlation coefficients (PRCCs) were used to assess which calibrated parameters influenced selected model outcomes the most, including: incidence rates of violence among all FSWs, relative reduction in prevalence of client violence among all FSWs due to elimination of police harassment, and relative reduction in ICU prevalence among all FSWs due to each of the five interventions. PRCCs measure the monotonic relationship between each input parameter and outcome measure while controlling for all other input parameters [23,25]. PRCCs range between -1 and +1, with value of -1 or +1 indicating a perfect negative or positive correlation, respectively [23,25].

2) *Univariate sensitivity of fixed parameters*: Univariate sensitivity analyses, using the best fitting parameter set (see Section 2.3.2.4), were conducted to examine the influence of fixed parameters on selected model outcomes. Fixed parameters of interest were the proportion of FSWs in each work environment and the duration of time in the recent violence compartment (θ). Although θ is based on the time-scale in the survey (FSWs are asked about experiencing violence in the last 6 months), potential recall bias means that it is important to understand the sensitivity of results to this parameter. Model outcomes of interest were the same as those examined in the first sensitivity analysis. Fixed model parameters were varied one at a time between an upper and lower value (±10% of their fixed value) (see Table B2 in Appendix B), while holding all other parameters at their baseline value (see Tables B2 and B3 in Appendix B). Further univariate sensitivity analyses were also conducted for the calibrated parameters that were most strongly associated with each outcome (PRCC=>0.5). Upper and lower values for these calibrated parameters were ±10% of their baseline value.

3) *Sensitivity of intervention impact to ICU assumptions*: The predicted impact of each intervention on ICU was re-calculated based on an alternative ICU assumption, where the increased risk in ICU for FSWs who have experienced multiple types of violence was a product of the increased risk associated with each type of violence (e.g. $RR_{R\text{-}PH}$ * $RR_{R\text{-}CPV}$), rather than being capped at the highest RR value.

4) *Importance of incorporating between-violence dynamics:* The model was re-calibrated and model outputs were re-estimated when assuming that there was no relationship between the different types of violence (i.e. $RR^{PHtoCPV}$=1, $RR^{PHtoCSV}$=1 and $RR^{CPVtoCSV}$=1). This was done to understand the importance of incorporating between-violence dynamics in the model for different outcomes, and if for some research questions between-violence dynamics could potentially be ignored to reduce model complexity and the number of model parameters.

2.4 Results

2.4.1 Calibration results

Fitting results

Figure 2.3 shows close agreement between the prevalence of violence predicted by the model and the data from AESHA used in the fitting process.

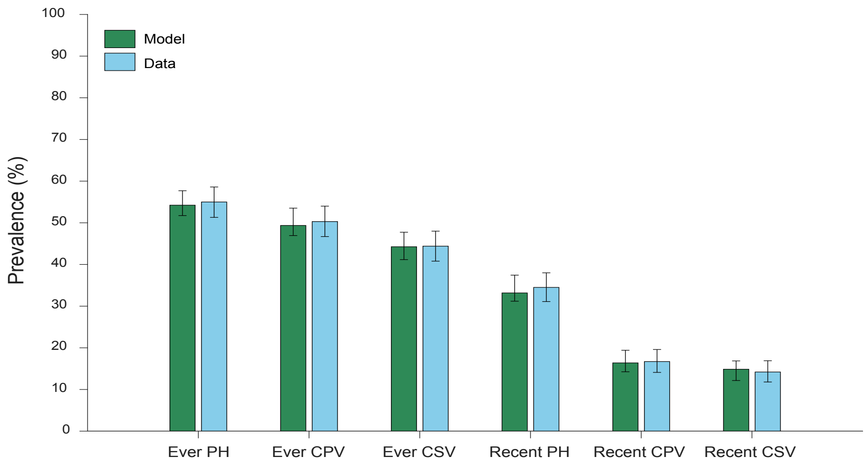


Figure 2.3 Prevalence of workplace violence among all FSWs: Model projections compared to AESHA data used in the fitting process. PH, police harassment; CPV, client physical violence; CSV, client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

Cross-validation results

Similarly, Figure B1 in Appendix B shows generally good agreement between model estimates for the prevalence of each type of violence by different FSW sub-groups and AESHA cross-validation data (i.e. data not used for fitting), apart for brothel-based FSWs who have ever injected drugs. Model estimates for experiencing multiple different types of violence also matched well to AESHA cross-validation data (Figure 2.4), although the model tended to underestimate prevalence of experiencing recent client sexual violence and recent client sexual violence and prevalence of experiencing all three types of workplace violence recently.

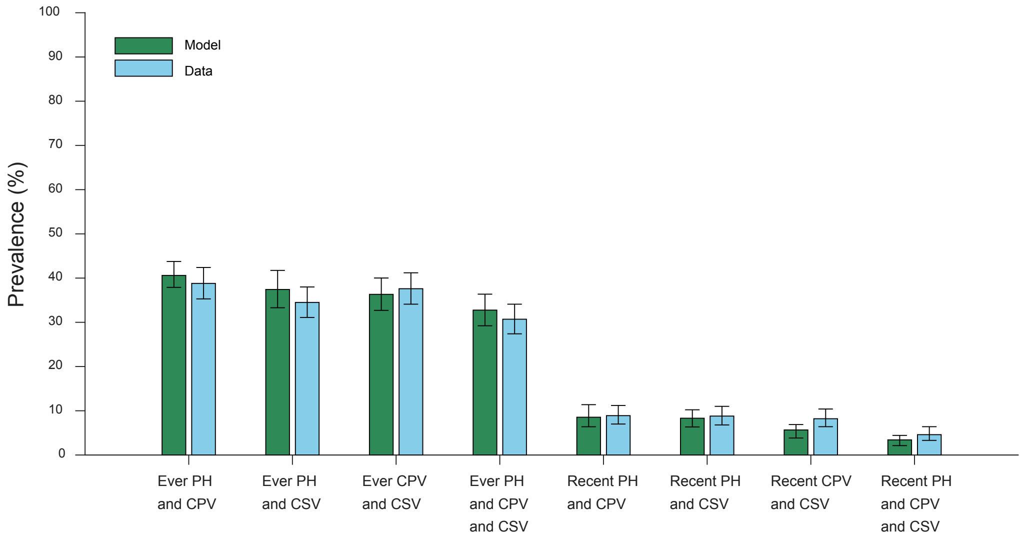


Figure 2.4 Prevalence of experiencing multiple types of workplace violence among all FSWs: Model projections compared to AESHA cross-validation data. PH, police harassment; CPV, client physical violence; CSV, client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

2.4.2 Insights from posterior parameter values

Table B4 in Appendix B shows the posterior median and 95% credible intervals of the calibrated parameters. The posterior parameter distributions that were more restricted and informed by the fitting data compared to their prior distributions, were the annual rates of first-time police harassment and the annual rates of repeat police harassment, which were typically skewed towards higher values; and the annual rates of repeat client sexual violence and increased risk of first-time and repeat client sexual violence if recently experienced police harassment ($RR^{PHtoCSV}$), which were typically skewed towards lower values.

The posterior parameter values for the annual rates at which FSWs re-experience workplace violence (v_{mn}^{PH}, v_{mn}^{CPV} and v_{mn}^{CSV}) are much higher than the annual rates at which FSWs experience workplace for the first-time (α_{mn}^{PH}, α_{mn}^{CPV} and α_{mn}^{CSV}). These suggest that FSWs who have previously been exposed to police harassment, client physical violence, and client sexual violence on average re-experience it again within 1.7-4.5 months, within 0.2-1.8 years, and within 0.7-7.1 years, respectively (based on the reciprocal of the relevant rate estimate of repeat violence). Some FSWs re-experience violence even sooner if they have recently been exposed to another type of violence, due to the interactions between violence types (i.e. $RR^{PHtoCPV}$, $RR^{PHtoCSV}$, $RR^{CPVtoCSV}$). Interestingly, FSWs in brothels who never injected drugs have the lowest rates of experiencing workplace violence for the first-time, but have the highest rates of repeat workplace violence once exposed to workplace violence. The model also suggests that FSWs who have recently experienced police harassment are on average 1.8 and 2.3 times more likely to experience client physical violence ($RR^{PHtoCPV}$) and client sexual violence ($RR^{PHtoCSV}$), respectively, than FSWs who have not recently experienced police harassment.

2.4.3 Incidence of violence and external validation

Model estimates

Table B5 in Appendix B shows the model estimates for incidence rates of FT and FTR violence. As would be expected, for each type of violence the incidence of FT violence is substantially lower than incidence of FTR violence, as it takes a lot longer on average to experience violence for the first-time (Table B4 in Appendix B). Overall, the median incidence of FT violence is highest for police harassment (5.2 per 100 person years), followed by client physical violence (4.1 per 100 person years) and then client sexual violence (3.3 per 100 person years). Similarly, the median incidence of FTR violence is highest for police harassment (67.8 per 100 person years), followed by client physical violence (33.4 per 100 person years) and then client sexual violence (30.3 per 100 person years). Outdoor-based FSWs had the highest incidence rates of each type of violence, followed by informal indoor-based FSWs, then brothel-based FSWs who had the lowest incidence rates, about 2-3 times lower than that of outdoor-based FSWs. FSWs who had ever injected drugs had 2-3 times higher incidence rates of violence compared to FSWs that had never injected drugs. Incidence rates were typically higher among brothel-based FSWs who had ever injected drugs compared to FSWs in other sub-groups, but the estimates for this sub-group also had the largest uncertainty.

Validation to empirical data

Figures 2.5 and 2.6 compare incidence rate estimates of FT and FTR violence predicted by the model with empirical estimates from the AESHA cohort data.

The model estimates for incidence rates of FT client sexual violence and client physical violence match reasonably well to the empirical estimates, but tended to underestimate the client violence incidence rates among all FSWs, and the client physical violence incidence rates among brothel based FSWs (Figure 2.5). The model estimates for incidence rates of FT police harassment did not match well to the empirical estimates, tending to underestimate the incidence rates substantially, but did reproduce the empirical trends in incidence rates across the work environments (Figure 2.5).

The model estimates for incidence rates of FTR violence did not match well to the empirical estimates (Figure 2.6), with the model overestimating all FTR violence incidence rates substantially. However, the trends in incidence rates across work environment were consistent for police harassment and client physical violence (Figure 2.6).

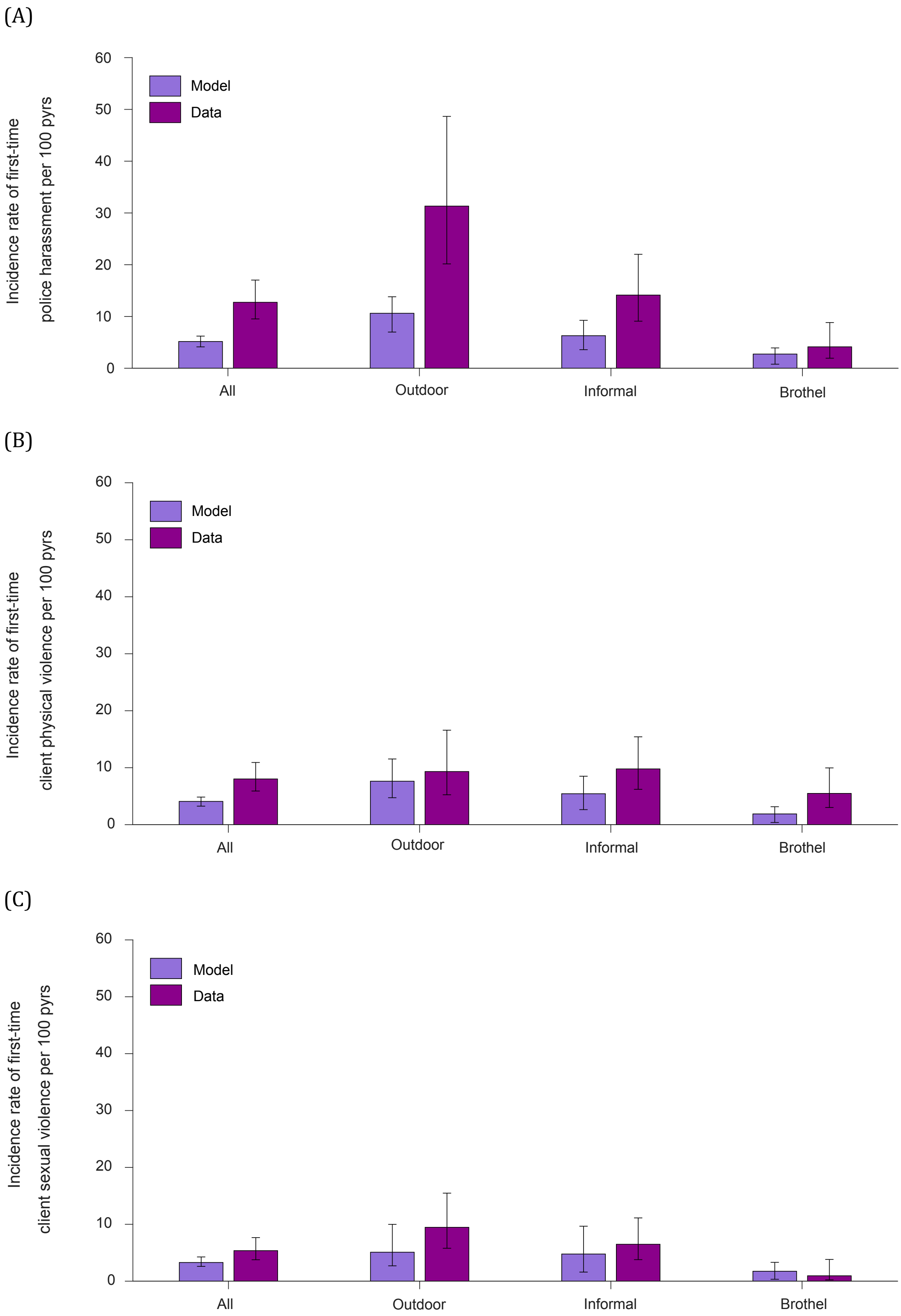
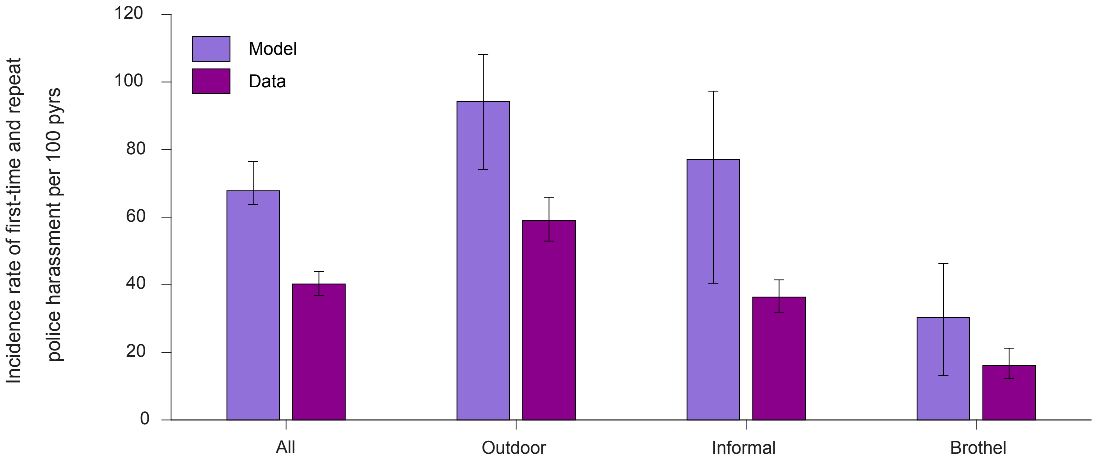
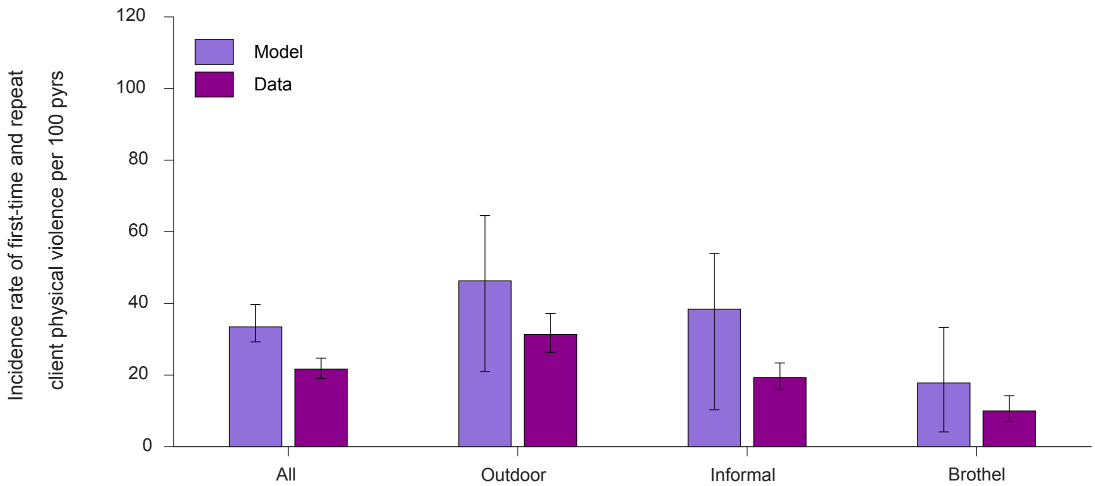


Figure 2.5 Incidence rates of first-time workplace violence among all FSWs and by FSWs work environment: model projections compared to empirical data. (A) Police harassment (B) Client physical violence. (C) Client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

(A)



(B)



(C)

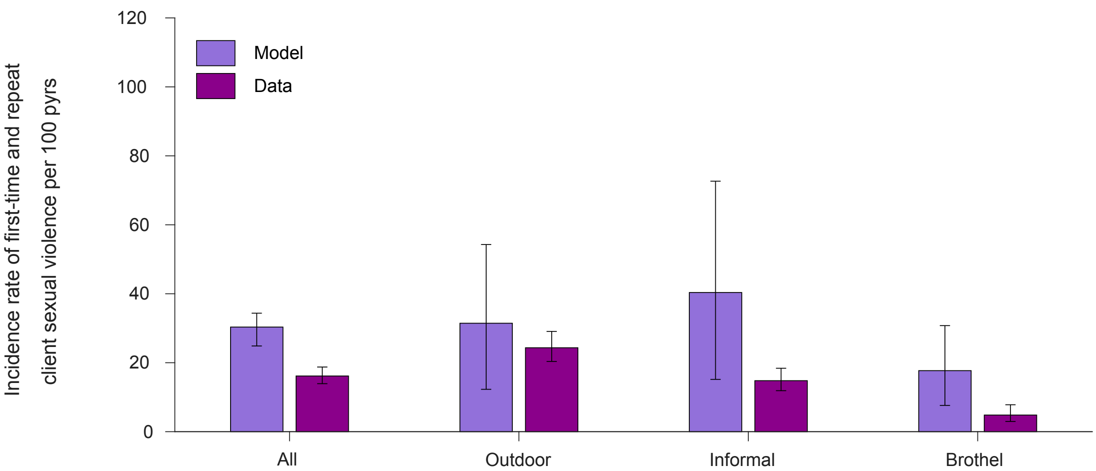


Figure 2.6 Incidence rates of first-time and repeat (i.e. all) workplace violence among all FSWs and by FSWs work environment: model projections compared to empirical data. (A) Police harassment (B) Client physical violence. (C) Client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

2.4.4 Impact of structural interventions

Impact on client violence

The potential impact that eliminating police harassment (Intervention 1) could have on reducing the prevalence of recent client violence is shown in Figure 2.7. Due to the interactions between police harassment and client violence, these results indicate the eliminating police harassment could reduce the prevalence of recent client physical violence in relative terms by a median of 18.1% (95% CrI: 7.6-28.8%) after 5 years, and could reduce the prevalence of recent client sexual violence in relative terms by a median of 26.8% (95% CrI: 18.4-41.1%) after 5 years. In general, larger reductions in prevalence are seen for FSWs who have ever injected drugs compared to FSWs who have never injected drugs. The lowest relative reduction in prevalence is among non-IDU brothel-based FSWs, due to the fact this this group of FSWs report the fewest recent experiences of police harassment.

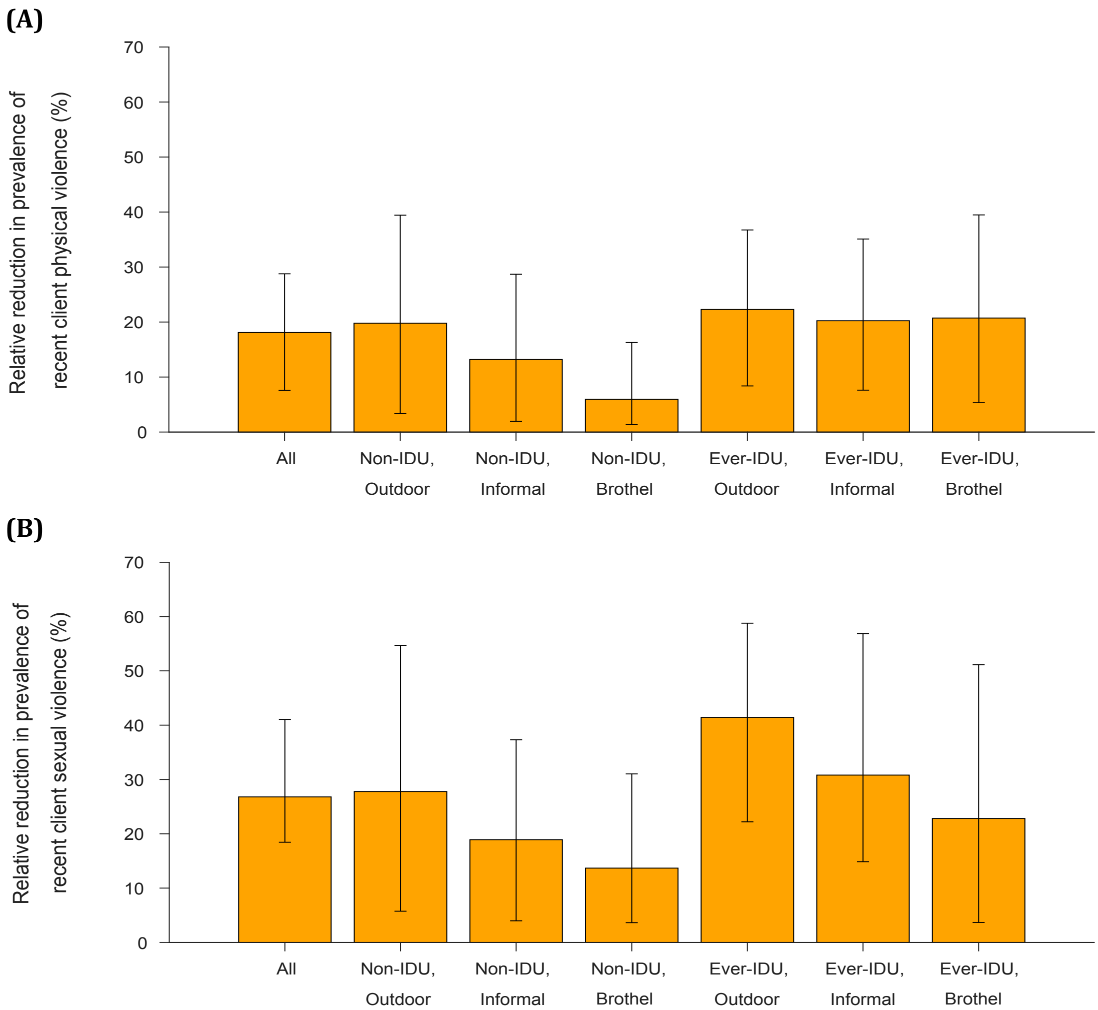


Figure 2.7 Five-year impact of eliminating police harassment (Intervention 1) on prevalence of (A) recent client physical violence and (B) recent client sexual violence among all FSWs and by risk group. Coloured bars represent the median value of the model fits and error bars represent the 95% credible interval of the model fits.

Impact on ICU

Figure 2.8 shows the relative reduction in average prevalence of ICU after 5 years of each structural intervention. The baseline level of ICU among all FSWs was 43% (Table B6 in Appendix B). Eliminating police harassment alone (Intervention 1) had the smallest impact on ICU, with a median relative reduction in ICU of 3.2%. Eliminating client violence alone (Intervention 2) had a larger impact, resulting in a median relative reduction in ICU of 9.8%. The combined elimination of both police harassment and client violence (Intervention 4) reduced the prevalence of ICU by a median of 12.1%. Interventions that eliminated workplace violence while also addressing the long-term negative effects of previous workplace violence on ICU (Interventions 3 and 5) resulted in the largest relative reductions in ICU (median relative reduction of 47.1% and 55.3%, respectively).

Results stratified by FSW sub-group all show the same trend in impact across interventions (see Table B7 in Appendix B). For Interventions 1, 2 and 4, the relative reduction in ICU was similar across sub-groups (Table B7, Appendix B). For Interventions 3 and 5 the relative reduction in ICU was much lower for non-IDU, brothel-based FSWs compared to FSWs in other sub-groups, as very few non-IDU, brothel-based FSWs have a history of workplace violence, so the impact of Interventions 3 and 5 will be similar to that of Interventions 1, 2, and 4 (Table B7, Appendix B).

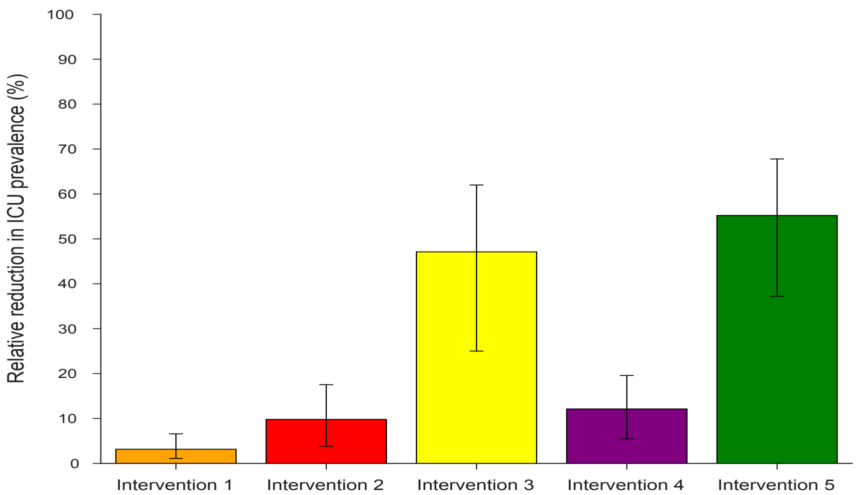


Figure 2.8 Relative reduction in prevalence of inconsistent condom use among all FSWs after 5 years of each intervention. Coloured bars represent the median value of the model fits and error bars represent the 95% credible interval of the model fits. Intervention key: Intervention 1 - Eliminate police harassment; Intervention 2 – Eliminate client physical violence; Intervention 3 - Eliminate client violence and eliminate ICU associated with previous exposure to client violence; Intervention 4 - Eliminate workplace violence; Intervention 5 - Eliminate workplace violence and eliminate ICU associated with previous exposure to workplace.

2.4.5 Sensitivity analyses

This section highlights the key results from across the four sensitivity analyses. Text B3 in Appendix B provides further details on each analysis, and Table B8-B11 and Figures B2-16 show the results from each sensitivity analysis.

As expected, the PRCC analysis showed that model estimates of workplace violence incidence were most strongly positively associated with the rates (first-time and/or repeat) at which FSWs experience each type of workplace violence (Tables B8-B9 in Appendix B). Due to the high prevalence of police harassment, incidence of client physical violence and incidence of client sexual violence also had strong positive correlations with $RR^{PHtoCPV}$ (the multiplier for increased rates of client physical violence if recently experienced police harassment) and $RR^{PHtoCSV}$ (the multiplier for increased rates of client sexual violence if recently experienced police harassment), respectively (Tables B8-B9 in Appendix B). The univariate sensitivity analysis also highlighted that incidence estimates of violence were sensitive to the proportion of FSWs who are brothel-based, the proportion of FSWs who ever injected drugs, and the time spent recently experiencing violence (θ) (Figures B2-B3 in Appendix B).

Unsurprisingly, the relative reduction in prevalence of recent client physical violence and prevalence of recent client sexual violence due to eliminating police harassment was strongly positively correlated with $RR^{PHtoCPV}$ and $RR^{PHtoCSV}$ (Table B10 in Appendix B).

As expected, estimates of the relative reduction in prevalence of ICU due to each intervention were larger under the alternative ICU assumption compared to the original ICU assumption (Figure B6 in Appendix B), as the average ICU at baseline is larger under the alternative ICU assumption than the original ICU assumption (Table B6 in Appendix B). The impact of Intervention 1 (elimination of police harassment) increased the most under this alternative ICU assumption (Figure B6). Univariate sensitivity analyses also showed that the relative reduction in prevalence of ICU due to each intervention was sensitive to the proportion of FSWs who are ever IDU (Figure B5 in Appendix B).

When the model was re-calibrated assuming that there was no relationship between the different types of workplace violence (i.e. $RR^{PHtoCPV}$=1, $RR^{PHtoCSV}$=1 and $RR^{CPVtoCSV}$=1), there were no longer any model fits that matched the cross-validation data for the prevalence of experiencing both recent client sexual violence and recent client physical violence or the prevalence of experiencing all three types of workplace violence recently (Figure B13 in Appendix B). Otherwise, the re-calibrated model agreed well with the fitting and other cross-validation AESHA data (Figures B7-B12 in Appendix B), and the majority of model outcomes were similar to the original model calibration (Figures B14-B16 in Appendix B).

2.5 Discussion

In this chapter, the dynamic, recurrent and interacting experiences of three different types of workplace violence among FSWs in Vancouver, Canada, were simulated using a mathematical model that was calibrated to workplace violence prevalence data. The model, which took into account differences in risk of workplace violence among FSWs in different work environments with different levels of injecting drug use, was used to characterise the dynamics of workplace violence, estimate incidence of workplace violence, estimate the impact of structural interventions, and explore the sensitivity of model results to model assumptions and parameters. The model estimates of violence incidence rates were also compared to empirical estimates.

2.5.1 Summary of key results and implications

Characterising dynamics of violence

By calibrating the model to prevalence data, the model provides some potential insights into the dynamics of workplace violence. The results suggest that regardless of work environment and injecting drug use, the time between recurrent experiences of police harassment is short, ranging on average between 1.7-4.5 months across the different FSW sub-groups. This suggests that there is a similar risk of repeat police harassment among all FSWs who have ever been exposed to police harassment, and that among these FSWs who have ever experienced police harassment there is a high frequency of repeat police harassment. Police harassment has many negative consequences for FSWs health and safety, so it will be important to address. As described previously in Chapter 1, potential strategies for reducing police harassment include community empowerment and building partnerships with police. FSWs in formal-establishments who never injected drugs had the lowest rates of experiencing workplace violence for the first-time, which agrees with previous studies which have found formal establishments to be one of the safer work environments for FSWs in Vancouver [2,5,6,11]. However, interestingly, once exposed to workplace violence this group of FSWs had the highest rates of repeat workplace violence, suggesting that there is potentially a vulnerable sub-group of FSWs in formal establishments who should be identified and supported.

Estimating incidence of violence and validation to empirical data

One aim of this analysis was to see if calibrating the model to prevalence data could be used as a method of estimating incidence of workplace violence, which would be particularly useful for settings where FSW cohorts do not exist or where longitudinal studies of FSWs are not feasible to conduct. The model was calibrated to baseline prevalence data and the resulting incidence projections were validated against empirical incidence estimates from AESHA longitudinal follow-up data. The model generally predicted well the incidence of first-time client physical violence and first-time client sexual violence, but tended to over or under-estimate other violence incidence rates. This indicates that the current method is of limited usefulness for estimating incidence of violence, and incidence estimates from the model should be interpreted with caution. However, there may have been changes in rates of violence exposure over time in reality [26], which may mean that assuming an equilibrium prevalence of violence and constant rates of violence may not hold. Additional prevalence and incidence estimates by year could help tease out if there have been changes in violence experiences. If evidence suggests any changes, the model could include rates of violence that vary over time in a pre-determined way based on the empirical data.

Even though the current method and model formulation was unable to satisfactorily reproduce empirical cohort data incidence estimates, this should not impact too much on the subsequent analyses where I evaluated the impact of structural interventions on ICU and client violence, as these impact outcomes are driven by prevalence of violence rather than incidence of workplace violence. The model matched well to the fitting and cross-validation prevalence data. This analysis is also an important first step in developing a method for estimating incidence of violence from prevalence data, and also motivated the generation of novel estimates of violence incidence from the AESHA cohort in Vancouver, which in themselves are important outcomes from this modelling exercise given the limited data on incidence of violence among FSWs [27,28]. Among FSWs enrolled in AESHA, incidence of violence averaged over a 4-year period was substantially lower among FSWs working in brothels or quasi-brothels compared to those working in outdoor/public spaces or those working in informal-indoor venues (Figure 2.6). Incidence of workplace violence was highest among FSWs working in outdoor/public spaces, tending to be one and a half to two times higher than the incidence of workplace violence among informal-indoor based FSWs (Figure 2.6). This highlights the need to promote and improve access to indoor work environments which are safer, and to implement strategies to improve safety for FSWs working in outdoor/public spaces [3].

Impact of structural interventions

The calibrated model was also used to evaluate the impact of structural interventions on client violence and levels of ICU with clients. Interventions examined focussed on elimination of violence and elimination of ICU associated with past experiences of workplace violence.

Due to the interaction between police harassment and client violence in the model, the results suggest that an intervention which eliminates police harassment (Intervention 1) could lead to an average 18% and 27% relative reduction in prevalence of client physical violence and client sexual violence, respectively over 5 years. This result supports calls to work with police to help improve the health and safety of sex workers [1,29,30]. There are emerging examples from around the world of positive partnerships between police and FSWs [30]. Larger reductions in prevalence were seen for FSWs who have ever injected drugs compared to FSWs who have never injected drugs, suggesting that police-related interventions may be particularly beneficial for improving safety among FSWs who inject drugs.

Due to the large and sustained effects of client violence on ICU, eliminating both client violence and the long-term negative effects of client violence, had a large impact on reducing levels of ICU, which supports WHO recommendations to incorporate violence prevention strategies into HIV prevention programmes for FSWs [13,31]. Elimination of both police harassment and client violence, coupled with support to address the long term negative effects of client violence, resulted in the largest reductions in ICU, which indicates the need for multi-pronged structural interventions to address and prevent workplace violence. Elimination of police harassment and client violence alone, without support to address the long-term negative effects of client violence, had a more limited impact over the next 5 years, which also highlights the importance of providing comprehensive care and support for FSWs who have previously experienced client violence. A similar result was found in the Shannon *et al* modelling analysis, where elimination of police harassment and client violence alone had a negligible impact on HIV infections averted over 10 years, whereas elimination of both police harassment and client violence, combined with support to address the sustained negative effects of violence on condom use, could avert 24% of HIV infections among FSWs and their clients over a decade [3].

Sensitivity analyses

The impact of eliminating violence on client violence was particularly sensitive to the degree of association between police harassment and client violence, which highlights the need for context-specific studies to understand and measure the degree to which different types of violence interact and influence each other, in order to more robustly estimate the impact of structural interventions on other related structural conditions.

The impact of each intervention on ICU was also particularly sensitive to ICU model assumptions. When it was assumed that the increased risk in ICU for FSWs who have experienced multiple types of workplace violence was a product of the RR associated with each type of workplace violence, rather than capped at the highest RR value, the impact of interventions was greater, and elimination of police harassment was markedly more impactful. This result highlights the importance of estimating ICU by number of types of violence experienced.

Univariate sensitivity analyses highlighted that a number of the model outcomes estimated in this analysis were sensitive to the relative sizes of the FSW sub-groups in the model, which suggests a need for more data to be collected on the size of FSW sub-groups, how they evolve over time, and how FSWs move between the sub-groups. Future work should seek to incorporate uncertainties in the size of FSW sub-groups, which was not done in the current analysis to reduce the number of parameters being varied in the LHS process.

Another issue that was explored in this analysis, was the importance of including between violence-dynamics in the model for different model outcomes and research questions. This was examined through re-calibrating the model when assuming that there was no relationship between the different types of workplace violence and comparing model outputs with the original model calibration where the different types of workplace do interact. I found that the two model calibrations produced very similar results in terms of model fitting and cross-validation to prevalence data, estimation of incidence of workplace violence, and impact of client violence interventions on ICU. The two model calibrations differed the most when cross-validating to prevalence of experiencing multiple types of workplace violence. Taken together, these results suggest that for research questions that relate to either estimating incidence of violence or the impact of structural interventions on HIV transmission, it may be acceptable, in the context of further study in Vancouver, to not include between-violence dynamics if model complexity could benefit from being reduced. This result does not apply when evaluating the impact of structural interventions on other interacting structural conditions.

2.5.2 Strengths and limitations

To the best of my knowledge, this is one of the first modelling studies among FSWs to focus on structural HIV determinants, and the multiple sensitivity analyses conducted provide useful insights for future model development and data collection. The model developed for this analysis is novel in terms of its more detailed representation of experiences of workplace violence among FSWs in Vancouver, and a key strength of this analysis is that the model design was informed by context-specific data and discussions with epidemiologists in Vancouver. Despite being able to utilise data from a large cohort of FSWs, data availability was still a limiting factor in the design of the model. As data on the frequency of workplace violence was not collected, the model was structured to reflect the available data on prevalence of workplace in the last 6 months (i.e. recent workplace violence) and ever. This results in a conservative model assumption that a maximum of one event of each type of workplace violence can occur in a 6 month period. This means that model is likely to be underestimating incidence of violence and the time it takes for FSWs to re-experience workplace violence. If new data on the frequency of violence becomes available (e.g.

from survey questions such as "how often have you experienced violence in the last 6 months?"), the model structure could be updated to reflect these more realistic inputs.

A strength of the model is that it takes into account important heterogeneities in risk of workplace violence by stratifying the FSW population into sub-groups with different rates of workplace violence. However, due to limited data, it was assumed that FSWs remained in their given sub-group for the duration of the model, which is unlikely to be an accurate representation of reality, and may influence the model estimates. For parsimony, the model also assumed that rates of workplace violence did not vary over time. This is a limitation of the model, as it does not take into account that experiences of workplace violence may have changed over time due to interventions and/or changes in policy (e.g. the introduction of Bill C-36 in Vancouver which criminalises clients) [15,18].

Another strength of this analysis was the model calibration approach where prior parameter ranges were sampled by LHS to identify multiple parameter sets for further analysis that agreed with the empirical data. This approach allows the model results to take into account uncertainty in the data. However, a limitation of this approach is that some parameter sets which agree with the empirical data may have combinations of parameter values that may not be realistic (e.g. rates of workplace violence being higher in non-IDU sub-groups compared to ever-IDU sub-groups) (see Text B3 in Appendix B). Future work should consider whether to place additional constraints on the parameter sets accepted for analysis.

There are also methodological limitations with the interventions modelled. Each intervention modelled assumes that workplace violence or the excess risk of ICU due to non-recent workplace violence is eliminated immediately following implementation of the intervention. The results therefore reflect the maximum potential impact of each structural intervention modelled. However, in reality, complete elimination of workplace violence could be challenging, and reductions in workplace violence and ICU are likely to occur slowly. Thus, the results are likely to be overestimates of the impact of structural interventions.

There are also additional limitations with the data used to parameterise and fit the model. First, under-reporting of violence due to social desirability bias could have occurred during the collection of the empirical data used in the model, which could lead to under-estimating incidence of violence and the potential impact of structural interventions. Second, it may be difficult for FSWs to remember exactly when violence experiences occurred, so the empirical data and thus the model estimates may be affected by recall accuracy.

Another limitation of this analysis is that the model results cannot be generalised to other settings, due to the context-specific nature of structural determinants. However, the flexible model structure I developed means that the model can be adapted and parameterised to other settings, provided that data is available. In chapter 5, I adapt the model to the context of violence against FSWs in Mombasa, Kenya. The adaptation of the model will be informed by data analysed in the next two chapters (Chapters 3 and 4).

2.5.3 Conclusions

In summary, in this chapter, workplace violence experiences among FSWs in Vancouver, Canada were dynamically modelled. The novel model developed more systematically simulates experiences of workplace violence among FSWs in Vancouver compared to the prior modelling study by Shannon and colleagues, and cross-validated well against prevalence data on workplace violence. However, future work is needed to improve the accuracy of incidence estimates projected by the model. The results highlighted the need to address different types of workplace violence to improve the safety and health of FSWs in Vancouver. This novel analysis is one of the first modelling studies conducted to try and understand structural determinants of HIV, estimate incidence of structural determinants, and evaluate the impact of structural interventions among FSWs; and provides important insights for future model development and data collection.

2.6 References

1. Decker MR, Crago AL, Chu SKH, et al. Human rights violations against sex workers: Burden and effect on HIV. Lancet. 2015 10 Jan;385(9963):186-99
2. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
3. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
4. Footer KH, Silberzahn BE, Tormohlen KN, Sherman SG. Policing practices as a structural determinant for HIV among sex workers: a systematic review of empirical findings. J Int AIDS Soc. 2016;19(4 Suppl 3):20883
5. Church S, Henderson M, Barnard M, Hart G. Violence by clients towards female prostitutes in different work settings: Questionnaire survey. BMJ. 2001 03 Mar;322(7285):524-5
6. Odinokova V, Rusakova M, Urada LA, Silverman JG, Raj A. Police sexual coercion and its association with risky sex work and substance use behaviors among female sex workers in St. Petersburg and Orenburg, Russia. Int J Drug Policy. 2014 Jan;25(1):96-104
7. Shannon K, Strathdee SA, Shoveller J, Rusch M, Kerr T, Tyndall MW. Structural and environmental barriers to condom use negotiation with clients among female sex workers: Implications for HIV-prevention strategies and policy. Am J Public Health. 2009 01 Apr;99(4):659-65
8. Deering KN, Bhattacharjee P, Mohan HL, et al. Violence and HIV Risk Among Female Sex Workers in Southern India. Sex Transm Dis. 2013 Feb;40(2):168-74
9. Erausquin JT, Reed E, Blankenship KM. Police-Related Experiences and HIV Risk Among Female Sex Workers in Andhra Pradesh, India. J Infect Dis. 2011 Dec 1;204:S1223-S8
10. Platt L, Grenfell P, Bonell C, et al. Risk of sexually transmitted infections and violence among indoor-working female sex workers in London: The effect of migration from Eastern Europe. Sex Transm Infect. 2011 August;87(5):377-84
11. Shannon K, Kerr T, Strathdee SA, Shoveller J, Montaner JS, Tyndall MW. Prevalence and structural correlates of gender based violence among a prospective cohort of female sex workers. BMJ. 2009 Aug 11;339
12. Shannon K, Goldenberg SM, Deering KN, Strathdee SA. HIV infection among female sex workers in concentrated and high prevalence epidemics: why a structural determinants framework is needed. Current Opinion in Hiv and Aids. 2014 Mar;9(2):174-82
13. WHO. Implementing Comprehensive HIV/STI Programmes with Sex Workers Practical Approaches from Collaborative Interventions. WHO, Geneva, Switzerland. 2013
14. Altice FL, Azbel L, Stone J, et al. The perfect storm: incarceration and the high-risk environment perpetuating transmission of HIV, hepatitis C virus, and tuberculosis in Eastern Europe and Central Asia. The Lancet. 2016 17 Sep;388(10050):1228-48
15. Krusi A, Pacey K, Bird L, et al. Criminalisation of clients: Reproducing vulnerabilities for violence and poor health among street-based sex workers in Canada - A qualitative study. BMJ open. 2014;4(6)
16. Shannon K, Kerr T, Allinott S, Chettiar J, Shoveller J, Tyndall MW. Social and structural violence and power relations in mitigating HIV risk of drug-using women in survival sex work. Social Science and Medicine. 2008 February;66(4):911-21
17. Goldenberg SM, Deering K, Amram O, et al. Community mapping of sex work criminalization and violence: impacts on HIV treatment interruptions among marginalized women living with HIV in Vancouver, Canada. Int J STD AIDS. 2017 01 Sep;28(10):1001-9
18. Sex Workers United Against Violence, the Gender and Sexual Health Initiative, and Pivot Legal Society. My work should not cost me my life. The case against criminalizing the purchase of sex in Canada. 2014.

19. Anderson S, Shannon K, Li J, et al. Condoms and sexual health education as evidence: impact of criminalization of in-call venues and managers on migrant sex workers access to HIV/STI prevention in a Canadian setting. BMC Int Health Hum Rights. 2016 17 Nov;16(1):1-10
20. Shannon K, Bright V, Allinott S, Alexson D, Gibson K, Tyndall MW. Community-based HIV prevention research among substance-using women in survival sex work: The Maka Project Partnership. Harm Reduction Journal. 2007 08 Dec;4 (no pagination)(20)
21. Argento E, Shannon K, Nguyen P, Dobrer S, Chettiar J, Deering KN. The role of dyad-level factors in shaping sexual and drug-related HIV/STI risks among sex workers with intimate partners. Drug Alcohol Depend. 2015 Dec 1;157:166-73
22. Deering KN, Montaner JS, Chettiar J, et al. Successes and gaps in uptake of regular, voluntary HIV testing for hidden street- and off-street sex workers in Vancouver, Canada. AIDS Care. 2015;27(4):499-506
23. Blower SM, Dowlatabadi H. Sensitivity and Uncertainty Analysis of Complex Models of Disease Transmission: an HIV Model, as an Example. International Statistical Review. 1994;62(2):229-43
24. Pickles M, Foss AM, Vickerman P, et al. Interim modelling analysis to validate reported increases in condom use and assess HIV infections averted among female sex workers and clients in southern India following a targeted HIV prevention programme. Sex Transm Infect. 2010 February;86(SUPPL. 1):i33-i43
25. Wu J, Dhingra R, Gambhir M, Remais JV. Sensitivity analysis of infectious disease models: methods, advances and their application. Journal of the Royal Society, Interface. 2013 Sep 6;10(86):20121018
26. Landsberg A, Shannon K, Krusi A, et al. Criminalizing Sex Work Clients and Rushed Negotiations among Sex Workers Who Use Drugs in a Canadian Setting. J Urban Health. 2017 Aug;94(4):563-71
27. Micheni M, Rogers S, Wahome E, et al. Risk of sexual, physical and verbal assaults on men who have sex with men and female sex workers in coastal Kenya. AIDS. 2015 Dec;29 Suppl 3:S231-6
28. Shannon K, Csete J. Violence, condom negotiation, and HIV/STI risk among sex workers. JAMA - Journal of the American Medical Association. 2010 04 Aug;304(5):573-4
29. Crofts N, Patterson D. Police must join the fast track to end AIDS by 2030. Journal of the International AIDS Society. 2016 18 Jul;19 (Supplement 3) (no pagination)(21153)
30. Tenni B, Carpenter J, Thomson N. Arresting HIV: Fostering Partnerships between Sex Workers and Police to Reduce HIV Risk and Promote Professionalization within Policing Institutions: A Realist Review. PLoS ONE [Electronic Resource]. 2015;10(10):e0134900
31. WHO. Violence against sex workers and HIV prevention. WHO Information Bulletin Series. 2005;Number 3

Chapter 3: Burden and determinants of violence among young women who self-identify as sex workers in Mombasa, Kenya

3.1 Overview

In this chapter, I examine the burden and determinants of violence among young women who sell sex in Mombasa, Kenya. I analyse data from the Transitions study, which is a cross-sectional study of young women in Mombasa, Kenya, that included participants who self-identified as sex workers. The work presented in this chapter has been written up as a manuscript for publication, and so has benefitted from the critical review of co-authors. The co-authors for this manuscript include: Dr Mike Pickles, Professor Marie-Claude Boily, Parinita Bhattacharjee, Dr Marissa Becker, Dr Sharmistha Mishra, Dr Eve Cheuk, Helgar Musyoki, Dr Shajy Isac and Professor James Blanchard. Dr Marissa Becker (University of Manitoba) and Dr Sharmistha Mishra (University of Toronto) shared the Transitions data which was analysed in this chapter.

3.2 Background and rationale

As highlighted in Chapter 1, violence against FSWs is widespread, and has negative consequences for FSW's physical, sexual, reproductive and mental health, including increased risk for HIV and other STIs [1-10]. FSWs commonly experience physical and sexual violence from multiple perpetrators, including clients, police and intimate partners [1-3,9]. Harassment, extortion, unlawful arrest and detention by police is also ubiquitous across many settings [1,3,9]. FSWs are particularly vulnerable to these abuses due to their stigmatised and marginalised position in society and the often criminalised nature of sex work [1,7,9,11,12]. Existing literature documents a wide range of individual, interpersonal and structural factors (e.g. duration in sex work, number of sexual partners, and work environment) that have been associated with increased risk of physical and sexual violence among FSWs globally [2].

In Kenya, where sex work is criminalised [13,14], emerging studies demonstrate that violence against FSWs perpetrated by clients, intimate partners and police are pervasive [7,11,13,15-32]. In Mombasa, 32% and 55% of FSWs reported client sexual violence and physical or sexual intimate partner violence (i.e. by husband or boyfriend) in the past year, respectively [18,22]. In a national pooling both survey across Kenya, 44% of FSWs reported being arrested or beaten up by police or criminal elements in the past 6 months [16]. However, these studies have typically focused on older populations of FSWs, with a mean (or median) age between 25 and 40 years. Little is known about the experiences of violence among young FSWs, who may be even more vulnerable to violence than their older peers [33-38]. It is important to understand the burden of violence among young FSWs so that policies and programmes for FSWs can be designed to take into account the specific needs of young FSWs [38].

In several studies outside of Kenya, harrasment, arrest and violence by police have been shown to increase FSW's risk for sexual and physical violence [2]. No comparable studies have yet been undertaken in Kenya, and prevalence estimates of police violence in Kenya still remain particularly scarce. A previous study in Kenya identified childhood abuse as a risk factor for experiencing intimate partner violence in adulthood, a phenomonen known as re-victimization [25], but no study has yet examined whether violence experienced early on in sex work increases FSWs risk of experiencing violence later on in sex work.

In this chapter, my objectives are to: (1) estimate the burden of sexual violence, physical violence and police assault or arrest among young FSWs in Mombasa, Kenya, according to different time periods (lifetime and since self-identifying as a FSW), (2) examine the individual, interpersonal and structural factors associated with lifetime experiences of sexual violence, physical violence and police assault or arrest among young FSWs in Mombasa, Kenya, and (3) examine the relationship between sexual violence, physical violence and police assault or arrest in the first month of sex work and most recent month of sex work among young FSWs in Mombasa, Kenya.

3.3 Methods

3.3.1 Study population and the Transitions study

The data analysed in this chapter were drawn from the Transitions study, which is a cross-sectional study of young women aged 14-24 years who self-report engaging in either formal sex work, transactional sex or casual sex in Mombasa, Kenya. In this chapter, my analyses focus on the 408 participants in the Transitions study who self-identified as sex workers; who for the remainder of this thesis will be referred to as young female sex workers (YFSWs).

The Transitions study, which is being led by a team of researchers from the University of Manitoba, primarily aims to characterise the factors that influence HIV risk in the transition period (time between first sex and formal entry into sex work) and access gap (time between formal entry into sex work and engagement with HIV prevention services). Prior to implementation of this study, geographical mapping was conducted to identify sex work "hotspots" (defined in this study as locations where FSWs congregate to solicit clients or where other women seek sexual partners). These hotspots formed the sampling frame for the study. A multi-stage cluster sampling approach with probability proportional to the size of the enumerated population of FSWs in each identified hotspot, was used to identify and recruit participants into the study between April-November 2015. Following written informed consent, trained interviewers conducted face-to-face interviews with participants using a structured questionnaire. I was able to provide input on the design and types of questions included in the violence section of the questionnaire, and to contribute to other questions included in the questionnaire relating to FSWs sexual behaviours, work environment, alcohol use, and health care access (e.g. HIV testing uptake and ART use), which provide important information for the analyses conducted here and other chapters of this thesis.

The Transitions study was approved by the institutional ethics review board of the University of Manitoba, Canada and the Kenyatta National Hospital-University of Nairobi Ethics and Research Committee, Kenya. The secondary data analyses I have conducted on Transitions data (including those presented here and in the following chapters) were also approved by the Imperial College Research Ethics Committee, United Kingdom.

3.3.2 Measures

3.3.2.1 Violence

I examined three types of violence against sex workers: sexual violence (being forced to have sex when not willing), physical violence (being physically hurt by a sex partner), and police assault or arrest (being physically assaulted or arrested by law enforcement during sex work). I created dichotomous variables to examine the experience of each type of violence during a YFSW's lifetime (i.e. ever), and in the first and most recent month of sex work. I also examined the age at which YFSWs first experience each type of violence, the frequency of each type of violence during the first and most recent month of sex work, and the perpetrators of sexual and physical violence.

3.3.2.2 Explanatory variables

Drawing on Shannon *et al.*'s structural HIV determinants framework [7], which was described in Chapter 1 (Section 1.5.1), I examined a number of individual, interpersonal and structural factors that could potentially increase risk for violence among sex workers. The selection of these factors (i.e. explanatory variables) was based on a review of the literature on determinants of violence against FSWs (see Box 3.1). Individual variables examined included age, literacy, education, marital status, having a regular source of income, alcohol use, drug use, age at entry into sex work, and duration in sex work. Interpersonal explanatory variables examined included number and type of sexual partners, and alcohol or drug use by the participant or a sexual partner during sex. Sexual partners include clients, transactional sex partners, and intimate partners. Clients are defined as men with whom the price of sex was negotiated before the sex event and by whom money is often paid before or immediately after the sex event. Transactional sex partners are defined as men with whom the participant had had sex, with the expectation that she would receive money, gifts or other resources in return, but where the price of sex was not negotiated upfront and was implicitly understood. Intimate partners are defined as a participant's husband, spouse or boyfriends. Structural explanatory variables examined included main place or way to meet clients, having a manager or pimp, and being coerced or deceived into sex with your first 10 clients after self-identifying as a sex worker. The dichotomous violence variables were also examined as explanatory variables.

Box 3.1 Literature review for determinants of violence against FSWs

Aim of literature review:
To identify individual, interpersonal and structural determinants of violence against sex workers

Relevant existing published reviews:
A systematic review was conducted by Deering *et al* in June 2013, and updated in September 2013, to identify factors shaping sexual or physical violence against sex workers globally [2].

Methods for my review of the literature:
I reviewed the literature in three stages:

1) I reviewed the papers included in the Deering *et al* systematic review
2) I conducted a supplementary search in Pubmed and Embase to identify peer-reviewed studies published after September 2013 which examined factors shaping sexual or physical violence against sex workers:
   - Searched in Pubmed and Embase on 13/09/2016 using the same search terms as the Deering *et al* systematic review: violence OR sexual violence OR physical violence OR victimization; AND sex work OR sex worker* OR prostitute* OR prostitution
   - Articles were limited to those published in English and published after September 2013
3) I conducted a supplementary search in Pubmed and Embase to identify peer-reviewed studies examining factors shaping other forms of police perpetrated violence against FSWs (e.g. harassment, arrest, extortion)
   - Searched in Pubmed and Embase on 16/09/2016, using the following search terms: police OR policing OR law enforcement OR officer* OR arrest* OR detention OR detain* OR raid* OR crackdown*; AND sex work OR sex worker* OR prostitute* OR prostitution
   - Articles were limited to those published in English and published from 2000 onwards

Findings from my literature review:
Table C1 in Appendix C summarises the different factors which were significantly associated with violence against sex workers in adjusted analyses of the peer-reviewed studies identified in the Deering *et al* systematic review (stage 1) and my supplementary literature review (stages 2 and 3). These findings were used to guide the selection of individual, interpersonal and structural explanatory variables for my analysis (see Section 3.3.2.2).

3.3.3 Data analysis

For objective 1, I used descriptive statistics to estimate the prevalence and characteristics of violence against YFSWs, and the McNemar test to compare the proportion of YFSWs reporting violence in the first and most recent month of sex work.

For objective 2, I used bivariate chi-square tests and conducted univariate and multivariate logistic regression to examine the association between explanatory variables and each lifetime violence outcome. For these analyses, all continuous explanatory variables were categorised into binary variables (based on the median), due to their non-linear relationships with the logits of at least one outcome. Explanatory variables displaying little heterogeneity (i.e. >95% of YFSWs falling in one category) were not evaluated. Multivariate logistic regression models were constructed separately for each of the three outcome variables, and included all explanatory variables associated with the outcome at p<0.1 from bivariate analyses [39,40]. For each multivariate model, a complete case analysis was used, and adjusted odds ratios (AORs) with 95% confidence intervals (CIs) are presented. Crude odds ratios (ORs) from univariate logistic regression models are also presented for each explanatory variable included in multivariate analysis. One explanatory variable (number of clients in the last week) was excluded from multivariate analysis due to having >10% missing data. Two explanatory variables were strongly correlated (frequency of inebriation in the past month and ever been inebriated when had sex in the past month). If both were statistically significant at a p-value<0.1 in bivariate analysis, the one most strongly associated with the outcome in bivariate analysis was kept in the multivariate model [40]. Age, age at entry into sex work and duration in sex work are collinear (age at entry into sex work is derived from age and duration in sex work), so only age and duration sex work are included in multivariate models if all three were associated with the violence exposure variable in bivariate analysis.

For objective 3, I used univariate logistic regression to examine the association between experiences of each type of violence in the first month of sex work (explanatory variables) and experiences of each type of violence in the most recent month of sex work (outcome variables). Crude ORs and their 95% CIs are reported for each outcome.

All the analyses described above were conducted using STATA statistical software (version 12), and took into account the survey design and within cluster-homogeneity using *svyset* commands.

3.4. Results

3.4.1 Participant characteristics

Table 3.1 summarises individual, interpersonal and structural characteristics of the self-identified YFSWs. Their median age was 20 years, and most participants were 18 years or older (84.6%). Most participants had never been married (93.4%). A third (29.7%) reported drinking alcohol almost every day or every day in the last month. Very few had ever injected drugs (1.2%). The median age at start of sex work was 18 years (IQR: 16-19.5), the median number of years in sex work was 2 (IQR: 1-3), and the median number of clients in the last week was 4 (IQR: 1-7). Just over half reported working in an entertainment venue (e.g. bar, disco, club, café, sauna) in both the first and most recent month of sex work (54.1% and 59.1%, respectively).

Table 3.1 Individual, interpersonal and structural characteristics of the YFSW participants

	% or median (IQR)	N
Individual		
Current age, years	20.0 (18.0-22.0)	408
Literate (i.e. can read and write)	97.3	408
Highest level of education completed		
None	30.2	407
Primary school	51.6	407
High school or higher	18.2	407
Ever married	6.6	408
Age at entry into sex work, years	18.0 (16.0-19.5)	385
Duration in sex work, years	2.0 (1.0-3.0)	385
Frequency of alcohol consumption, in last month		
Less than once a month	22.9	407
1-3 times a month	14.7	407
1 to 3 times a week	32.7	407
Almost every day	13.0	407
Every day	16.7	407
Binge-drank in, last month	29.7	407
No. of times inebriated, in last month		
0 times	62.2	407
1-3 times	23.8	407
4-6 times	7.4	407
7+ times	6.6	407
Ever used drugs	31.0	406
Ever injected drugs	1.2	405
Has a regular source of income	16.5	407
Interpersonal		
No. of clients in a typical week, in first month of sex work	3.0 (2.0-4.0)	392
No. of clients, in last week	4.0 (1.0-7.0)	362
No. of transactional sex partners, in first month of sex work	1.0 (0.0-2.0)	396
No. of transactional sex partners, in last week	0.0 (0.0-1.0)	396
Had sex with an intimate partner, in last month	44.8	400
Ever been inebriated when had sex, in last month	27.7	404
Ever had sex with an inebriated partner, in last month	69.7	406
Ever been high when had sex, in last month	15.2	401
Structural		
Main place/way met paying clients, in first month of sex work		
Entertainment venue	54.1	405

Street/bus stop	25.4	405
Other (e.g. hotel, home)	20.5	405
Main place/way met paying clients, in most recent month of sex work		
Entertainment venue	59.1	403
Street/bus stop	16.6	403
Other (e.g. hotel, home)	24.3	403
Had a manager or pimp, in first month of sex work	10.8	408
Had a manager or pimp, in most recent month of sex work	2.9	408
Coerced or deceived into having sex with first 10 clients after self-identifying as a sex worker	27.3	407
No. of sex workers that you know personally		
0-5	31.5	406
6-15	40.2	406
16-30	17.0	406
31+	11.3	406

Abbreviations: YFSWs, young female sex workers; IQR, inter-quartile range

3.4.2 Burden of violence

3.4.2.1 Prevalence

Figure 3.1 shows the prevalence of each type of violence among the sample of YFSWs. Two-thirds (65%) had already experienced at least one type of violence in their lifetime. The lifetime prevalence of each type of violence was high: police assault or arrest was most common (45.3%), followed by physical violence (29.8%) and sexual violence (29.5%). Many YFSWs had experienced multiple types of violence; 17.5% and 11.0% reported two and three types, respectively in their lifetime.

Prevalence of police assault or arrest increased nearly four-fold between the first and most recent month of sex work (4.0% versus 14.7%; p-value<0.001), while prevalence of physical violence increased by half (5.0% versus 7.7%; p-value=0.007). There was a non-significant increase in prevalence of sexual violence between the first and most recent month of sex work (4.8% versus 7.2%, p-value=0.149). Overall, twice as many YFSWs reported experiencing at least one type of violence in the most recent month of sex work compared to the first month of sex work (23.5% versus 11.9%, p-value<0.001).

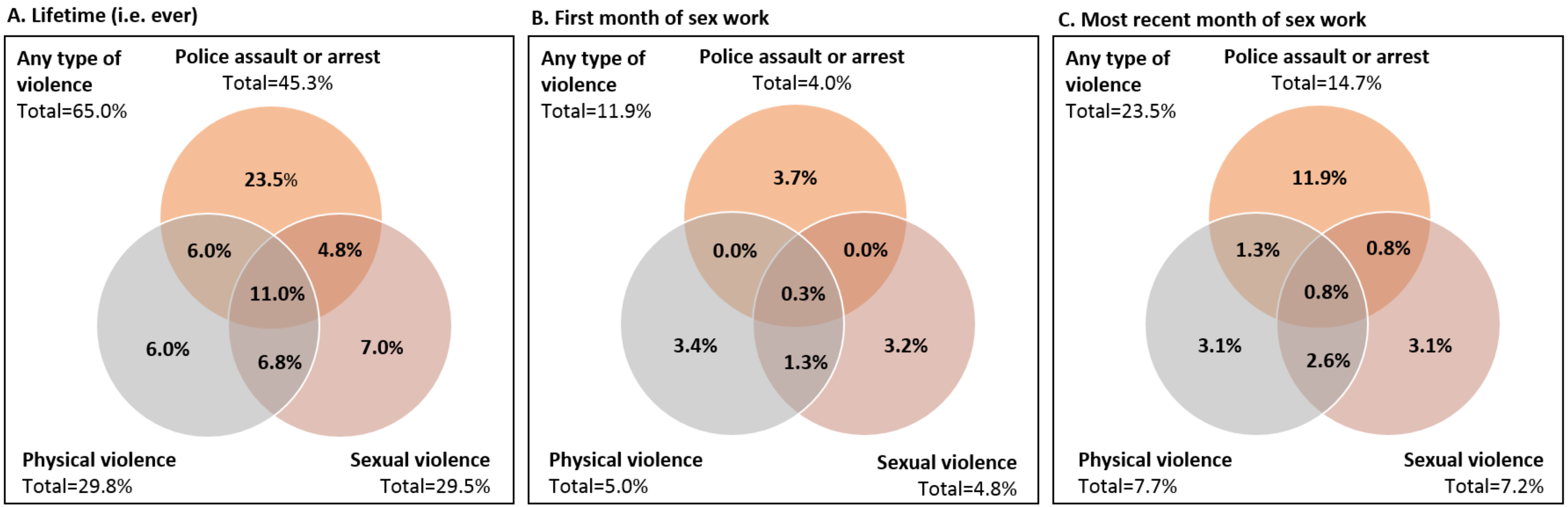


Figure 3.1 Prevalence of each type of violence (sexual violence, physical violence and police assault or arrest) during a YFSWs A) lifetime (N=400), B) first month of sex work (N=379), and C) most recent month of sex work (N=388). YFSWs, female sex workers.

3.4.2.2 Age at first experience of violence

The first experience of sexual violence, physical violence and police assault or arrest occurred at a median age of 17.0, 18.9 and 19.0 years, respectively (Table 3.2). In half of YFSWs, the first experience of sexual violence occurred before they started sex work (Table 3.2). In contrast, the majority of YFSWs (87.2%) reported that their first physical violence experience occurred after starting sex work (a median of 1 year after) (Table 3.2). Experiencing police assault or arrest during sex work first occurred a median of 1 year after starting sex work (Table 3.2).

3.4.2.3 Frequency of experiencing violence during sex work

Among YFSWs who reported sexual violence in their first or most recent month of sex work, 61.1% and 43.3%, respectively, reported that multiple men (2 or more) perpetrated sexual violence against them during that month (Table 3.2). Of those who experienced physical violence in the first or most recent month of sex work, the majority (75.0% and 81.1%, respectively) reported that one sexual partner perpetrated physical violence against them during that month (Table 3.2). Among YFSWs who reported police assault or arrest during the first or most recent month of sex work, just over two-thirds (73.7% and 69.5%, respectively) reported one occurrence of police assault or arrest during that month (Table 3.2).

3.4.2.4 Perpetrators of sexual and physical violence

The majority of YFSWs reported that their first experience of sexual violence or physical violence was perpetrated by a client (41.4% and 74.6%, respectively) or intimate partner (31.9% and 18.9%, respectively) (Table 3.2). In the first and most recent month of sex work, clients remained the main perpetrator of sexual and physical violence (see Table C2 in Appendix C).

Table 3.2 Characteristics of YFSWs violence experiences

	Sexual violence		Physical violence		Police assault or arrest	
	% or median (IQR)	N	% or median (IQR)	N	% or median (IQR)	N
First lifetime experience						
Age when it occurred, years	17.0 (15.0-19.5)	110	18.9 (16.9-20.7)	114	19.0 (17.0-21.0)	179
Occurred prior to entering sex work						
Yes	46.3	108	12.8	109	NA	NA
No. of years prior to entering sex work	1.6 (0.8-3.0)	50	1.0 (0.5-3.0)	14	NA	NA
No	53.7	108	87.2	109	100.0	155
No. of years after entering sex work	0.5 (0.0-1.8)	58	1.0 (0.2-2.0)	95	1.0 (0.5-2.0)	155
Perpetrator						
Regular client	18.1	116	36.9	122	NA	NA
New client	23.3	116	37.7	122	NA	NA
Regular transactional sex partner	5.2	116	4.1	122	NA	NA
New transactional sex partner	6.0	116	1.6	122	NA	NA
Intimate partner	31.9	116	18.9	122	NA	NA
Other (e.g. stranger, friend, relative)	15.5	116	0.8	122	NA	NA
Perpetrator was first sex partner	49.6	119	NA	NA	NA	NA
First month of sex work						
No. of men who perpetrated sexual violence against you[1]						
One	38.9	18	NA	NA	NA	NA
Two or more	61.1	18	NA	NA	NA	NA
No. of sexual partners who perpetrated physical violence against you[2]						
One	NA	NA	75.0	20	NA	NA
Two or more	NA	NA	25.0	20	NA	NA
No. of times you were assaulted or arrested by police[3]						
Once	NA	NA	NA	NA	73.7	19
Two or more times	NA	NA	NA	NA	26.3	19
Most recent month of sex work						
No. of men who perpetrated sexual violence against you[1]						
One	56.7	30	NA	NA	NA	NA
Two or more	43.3	30	NA	NA	NA	NA
No. of sexual partners who perpetrated physical violence against you[2]						
One	NA	NA	81.1	37	NA	NA
Two or more	NA	NA	18.9	37	NA	NA
No. of times you were assaulted or arrested by police[3]						
Once	NA	NA	NA	NA	69.5	59
Two or more times	NA	NA	NA	NA	30.5	59

Abbreviations: YFSWs, young female sex workers; IQR, inter-quartile range.[1] Among those who reported sexual violence in that month; [2] Among those who reported physical violence in that month; [3] Among those who reported police assault or arrest in that month

3.4.3 Determinants of violence

3.4.3.1 Factors associated with lifetime violence

Tables C3-C5 in Appendix C show the bivariate relationships between individual, interpersonal and structural factors and lifetime experience of sexual violence, physical violence and police assault or arrest. Factors significantly associated with at least one type of violence at a p-value<0.1 in bivariate analysis were age, marital status, having a regular sources of income, frequency of alcohol use, binge-drinking, frequency of inebriation, age at entry and duration in sex work, number of clients and transactional sex partners, being drunk or having a partner that was drunk when had sex, being coerced or deceived into sex with your first 10 clients after self-identifying as a sex worker, and lifetime experience of sexual violence, physical violence and police assault or arrest.

Table 3.3 shows the multivariate results. After adjustment for other factors, lifetime sexual violence was significantly associated with being coerced or deceived into having sex with the first 10 clients after self-identifying as a sex worker (AOR 2.4; 95%CI: 1.3-4.6) and experiencing lifetime physical violence (AOR 7.3; 95%CI: 4.2-12.6). Lifetime physical violence was significantly associated with drinking alcohol every day in the last month compared to drinking alcohol less than once in the last month (AOR 2.6; 95%CI: 1.1-6.0), having a regular source of income (AOR 0.5; 95%CI: 0.3-0.9) and experiencing lifetime sexual violence (AOR 6.8; 95%CI: 3.7-12.4). Lifetime police assault or arrest was significantly associated with working for three or more years in sex work compared to less than three years (AOR 1.6; 95%CI: 1.0-2.4), being inebriated one to three times or seven or more times compared to never being inebriated in the last month (AOR 2.8; 95%CI: 1.5-5.3, and AOR 3.9; 95%CI: 1.4-11.5, respectively), and having at least one transactional sex partner compared to not having any in the last week (AOR 0.5; 95%CI: 0.3-0.8).

3.4.3.2 Re-victimization after experiencing violence in first month of sex work

Table 3.4 shows relationships between different types of violence in the first and most recent month of sex work. Experience of sexual violence in the first month was associated with experiencing both sexual and physical violence in the most recent month of sex work (OR 15.8; 95%CI: 5.5-45.9, and OR 3.8; 95%CI: 1.2-12.3, respectively). Similarly, experience of physical violence in the first month was associated with both physical and sexual violence in the most recent month of sex work (OR 13.0; 95%CI: 4.8-35.0, and OR 5.2; 95%CI: 1.8-15.1, respectively). YFSWs who reported police assault or arrest in the first month were more likely to report experiencing police assault or arrest in the most recent month of sex work, compared to those that did not report police assault or arrest in the first month (OR 7.5; 95%CI: 3.4-16.5), but were not more likely to report sexual or physical violence.

Table 3.3 Determinants of lifetime sexual violence, lifetime physical violence and lifetime police assault or arrest: crude and adjusted odds ratio for factors assessed in multivariate analysis[1]

Multivariate model	Crude OR (95% CI)	Adjusted OR (95% CI)[2]	p-value[3]
Lifetime sexual violence			
Frequency of alcohol consumption, in last month **			
Less than once a month	1.0 (ref)	1.0 (Ref)	
1-3 times a month	1.9 (0.9-3.8)	1.4 (0.6-3.0)	0.440
1 to 3 times a week	1.5 (0.8-2.8)	1.1 (0.5-2.4)	0.794
Almost every day	2.3 (0.9-5.4)	1.5 (0.6-3.8)	0.383
Every day	2.7 (1.4-5.5)	1.3 (0.6-3.1)	0.490
No. of times inebriated, in last month*			
0 times	1.0 (ref)	1.0 (Ref)	
1-3 times	1.1 (0.7-1.9)	0.6 (0.4-1.1)	0.093
4-6 times	1.9 (0.8-4.8)	1.2 (0.4-4.0)	0.745
7+ times	2.4 (1.1-5.0)	1.8 (0.8-4.0)	0.151
Has a regular source of income (yes vs no) **	0.6 (0.4-1.0)	0.8 (0.4-1.6)	0.539
No. of clients in a typical week, in first month of sex work *			
0-3	1.0 (Ref)	1.0 (Ref)	
4+	1.6 (1.0-2.8)	1.7 (0.9-3.1)	0.124
No. of transactional sex partners, in first month of sex work **			
0-1	1.0 (Ref)	1.0 (Ref)	
2+	1.6 (1.0-2.5)	1.5 (0.9-2.5)	0.142
Coerced or deceived into having sex with first 10 clients after self-identifying as a sex worker **	2.0 (1.3-3.1)	2.4 (1.3-4.6)	0.006
Lifetime physical violence (yes vs no) **	7.5 (4.4-12.8)	7.3 (4.2-12.6)	<0.001
Lifetime police assault or arrest (yes vs no) *	1.6 (1.0-2.5)	1.4 (0.8-2.3)	0.209
Lifetime physical violence			
Frequency of alcohol consumption, in last month **			
Less than once a month	1.0 (Ref)	1.0 (Ref)	
1-3 times a month	2.2 (1.1-4.5)	1.4 (0.7-3.0)	0.355
1 to 3 times a week	2.5 (1.4-4.4)	1.6 (0.8-3.2)	0.213
Almost every day	3.7 (1.6-8.2)	2.5 (0.9-6.5)	0.066
Every day	4.4 (2.1-9.3)	2.6 (1.1-6.0)	0.033
Binge-drank, in last month **	1.8 (1.2-2.7)	0.9 (0.5-1.6)	0.772
Has a regular source of income (yes vs no) **	0.5 (0.3-0.9)	0.5 (0.3-0.9)	0.020
No. of transactional sex partners, in first month of sex work *			
0-1	1.0 (Ref)	1.0 (Ref)	
2+	1.6 (1.0-2.5)	1.2 (0.7-2.0)	0.527
Ever been inebriated when had sex, in last month (yes vs no) **	2.2 (1.3-3.6)	1.4 (0.8-2.7)	0.259
Ever had sex with an inebriated partner, in last month (yes vs no) **	1.8 (1.1-3.0)	1.6 (0.8-2.9)	0.159
Lifetime sexual violence (yes vs no) **	7.5 (4.4-12.8)	6.8 (3.7-12.4)	<0.001
Lifetime police assault or arrest (yes vs no) **	2.0 (1.3-3.2)	1.4 (0.8-2.5)	0.226
Lifetime police assault or arrest			
Current age, years **			
14-20	1.0 (Ref)	1.0 (Ref)	
21-24	1.7 (1.2-2.4)	1.5 (1.0-2.2)	0.059
Ever married (yes vs no) **	2.6 (1.2-5.7)	1.1 (0.4-2.9)	0.818
Duration in sex work, years **			
0-2	1.0 (Ref)	1.0 (Ref)	
3+	1.5 (1.1-2.2)	1.6 (1.0-2.4)	0.031
Frequency of alcohol consumption, in last month **			
Less than once a month	1.0 (Ref)	1.0 (Ref)	
1-3 times a month	1.7 (0.9-3.2)	1.1 (0.5-2.3)	0.840
1 to 3 times a week	2.4 (1.4-4.1)	1.8 (0.9-3.7)	0.082
Almost every day	2.7 (1.3-5.3)	1.9 (0.8-4.7)	0.162
Every day	2.7 (1.5-4.6)	1.7 (0.8-3.9)	0.165
Binge-drank, in last month **	1.6 (1.0-2.6)	0.7 (0.4-1.4)	0.298
No. of times inebriated, in last month **			
0 times	1.0 (Ref)	1.0 (Ref)	
1-3 times	2.4 (1.5-3.9)	2.8 (1.5-5.3)	0.002

4-6 times	1.5 (0.6-3.4)	1.4 (0.6-3.6)	0.467
7+ times	4.0 (2.0-8.2)	3.9 (1.4-11.5)	0.013
No. of clients in a typical week, in first month of sex work *			
0-3	1.0 (Ref)	1.0 (Ref)	
4+	1.4 (1.0-2.1)	1.4 (0.9-2.2)	0.121
No. of transactional sex partners, in last week *			
0	1.0 (Ref)	1.0 (Ref)	
1+	0.7 (0.5-1.1)	0.5 (0.3-0.8)	0.002
Ever had sex with an inebriated partner, in last month (yes vs no) **	1.9 (1.3-2.9)	1.3 (0.8-2.1)	0.361
Lifetime sexual violence (yes vs no) *	1.6 (1.0-2.5)	1.3 (0.8-2.2)	0.241
Lifetime physical violence (yes vs no) **	2.0 (1.3-3.2)	1.6 (0.9-2.7)	0.096

Abbreviations: OR, odds ratio; CI, confidence interval

[1] Table only includes explanatory variables entered into each multivariate model

[2] OR adjusted for all other variables included in multivariate model

[3] p-value for adjusted OR

* variable was significant at p<0.1 in bivariate analysis

** variable was significant at p<0.05 in bivariate analysis

Table 3.4 Associations between experiences of violence in the first month of sex work and most recent month of sex work

	Violence in most recent month of sex work								
	Sexual violence			Physical violence			Police assault or arrest		
	Yes (%)	Crude OR (95% CI)	p-value	Yes (%)	Crude OR (95% CI)	p-value	Yes (%)	Crude OR (95% CI)	p-value
History of violence in first month of sex work									
Sexual violence									
No	4.8	1.0 (Ref)		7.0	1.0 (Ref)		14.4	1.0 (Ref)	
Yes	44.4	15.8 (5.5-45.9)	<0.001	22.2	3.8 (1.2-12.3)	0.025	16.7	1.2 (0.3-4.6)	0.799
Physical violence									
No	6.4	1.0 (Ref)		6.6	1.0 (Ref)		14.4	1.0 (Ref)	
Yes	26.3	5.2 (1.8-15.1)	0.003	47.6	13.0 (4.8-35.0)	<0.001	23.8	1.9 (0.6-5.4)	0.260
Police assault or arrest									
No	7.4	1.0 (Ref)		8.6	1.0 (Ref)		11.8	1.0 (Ref)	
Yes	11.8	1.7 (0.3-8.5)	0.530	15.8	2.0 (0.6-7.1)	0.283	50.0	7.5 (3.4-16.5)	<0.001

Note: Percentages refer to the proportion of YFSWs reporting violence in the most recent month of sex work (e.g. 44.4% of YFSWs who reported a history of sexual violence in the first month of sex work experienced sexual violence in the most recent month of sex work compared to only 4.8% of YFSWs who did not report a history of sexual violence in the first month of sex work).
Abbreviations: OR, odds ratio; YFSWs, young female sex workers

3.5 Discussion

3.5.1 Summary of key results

In this chapter I examined the burden and determinants of violence against YFSWs in Mombasa, Kenya. The findings from this analysis highlight that there is a heavy burden of violence against YFSWs. By age 24, one in three YFSWs had experienced sexual or physical violence and one in two had experienced police assault or arrest. Nearly two-thirds had experienced at least one type of violence, and one in ten had experienced all three violence types. The high prevalence of violence found is consistent with previous studies among older FSWs from Mombasa and elsewhere in Kenya and add to the growing body of evidence documenting high rates of violence experienced by sex workers in Kenya [7,11,15-19,21-32].

Over 10% of YFSWs reported experiencing at least one type of violence during their first month of sex work, suggesting that the first month of sex work is already a vulnerable time in a young sex workers career. On average two years later, in their most recent month of sex work, almost a quarter of YFSWs (24%) experienced at least one type of violence. The increase in prevalence across the two-time periods could be due to a number of factors such as taking on more clients or becoming known to police the longer you remain a sex worker. In other studies, a longer time spent in sex work was associated with higher rates of recent violence or negative police interactions [41,42].

The age at which FSWs first experience violence has received little attention in the existing literature. The YFSWs in this study first experienced sexual violence at an average age of 17 years, which was about two years younger than the average age of first experiencing physical violence or police assault or arrest. I also found that half of YFSWs who experienced sexual violence first did so before starting sex work, whereas the majority (87%) of YFSWs who experienced physical violence first did so after starting sex work. Taken together, these results highlight a high vulnerability to sexual violence early on in life, even before entry into sex work, and suggest that the period of time selling sex is a high risk time for experiencing physical violence.

Consistent with findings from other studies in Kenya and worldwide, heavier alcohol use was associated with a higher prevalence of lifetime physical violence and lifetime police assault or arrest [17,18,23,25,28,42-45]. Higher frequency of alcohol use and inebriation may directly lead to violence, but given the cross-sectional nature of the data it also possible that YFSWs use alcohol as a coping mechanism for the acts of violence they have experienced. This analysis also showed that lifetime experience of sexual violence and physical violence were strongly correlated.

Although it is difficult to assess the direction of this relationship in cross-sectional studies, the younger age at which YFSWs first experienced sexual violence compared to physical violence may potentially suggest that sexual violence occurs first and subsequently increases the risk of experiencing physical violence. In other settings, police arrests, raids, and violence have been associated with higher rates of physical and sexual violence against FSWs [46-49]. Although police assault or arrest was significantly associated with a higher prevalence of lifetime physical and sexual violence in bivariate analyses, these associations did not remain significant in multivariate analysis.

I also found factors that were associated with lower prevalence of violence. YFSWs who reported having a regular source of income were less likely to report lifetime physical violence. Other studies have also found that FSWs with higher income levels or in a better financial situation report less violence [50-53]. YFSWs with more transactional partners were also less likely to report lifetime police assault or arrest. It could be that young women with transactional sex partners, have fewer clients, and so come into contact less with police [15,54,55].

Finally, I found that FSWs reporting a history of violence in the first month of sex work were more likely to report violence in the most recent month of sex work, suggesting that experiences of violence early on in sex work perpetuate a cycle of violence, increasing the likelihood of re-victimization later on in sex work [56].

3.5.2 Implications

These results highlight the need to prevent and address violence against young women selling sex in Kenya. Programmes with FSWs need to prioritise young sex workers, and enable them to understand violence, understand their rights and inform them about violence prevention and response services within and outside the programmes. Evidence of re-victimisation among the YFSWs in this study suggests a need to prioritise identification and linkage of women with a history of violence to violence prevention and response services and to develop and implement interventions to prevent additional experiences of violence among these YFSWs. FSW programmes should have good assessment and screening processes in place (e.g. during their intake process) to ask YFSWs about their experiences of violence so that they can be linked to violence prevention and response services if they report recent or non-recent experiences of violence. The high prevalence of frequent alcohol use and inebriation among the YFSWs in this study and the relationship between this heavy alcohol use and experiences of violence, also suggests a need to prioritise linkage of YFSWs with heavy alcohol use to violence prevention and response services.

In a number of settings, community empowerment has been effective in reducing violence against FSWs [1,33,57], so trying to engage young women who sell sex in community empowerment activities could be effective at reducing violence in this vulnerable population of women. Given the high lifetime prevalence of police arrest or assault experienced by the YFSWs in this study, it will be important to foster new and improve existing partnerships with police to reduce police violence [1,9,57]. Regular and ongoing advocacy meetings and sensitization workshops with police to reform police attitudes towards YFSWs and educate them about violence and sex workers rights may help to reduce police violence and arrests [1,9,55,57,58]. Half of YFSWs reported working in entertainment venues, so sensitisation meetings with bar owners and managers at entertainment venues which specifically addresses violence against younger FSWs could be helpful in creating safer workspace for YFSWs with reduced client violence. In this study, YFSWs with a regular source of income had a lower prevalence of violence, so implementing and targeting economic strengthening or empowerment interventions (e.g. microfinance and vocational training) to YFSWs that increase their regular income and reduce their dependency on sex work may also help to reduce violence among young women selling sex in Kenya [59-63].

Existing literature documents the numerous negative health outcomes associated with experiencing violence among FSWs, including increased risk for HIV and non-condom use [1,7]. So ensuring that YFSWs in Mombasa who have experienced violence are linked to comprehensive HIV/STI, reproductive and mental health services is an important part of the violence response. It is also important to conduct further studies to examine what impact these experiences of violence have on YFSWs health, HIV outcomes, and health service uptake, and this will be the focus of my next chapter (Chapter 4). Furthermore, given the high levels of violence found in this study, HIV prevention programmes for FSWs, who often find it difficult to reach young women selling sex, could utilise violence prevention and response services to reach young women selling sex who have accessed violence services but not yet enrolled in any HIV prevention or other FSW programmes.

It is also important to note that some of the young women self-identifying as FSWs in this study were less than 18 years old. Often the policy and legal environment makes it very challenging for those selling sex under the age of 18 years to access services and for FSW programmes to legally provide services to young women selling sex, so strategies will need to be tailored to reach, address and prevent violence in this vulnerable group of young women selling sex [35,38]. The WHO recommends that countries should examine their current consent policies and consider revising them to reduce age-related barriers to access and uptake of services, and that young people under the age of 18 who sell sex should be protected from criminal charges, law-enforcement violence and compulsory “rehabilitation” and detention” [38].

3.5.3 Limitations and strengths

There are a few limitations to this analysis. First, data were self-reported in face-to-face interviews, so violence could have been underreported due to sensitivity of the topic [64], while assessment of earlier violence experiences (e.g. in first month of sex work) may have been subject to recall bias. Second, the study only assessed experiences of physical assault or arrest by law enforcement. Other types of violence and abuse by law enforcement, such as harassment and extortion were not examined and merit future study among YFSWs in Kenya. Third, the survey ascertained if more than one man or sexual partner perpetrated sexual or physical violence, but did not detail whether multiple perpetrators reflect one incident (i.e. gang rape) or separate incidents. Fourth, the survey did not differentiate lifetime sexual and physical violence outcomes by type of perpetrator. Factors associated with sexual and physical violence could differ by perpetrator type, so this should be explored in future studies [2]. Fifth, this survey did not ascertain the location where violence occurred. Future research should seek to identify where violence occurs, as developing a supportive network where violence takes place could help to reduce violence. Finally, the cross-sectional nature of the data precluded an assessment of causality in these analyses.

Nevertheless this analysis also has many strengths. To the best of my knowledge this is the first study in Kenya to provide estimates of the prevalence and determinants of violence among YFSWs. Second, this study provides novel information on characteristics (e.g. age and frequency) of YFSWs violence experiences in Kenya. Third, this study provides the first reported comparison of the association between violence experienced during two different time-periods in sex work (first and month recent month) in Kenya.

3.5.4 Conclusion

In conclusion, there is a high prevalence of sexual violence, physical violence and police assault or arrest among YFSWs in Mombasa, Kenya. It will be crucial to reach and target violence prevention efforts to YFSWs, in particular those with past experiences of violence and heavy alcohol use, and to work with police to address police assault and arrest.

3.6 References

1. Decker MR, Crago AL, Chu SKH, et al. Human rights violations against sex workers: Burden and effect on HIV. Lancet. 2015 10 Jan;385(9963):186-99
2. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
3. Footer KH, Silberzahn BE, Tormohlen KN, Sherman SG. Policing practices as a structural determinant for HIV among sex workers: a systematic review of empirical findings. J Int AIDS Soc. 2016;19(4 Suppl 3):20883
4. McDougal L, Strathdee SA, Rangel G, et al. Adverse pregnancy outcomes and sexual violence among female sex workers who inject drugs on the United States-Mexico border. Violence Vict. 2013;28(3):496-512
5. Patel SK, Ganju D, Prabhakar P, Adhikary R. Relationship between mobility, violence and major depression among female sex workers: a cross-sectional study in southern India. BMJ open. 2016;6(9):e011439
6. Sagtani RA, Bhattarai S, Adhikari BR, Baral D, Yadav DK, Pokharel PK. Violence, HIV risk behaviour and depression among female sex workers of eastern Nepal. BMJ open. 2013;3(6):1-6
7. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
8. Sherwood JA, Grosso A, Decker MR, et al. Sexual violence against female sex workers in The Gambia: a cross-sectional examination of the associations between victimization and reproductive, sexual and mental health. BMC Public Health. 2015;15:270
9. Tenni B, Carpenter J, Thomson N. Arresting HIV: Fostering Partnerships between Sex Workers and Police to Reduce HIV Risk and Promote Professionalization within Policing Institutions: A Realist Review. PLoS ONE [Electronic Resource]. 2015;10(10):e0134900
10. Ulibarri MD, Hiller SP, Lozada R, et al. Prevalence and characteristics of abuse experiences and depression symptoms among injection drug-using female sex workers in Mexico. J Environ Public Health. 2013;2013:631479
11. Hampanda KM. The social dynamics of selling sex in Mombasa, Kenya: a qualitative study contextualizing high risk sexual behaviour. Afr J Reprod Health. 2013 Jun;17(2):141-9
12. WHO. Violence against sex workers and HIV prevention. WHO Information Bulletin Series. 2005;Number 3
13. The Federation of Women Lawyers. Documenting human rights violation of sex workers in Kenya. FIDA Kenya: 2008.
14. The Kenya Legal & Ethical Issues Network on HIV and AIDS. Punitive laws affecting sex workers. KELIN, Kenya: 2016.
15. Benoit C, Roth E, Hallgrimsdottir H, Jansson M, Ngugi E, Sharpe K. Benefits and constraints of intimate partnerships for HIV positive sex workers in Kibera, Kenya. Int J Equity Health. 2013;12(1)
16. Bhattacharjee P, McClarty LM, Musyoki H, et al. Monitoring HIV Prevention Programme Outcomes among Key Populations in Kenya: Findings from a National Survey. PLoS ONE [Electronic Resource]. 2015;10(8):e0137007
17. Chersich MF, Bosire W, King'ola N, Temmerman M, Luchters S. Effects of hazardous and harmful alcohol use on HIV incidence and sexual behaviour: a cohort study of Kenyan female sex workers. Global health. 2014;10:22
18. Chersich MF, Luchters SMF, Malonza IM, Mwarogo P, King'ola N, Temmerman M. Heavy episodic drinking among Kenyan female sex workers is associated with unsafe sex, sexual violence and sexually transmitted infections. Int J STD AIDS. 2007 Nov;18(11):764-9
19. Elmore-Meegan M, Conroy RM, Agala CB. Sex workers in Kenya, numbers of clients and associated risks: an exploratory survey. Reprod Health Matters. 2004 May;12(23):50-7

20. Izugbara CO. Client retention and health among sex workers in Nairobi, Kenya. Arch Sex Behav. 2012 Dec;41(6):1345-52
21. L'Engle KL, Mwarogo P, Kingola N, Sinkele W, Weiner DH. A randomized controlled trial of a brief intervention to reduce alcohol use among female sex workers in Mombasa, Kenya. J Acquir Immune Defic Syndr. 2014 Dec 1;67(4):446-53
22. Luchters S, Richter ML, Bosire W, et al. The Contribution of Emotional Partners to Sexual Risk Taking and Violence among Female Sex Workers in Mombasa, Kenya: A Cohort Study. PLoS ONE. 2013 07 Aug;8(8)
23. Micheni M, Rogers S, Wahome E, et al. Risk of sexual, physical and verbal assaults on men who have sex with men and female sex workers in coastal Kenya. AIDS. 2015 Dec;29 Suppl 3:S231-6
24. Okal J, Chersich MF, Tsui S, Sutherland E, Temmerman M, Luchters S. Sexual and physical violence against female sex workers in Kenya: a qualitative enquiry. AIDS Care. 2011 May;23(5):612-8
25. Pack AP, L'Engle K, Mwarogo P, Kingola N. Intimate partner violence against female sex workers in Mombasa, Kenya. Cult Health Sex. 2013 Dec 11;11:11
26. Scorgie F, Vasey K, Harper E, et al. Human rights abuses and collective resilience among sex workers in four African countries: a qualitative study. Global health. 2013;9(1):33
27. Tegang SP, Abdallah S, Emukule G, et al. Concurrent sexual and substance-use risk behaviours among female sex workers in Kenya's Coast Province: findings from a behavioural monitoring survey. Sahara J. 2010 Dec;7(4):10-6
28. Wilson KS, Deya R, Masese L, et al. Prevalence and correlates of intimate partner violence in HIV-positive women engaged in transactional sex in Mombasa, Kenya. Int J STD AIDS. 2016 Nov;27(13):1194-203
29. Wilson KS, Deya R, Yuhas K, et al. A Prospective Cohort Study of Intimate Partner Violence and Unprotected Sex in HIV-Positive Female Sex Workers in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2054-64
30. Wilson KS, Wanje G, Yuhas K, et al. A Prospective Study of Intimate Partner Violence as a Risk Factor for Detectable Plasma Viral Load in HIV-Positive Women Engaged in Transactional Sex in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2065-77
31. Parcesepe AM, KL LE, Martin SL, et al. The impact of an alcohol harm reduction intervention on interpersonal violence and engagement in sex work among female sex workers in Mombasa, Kenya: Results from a randomized controlled trial. Drug Alcohol Depend. 2016 Apr 1;161:21-8
32. Parcesepe AM, L'Engle KL, Martin SL, Green S, Suchindran C, Mwarogo P. Early Sex Work Initiation and Violence against Female Sex Workers in Mombasa, Kenya. J Urban Health. 2016 Dec;93(6):1010-26
33. Beattie TSH, Bhattacharjee P, Ramesh BM, et al. Violence against female sex workers in Karnataka state, south India: impact on health, and reductions in violence following an intervention program. BMC Public Health. 2010 Aug 11;10
34. Decker MR, Lyons C, Billong SC, et al. Gender-based violence against female sex workers in Cameroon: prevalence and associations with sexual HIV risk and access to health services and justice. Sex Transm Infect. 2016 Jun 8;8:8
35. FHI. Young People Most at Risk of HIV: A Meeting Report and Discussion Paper from the Interagency Youth Working Group, U.S. Agency for International Development, the Joint United Nations Programme on HIV/AIDS (UNAIDS) Inter-Agency Task Team on HIV and Young People, and FHI. 2010.
36. Panchanadeswaran S, Johnson SC, Sivaram S, et al. A descriptive profile of abused female sex workers in India. J Health Popul Nutr. 2010 Jun;28(3):211-20
37. Su S, Li X, Zhang L, Lin D, Zhang C, Zhou Y. Age group differences in HIV risk and mental health problems among female sex workers in Southwest China. AIDS Care. 2014 03 Aug;26(8):1019-26
38. WHO. HIV and young people who sell sex: A technical brief. 2014.

39. Hosmer D, Lemeshow S. Applied Logistic Regression. 2nd edition ed. United States of America: John Wiley & Sons, Inc; 2000.
40. Kirkwood B, Sterne J. Essential Medical Statistics. 2nd edition ed. Oxford: Blackwell Science Ltd; 2008.
41. Richter M, Chersich MF, Vearey J, Sartorius B, Temmerman M, Luchters S. Migration status, work conditions and health utilization of female sex workers in three South African cities. J Immigr Minor Health. 2014 Feb;16(1):7-17
42. Schwitters A, Swaminathan M, Serwadda D, et al. Prevalence of rape and client-initiated gender-based violence among female sex workers: Kampala, Uganda, 2012. Aids Behav. 2015 01 Feb;19:S68-S76
43. Odinokova V, Rusakova M, Urada LA, Silverman JG, Raj A. Police sexual coercion and its association with risky sex work and substance use behaviors among female sex workers in St. Petersburg and Orenburg, Russia. Int J Drug Policy. 2014 Jan;25(1):96-104
44. Zhang C, Li X, Stanton B, et al. Alcohol use and client-perpetrated sexual violence against female sex workers in China. Psychol Health Med. 2013 May 1;18(3):330-42
45. Zhang C, Li X, Su S, et al. Violence against Chinese female sex workers from their stable partners: a hierarchical multiple regression analysis. Health Care Women Int. 2015;36(7):797-815
46. Deering KN, Bhattacharjee P, Mohan HL, et al. Violence and HIV Risk Among Female Sex Workers in Southern India. Sex Transm Dis. 2013 Feb;40(2):168-74
47. Erausquin JT, Reed E, Blankenship KM. Police-Related Experiences and HIV Risk Among Female Sex Workers in Andhra Pradesh, India. J Infect Dis. 2011 Dec 1;204:S1223-S8
48. Platt L, Grenfell P, Bonell C, et al. Risk of sexually transmitted infections and violence among indoor-working female sex workers in London: The effect of migration from Eastern Europe. Sex Transm Infect. 2011 August;87(5):377-84
49. Shannon K, Kerr T, Strathdee SA, Shoveller J, Montaner JS, Tyndall MW. Prevalence and structural correlates of gender based violence among a prospective cohort of female sex workers. BMJ. 2009 Aug 11;339
50. Alemayehu M, Yohannes G, Damte A, et al. Prevalence and predictors of sexual violence among commercial sex workers in Northern Ethiopia. Reprod Health. 2015;12:47
51. Choi SY. Heterogeneous and vulnerable: the health risks facing transnational female sex workers. Sociol Health Illn. 2011 Jan;33(1):33-49
52. Reed E, Gupta J, Biradavolu M, Devireddy V, Blankenship KM. The context of economic insecurity and its relation to violence and risk factors for HIV among female sex workers in Andhra Pradesh, India. Public Health Rep. 2010;125(SUPPL. 4):81-9
53. Semple SJ, Stockman JK, Pitpitan EV, et al. Prevalence and Correlates of Client-Perpetrated Violence against Female Sex Workers in 13 Mexican Cities. PLoS ONE [Electronic Resource]. 2015;10(11):e0143317
54. Ngugi E, Benoit C, Hallgrimsdottir H, Jansson M, Roth EA. Partners and clients of female sex workers in an informal urban settlement in Nairobi, Kenya. Cult Health Sex. 2012;14(1):17-30
55. Bhattacharjee P, Isac S, McClarty LM, et al. Strategies for reducing police arrest in the context of an HIV prevention programme for female sex workers: evidence from structural interventions in Karnataka, South India. J Int AIDS Soc. 2016;19(4 Suppl 3):20856
56. Dunkle KL, Decker MR. Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups. Am J Reprod Immunol. 2013 Feb;69:20-6
57. WHO. Implementing Comprehensive HIV/STI Programmes with Sex Workers Practical Approaches from Collaborative Interventions. WHO, Geneva, Switzerland. 2013
58. Erausquin JT, Reed E, Blankenship KM. Change over Time in Police Interactions and HIV Risk Behavior Among Female Sex Workers in Andhra Pradesh, India. Aids Behav. 2015 Jun;19(6):1108-15

59. Moret W. Economic Strengthening for Female Sex Workers: A Review of the Literature. ASPIRES, FHI 360: 2014.
60. Odek WO, Busza J, Morris CN, Cleland J, Ngugi EN, Ferguson AG. Effects of Micro-Enterprise Services on HIV Risk Behaviour Among Female Sex Workers in Kenya's Urban Slums. Aids Behav. 2009 Jun;13(3):449-61
61. Pronyk PM, Hargreaves JR, Kim JC, et al. Effect of a structural intervention for the prevention of intimate-partner violence and HIV in rural South Africa: a cluster randomised trial. Lancet. 2006 Dec 02;368(9551):1973-83
62. Sherman SG, Srikrishnan AK, Rivett KA, Liu S-H, Solomon S, Celentano DD. Acceptability of a Microenterprise Intervention Among Female Sex Workers in Chennai, India. Aids Behav. 2010 Jun;14(3):649-57
63. Tsai LC, Carlson CE, Aira T, Norcini Pala A, Riedel M, Witte SS. The impact of a microsavings intervention on reducing violence against women engaged in sex work: a randomized controlled study. BMC Int Health Hum Rights. 2016 Oct 28;16(1):27
64. Phillips AE, Gomez GB, Boily MC, Garnett GP. A systematic review and meta-analysis of quantitative interviewing tools to investigate self-reported HIV and STI associated behaviours in low- and middle-income countries. Int J Epidemiol. 2010 Dec;39(6):1541-55

Chapter 4: Associations between violence, HIV prevention and HIV infection among young women who self-identify as sex workers in Mombasa, Kenya

4.1 Overview

In the previous chapter, I examined the burden and determinants of violence among young female sex workers (YFSWs) in Mombasa, Kenya. In this chapter, I aim to examine whether there is a relationship between experiences of violence and HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection among these YFSWs in Mombasa, Kenya. I also aim to explore the pathways underlying the associations found between violence and HIV infection. Dr Marissa Becker (University of Manitoba) and Dr Sharmistha Mishra (University of Toronto) shared the Transitions study data which was analysed in this chapter.

4.2 Background and rationale

As highlighted in Chapter 1, FSWs experience a heavy burden of violence from multiple perpetrators and these experiences of violence have been identified as important structural determinants of HIV risk among FSWs [1,2]. There are multiple direct and indirect pathways through which violence is thought to increase risk of HIV acquisition and transmission (see Section 1.5.2.2 in Chapter 1). For example, sexual violence can cause genital trauma which directly increases risk of HIV acquisition and men who are violent are more likely to be HIV positive [3]. Violence is also a barrier to FSWs access to and uptake of HIV prevention programmes and services (e.g. HIV/STI testing) and uptake of HIV prevention interventions (e.g. consistent condom use), which increases risk for HIV acquisition and transmission either directly or indirectly [2-12].

In Kenya, FSWs are a key population disproportionately burdened by both violence (see Section 3.2 in Chapter 3) and HIV, with a HIV prevalence of 29.3% [13,14]. To date, in Kenya, only two studies have examined associations between violence and condom use [15,16]; no studies have examined the association of violence with HIV prevalence, or exposure to and uptake of HIV prevention programmes, services and interventions. Furthermore, neither of these two studies focused on YFSWs. YFSWs are particularly vulnerable to HIV infection, however there is scant data globally on HIV, HIV risk factors and access to and uptake of HIV prevention services and interventions among YFSWs [17-19].

In Chapter 3, I examined the burden and determinants of i) sexual violence, ii) physical violence and iii) police assault or arrest, among YFSWs in Mombasa, Kenya. Following on from that analysis, this chapter aims to investigate the associations between violence, access to HIV prevention programmes, inconsistent condom use, HIV/STI testing, and HIV infection among the YFSWs in Mombasa, Kenya. I also aim to explore whether access to HIV prevention programmes and uptake of HIV prevention interventions and services (i.e. inconsistent condom use and HIV/STI testing) are mediating factors on the pathway between violence and HIV infection. Figure 4.1 shows a conceptual framework outlining the hypothesised relationships that I will be investigating in this chapter. The specific objectives of this chapter are:

1) To describe access to HIV prevention programmes, levels of inconsistent condom use, uptake of HIV/STI testing, and prevalence of HIV among YFSWs in Mombasa, Kenya

2) Establish whether violence against YFSWs is associated with reduced access to HIV prevention programmes, increased inconsistent condom use and reduced HIV/STI testing uptake, thereby potentially increasing risk of HIV infection

3) Determine whether violence is associated with a higher HIV prevalence among the YFSWs, and ascertain if that relationship is mediated by HIV prevention programme access, inconsistent condom use and HIV/STI testing

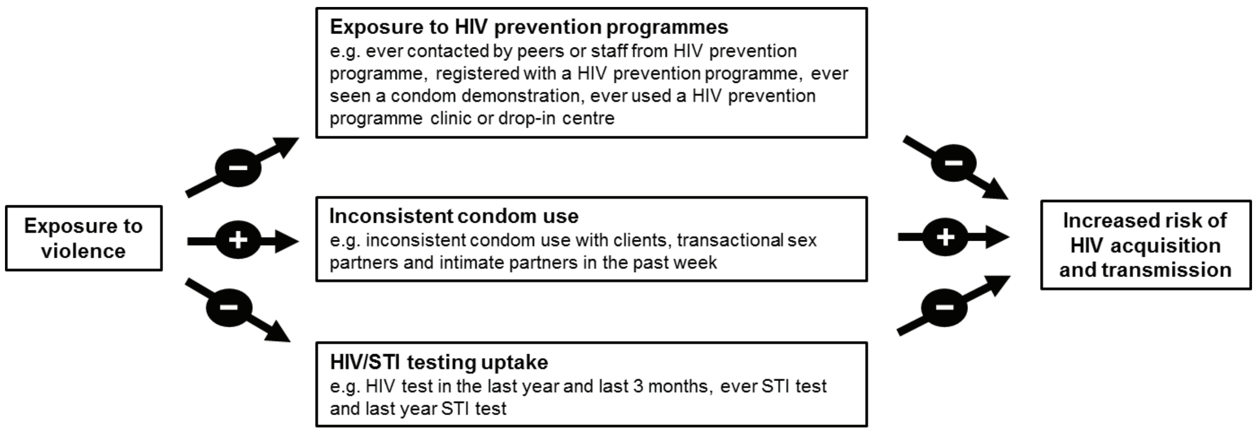


Figure 4.1. The hypothesised relationships between violence, exposure to HIV prevention programmes, inconsistent condom use (ICU), HIV/STI testing uptake, and HIV that I will investigate in this chapter. Associations between potential mediating factors (i.e. outcomes relating to HIV prevention programme exposure, ICU and HIV/STI testing) are not investigated in this chapter.

4.3 Methods

4.3.1 Study population

This chapter uses data from the YFSWs in the Transitions study (N=408). A full description of the Transitions study, which is a cross-sectional study of young women aged 14-24 years in Mombasa, Kenya, is provided in Chapter 3 (Section 3.3.1).

4.3.2 Study variables

4.3.2.1 Violence

Four violence exposure variables are examined, including three dichotomous (yes/no) variables: *lifetime sexual violence* (defined as ever being forced to have sex when not willing), *lifetime physical violence* (defined as ever being physically hurt by a sex partner), and *lifetime police assault or arrest* (defined as ever being physically assaulted or arrested by law enforcement during sex work), and one categorical variable which is the *number of different types of lifetime violence ever experienced* (0,1,2 or 3).

4.3.2.2 HIV prevention programme exposure, inconsistent condom use, and HIV/STI testing

Four dichotomous (yes/no) HIV prevention programme exposure outcomes are examined: *ever contacted by peers or staff from HIV prevention programmes*, *registered with a HIV prevention programme, ever seen a condom demonstration*, and *ever used a HIV prevention programme clinic or drop-in centre*. Four dichotomous (yes/no) outcomes measuring inconsistent condom use (defined as having any sexual intercourse without a condom in the past week) with different types of sexual partners were examined: *inconsistent condom use with regular clients* , *inconsistent condom use with new clients, inconsistent condom use with transactional sex partners*, and *inconsistent condom use with intimate partners*. Definitions for each type of sexual partner were presented in Chapter 3 (Section 3.3.2.2). Four dichotomous HIV and STI testing uptake outcomes (yes/no) were examined: *HIV tested in the past year*, *HIV tested in the past 3 months*, *ever STI tested*, and *STI tested in the past year*.

4.3.2.3 HIV status

The HIV infection outcome (HIV-positive or HIV-negative) was determined from dried blood spot (DBS) sampling in the biological component of the Transitions study. A fingerprick for DBS sampling was conducted and transferred to the ICRH-Kenya laboratory at the Coast Provincial General Hospital in Mombasa. DBS samples were then transferred to the National HIV and Retrovirology Laboratories in Winnipeg, Canada and were tested for HIV serology using the Avioq HIV-1 Microelisa System. A rapid HIV test was also done in the Transitions study, and this was supposed to be the primary test used to determine HIV status. However, the rapid HIV test was found to have a low sensitivity in the field, so the available DBS data were used in this analysis.

4.3.2.4 Sociodemographic and sex work characteristics

Sociodemographic and sex work variables examined as potential confounders to be included in multivariate analysis were *age* (14-20 years or 21-24 years), *ever married* (yes/no), *age at entry into sex work* (≤18 years or 19+ years), *duration in sex work* (0-2 years or 3+ years), *having a* *regular source of income* (yes/no), and *main place to solicit clients in the most recent month of sex work* (entertainment venue, street/bus stop, or other). Categorisation of age, age at entry into sex work, and duration in sex work was based on the median.

4.3.3 Data analysis

For objective 1, descriptive statistics were used to examine sociodemographic and sex work characteristics, violence experiences, HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection among the YFSWs in the sample.

For objective 2, to examine the associations between the four violence exposure variables and the twelve HIV prevention related outcomes described in Section 4.3.2.2 (i.e. related to HIV prevention programme exposure, inconsistent condom use, and HIV/STI testing uptake), bivariate and multivariate Poisson regression models with robust error variance were used to estimate unadjusted and adjusted prevalence ratios (PRs) with 95% confidence intervals (95% CIs). Multivariate models for each violence exposure variable and each HIV prevention related outcome were adjusted for age (a priori), and were also adjusted for sociodemographic and sex work variables associated with the violence exposure variable in bivariate analysis (chi-square tests) at $p<0.1$.

For objective 3, the associations between the four violence exposure variables and HIV infection were also examined using bivariate and multivariate Poisson regression models with robust error variance. Unadjusted and adjusted prevalence ratios (PRs) with 95% confidence intervals (95% CIs) are presented. Mediation analyses following the Baron and Kenny approach were also conducted to ascertain if HIV prevention related outcomes were mediators on the pathway between violence and HIV [20]. For this analysis, additional bivariate regression models were first run to examine associations between the twelve HIV prevention related outcomes and HIV infection. When, (1) a violence exposure was associated with both a HIV prevention related outcome (assessed in objective 2) and HIV infection (assessed in objective 3), and (2) that HIV prevention related outcome was also associated with HIV infection (assessed in objective 3), a final multivariate regression model was run to examine the association between the violence exposure and HIV infection, when adjusting for the HIV-prevention related outcome. For a full mediating effect, the violence exposure must no longer be associated with HIV when the HIV-prevention related outcome is adjusted for (while the HIV prevention related outcome should remain associated with HIV). For a partial mediating effect, the association between the violence exposure and HIV would be weakened (i.e. adjusted PR shifting closer to 1.0), but remain significant.

All analyses were conducted using STATA statistical software, version 12, taking into account the Transitions study survey design and within cluster-homogeneity using *svyset* commands. A complete case analysis was used for all analyses.

4.4 Results

4.4.1 Participant characteristics

Participant characteristics are described in Table 4.1. Sociodemographic and sex work characteristics and experiences of violence were reported previously in Chapter 3 (Section 3.4). In brief, the median age of YFSWs was 20 years, the median age at entry into sex work was 18 years, and the median number of years in sex work was 2 years. Almost half of YFSWs reported ever having experienced police assault or arrest (45.3%), and the lifetime prevalence of sexual violence and physical violence was 29.6% and 30.3%, respectively. Overall, 35% had not experienced any type of violence, 36.5% had experienced one type of violence, 17.5% had experienced 2 types of violence and 11.0% had experienced all three types of violence in their lifetime.

Very few participants reported ever being contacted by peers or staff from a HIV prevention programme (14.9%) and ever seeing a condom demonstration (11.9%). Similarly, less than ten percent of YFSWs were registered with a HIV prevention programme (9.2%) and had ever used a clinic or drop-in centre run by a HIV prevention programme (9.0%).

Inconsistent condom use with regular and new clients was reported by 24.5% and 20.0% of YFSWs, respectively. Similarly, a third of YFSWs reported inconsistent condom use with transactional sex partners (29.3%). A much higher proportion of YFSWs reported inconsistent condom use with intimate partners (71.5%).

The majority of YFSWs had ever been tested for HIV (92%), and a similarly high proportion had been tested for HIV in the past year (84.5%). Almost 60% had tested for HIV in the last 3 months (57.3%). A third reported ever having an STI test (34.9%), and a quarter had one in the past year (26.4%).

34 YFSWs in the sample were HIV-positive (9.8%). Of those that were HIV-positive, 7 self-reported a HIV positive status in the survey. Among these 7 YFSWs, 6 reported that they were currently on ART, of whom 4 reported 100% adherence to ART in the last week.

Table 4.1 Characteristics of YFSWs in Mombasa, Kenya

	%	n	N
Sociodemographic and sex work characteristics			
Current age, years			
14-20	58.1	237	408
21-24	41.9	171	408
Highest level of education completed			
None	30.2	123	407
Primary school	51.6	210	407
High school or higher	18.2	74	407
Ever married	6.6	27	408
Age at entry into sex work, years			
<=18	59.5	229	385
19+	40.5	156	385
Duration in sex work, years			
0-2	64.4	248	385
3+	35.6	137	385
Has a regular source of income	16.5	67	407
Main place/way met paying clients, in most recent month of sex work			
Entertainment venue	59.1	238	403
Street/bus stop	16.6	67	403
Other (e.g. hotel, home)	24.3	98	403
Violence experiences			
Lifetime sexual violence	29.6	119	402
Lifetime physical violence	30.3	123	406
Lifetime police assault or arrest	45.3	183	404
Lifetime number of types of violence experienced			
None	35.0	140	400
1 type	36.5	146	400
2 types	17.5	70	400
3 types	11.0	44	400
HIV prevention programme exposure			
Ever contacted by peers or staff from HIV prevention programmes	14.9	56	403
Registered with a HIV prevention programme	9.2	37	403
Ever seen a condom demonstration	11.9	48	402
Ever used a HIV prevention programme clinic or drop-in centre	9.0	36	402
Inconsistent condom use			
Inconsistent condom use with regular clients, last week	24.5	61	249
Inconsistent condom use with new clients, last week	20.0	40	200
Inconsistent condom use with transactional sex partners, last week	29.3	39	116
Inconsistent condom use with intimate partners, last week	71.5	98	137
HIV and STI testing uptake			
HIV test past 12 months	84.5	332	393
HIV test past 3 months	57.3	225	393
Ever STI tested	34.9	142	407
STI test past 12 months	26.4	105	398
HIV infection			
HIV-positive	9.8	34	346

4.4.2 Association between violence and HIV prevention related outcomes

4.4.2.1 HIV prevention programme exposure

There were no significant associations between any of the violence exposure variables and any of the HIV prevention programme exposure outcomes in both bivariate and multivariate analysis (Table 4.2).

4.4.2.2 Inconsistent condom use

Several of the violence exposures variables were associated with inconsistent condom use outcomes (Table 4.3). Inconsistent condom use with new clients was more likely to be reported by YFSWs who ever experienced sexual violence (adjusted PR: 1.9 [95%CI: 1.19-4.09]), and by YFSWs who reported 1 or 2 types of violence compared to those who reported no violence (adjusted PRs: 1.96 [95% CI: 1.03-4.76) and 2.93 [95% CI: 1.46-5.85], respectively). Inconsistent condom use with intimate partners was more likely to be reported by YFSWs who ever experienced physical violence (adjusted PR: 1.28 [95% CI: 1.09-1.49]), by YFSWs who ever experienced police assault or arrest (adjusted PR: 1.27 [95% CI: 1.01-1.60]), and by YFSWs who reported 3 types of violence compared to those who reported no violence (adjusted PR: 1.39 [95% CI: 1.01-1.90]). Inconsistent condom use with regular clients and inconsistent condom use with transactional sex partners were not associated with any of the violence exposures in bivariate or multivariate analysis, although in bivariate analysis there were borderline associations between inconsistent condom use with regular clients and lifetime sexual violence, and between inconsistent condom use with transactional sex partners and lifetime physical violence and the number of types of violence experienced.

4.4.2.3 HIV and STI testing

A number of the violence exposures variables were also associated with HIV testing uptake, while none were associated with STI testing uptake (Table 4.4). In multivariate analysis, HIV testing in the past 3 months was less likely to be reported by YFSWs who reported experiencing one type of violence and all three types of violence compared to those who reported no violence (adjusted PRs: 0.79 [95% CI: 0.66-0.96) and 0.56 [95% CI: 0.37-0.85], respectively), and was also borderline significantly associated with lifetime sexual violence, lifetime physical violence, and lifetime police assault or arrest (adjusted PRs: 0.82 [95% CI: 0.66-1.01], 0.84 [95% CI: 0.68-1.03], and 0.84 [95% CI: 0.68-1.04], respectively). In multivariate analysis, HIV testing in the past 12 months was borderline significantly associated with three violence exposure variables: lifetime sexual violence, lifetime police assault or arrest, and number of types of lifetime violence experienced.

Table 4.2 Associations between violence and HIV prevention programme exposure outcomes

	OUTCOMES				
	Ever contacted by peers or staff from HIV prevention programme				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	15.8	1.00 (reference)		1.00 (reference)	
Yes	10.1	0.64 (0.37-1.10)	0.107	0.63 (0.36-1.10)	0.107
Lifetime physical violence					
No	14.7	1.00 (reference)		1.00 (reference)	
Yes	12.2	0.83 (0.52-1.32)	0.433	0.82 (0.51-1.32)	0.409
Lifetime police assault or arrest					
No	10.9	1.00 (reference)		1.00 (reference)	
Yes	17.2	1.58 (0.93-2.69)	0.093	1.45 (0.87-2.43)	0.154
No. of types of violence experienced					
0	11.5	1.00 (reference)		1.00 (reference)	
1	17.5	1.52 (0.85-2.72)	0.158	1.57 (0.87-2.85)	0.133
2	12.9	1.12 (0.53-2.37)	0.772	0.92 (0.43-1.99)	0.841
3	11.4	0.99 (0.40-2.46)	0.978	0.98 (0.39-2.49)	0.970
	Registered with a HIV prevention programme				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	10.0	1.00 (reference)		1.00 (reference)	
Yes	7.6	0.75 (0.40-1.43)	0.383	0.74 (0.39-1.41)	0.358
Lifetime physical violence					
No	10.0	1.00 (reference)		1.00 (reference)	
Yes	7.3	0.73 (0.39-1.36)	0.321	0.70 (0.37-1.33)	0.274
Lifetime police assault or arrest					
No	6.9	1.00 (reference)		1.00 (reference)	
Yes	11.6	1.69 (0.88-4.27)	0.116	1.44 (0.76-2.74)	0.261
No. of types of violence experienced					
0	7.3	1.00 (reference)		1.00 (reference)	
1	11.1	1.53 (0.70-4.37)	0.286	1.49 (0.67-4.31)	0.332
2	10.0	1.38 (0.55-4.46)	0.490	1.04 (0.40-2.70)	0.938
3	6.8	0.94 (0.32-2.73)	0.910	0.87 (0.31-2.44)	0.794
	Ever seen a condom demonstration				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	14.3	1.00 (reference)		1.00 (reference)	
Yes	9.2	0.69 (0.39-1.23)	0.211	0.70 (0.39-1.24)	0.219
Lifetime physical violence					
No	12.5	1.00 (reference)		1.00 (reference)	
Yes	10.7	0.85 (0.51-1.41)	0.529	0.85 (0.51-1.42)	0.528
Lifetime police assault or arrest					
No	9.1	1.00 (reference)		1.00 (reference)	
Yes	15.6	1.70 (0.97-2.99)	0.064	1.43 (0.82-2.48)	0.207
No. of types of violence experienced					
0	8.7	1.00 (reference)		1.00 (reference)	
1	16.7	1.92 (0.93-4.93)	0.076	1.83 (0.87-4.85)	0.109
2	11.6	1.33 (0.60-2.96)	0.478	1.08 (0.48-2.45)	0.844
3	9.1	1.05 (0.40-2.71)	0.927	1.04 (0.40-2.70)	0.940
	Ever used a HIV prevention programme clinic or drop-in centre				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	9.4	1.00 (reference)		1.00 (reference)	
Yes	8.4	0.90 (0.49-1.64)	0.727	0.91 (0.49-1.67)	0.749
Lifetime physical violence					
No	9.7	1.00 (reference)		1.00 (reference)	
Yes	7.3	0.75 (0.40-1.41)	0.376	0.75 (0.40-1.43)	0.382
Lifetime police assault or arrest					
No	6.9	1.00 (reference)		1.00 (reference)	
Yes	11.1	1.62 (0.76-4.44)	0.206	1.32 (0.64-2.72)	0.450
No. of types of violence experienced					
0	6.5	1.00 (reference)		1.00 (reference)	
1	11.9	1.82 (0.84-4.96)	0.129	1.79 (0.80-4.97)	0.154
2	7.1	1.10 (0.37-4.21)	0.868	0.76 (0.23-2.46)	0.645
3	9.1	1.39 (0.49-4.98)	0.534	1.35 (0.49-4.75)	0.563

Note: Multivariate regression models were adjusted for age and regular income when lifetime sexual violence and lifetime physical violence were the exposure variables; for age, ever married and duration in sex work when lifetime physical assault or arrest was the exposure variable; and for age and age at entry into sex work when number of types of violence experienced was the exposure variable (see Section 4.3.3 for further details). PR, prevalence ratio; CI – confidence interval.

Table 4.3 Associations between violence and inconsistent condom use outcomes

	OUTCOMES				
	ICU with regular clients, last week				
	%	Crude PR (95% CI)	p-value	Adjusted PR (95% CI)	p-value
Lifetime sexual violence					
No	21.3	1.00 (reference)		1.00 (reference)	
Yes	32.4	1.53 (0.99-2.36)	0.057	1.40 (0.89-2.22)	0.148
Lifetime physical violence					
No	24.2	1.00 (reference)		1.00 (reference)	
Yes	27.6	1.20 (0.70-2.03)	0.510	1.08 (0.62-1.87)	0.783
Lifetime police assault or arrest					
No	24.6	1.00 (reference)		1.00 (reference)	
Yes	24.6	1.00 (0.66-1.50)	0.994	0.97 (0.62-1.52)	0.898
No. of types of violence experienced					
0	20.7	1.00 (reference)		1.00 (reference)	
1	25.9	1.25 (0.77-2.03)	0.364	1.32 (0.80-2.16)	0.271
2	25.0	1.21 (0.69-2.12)	0.506	1.14 (0.65-2.01)	0.636
3	32.3	1.56 (0.80-4.05)	0.193	1.68 (0.87-4.23)	0.122
	ICU with new clients, last week				
	%	Crude PR (95% CI)	p-value	Adjusted PR (95% CI)	p-value
Lifetime sexual violence					
No	15.2	1.00 (reference)		1.00 (reference)	
Yes	31.2	**2.05 (1.28-4.27)**	**0.003**	**1.92 (1.19-4.09)**	**0.008**
Lifetime physical violence					
No	18.0	1.00 (reference)		1.00 (reference)	
Yes	24.6	1.37 (0.84-2.22)	0.204	1.31 (0.82-2.10)	0.258
Lifetime police assault or arrest					
No	19.2	1.00 (reference)		1.00 (reference)	
Yes	21.1	1.09 (0.65-1.86)	0.736	1.13 (0.69-1.84)	0.627
No. of types of violence experienced					
0	11.9	1.00 (reference)		1.00 (reference)	
1	20.5	1.73 (0.86-4.46)	0.124	**1.96 (1.03-4.76)**	**0.042**
2	32.4	**2.73 (1.31-5.70)**	**0.008**	**2.93 (1.46-5.85)**	**0.003**
3	22.7	1.92 (0.74-5.70)	0.180	1.96 (0.74-5.18)	0.176
	ICU with transactional sex partners, last week				
	%	Crude PR (95% CI)	p-value	Adjusted PR (95% CI)	p-value
Lifetime sexual violence					
No	26.8	1.00 (reference)		1.00 (reference)	
Yes	35.3	1.32 (0.72-2.39)	0.367	1.26 (0.67-2.36)	0.471
Lifetime physical violence					
No	24.7	1.00 (reference)		1.00 (reference)	
Yes	40.0	1.69 (0.96-2.98)	0.070	1.51 (0.82-2.77)	0.184
Lifetime police assault or arrest					
No	28.6	1.00 (reference)		1.00 (reference)	
Yes	30.4	1.07 (0.58-1.94)	0.836	1.16 (0.63-2.15)	0.628
No. of types of violence experienced					
0	22.7	1.00 (reference)		1.00 (reference)	
1	27.8	1.22 (0.62-2.41)	0.560	1.47 (0.71-4.04)	0.304
2	41.7	1.83 (0.92-4.66)	0.085	1.83 (0.94-4.57)	0.076
3	34.3	1.47 (0.50-4.32)	0.485	1.59 (0.55-4.59)	0.392
	ICU with intimate partners, last week				
	%	Crude PR (95% CI)	p-value	Adjusted PR (95% CI)	p-value
Lifetime sexual violence					
No	70.7	1.00 (reference)		1.00 (reference)	
Yes	72.1	1.02 (0.83-1.25)	0.845	1.03 (0.84-1.26)	0.791
Lifetime physical violence					
No	66.7	1.00 (reference)		1.00 (reference)	
Yes	85.7	**1.29 (1.10-1.51)**	**0.002**	**1.28 (1.09-1.49)**	**0.003**
Lifetime police assault or arrest					
No	64.3	1.00 (reference)		1.00 (reference)	
Yes	78.8	1.23 (0.98-1.54)	0.077	**1.27 (1.01-1.60)**	**0.041**
No. of types of violence experienced					
0	62.2	1.00 (reference)		1.00 (reference)	
1	70.6	1.13 (0.86-1.50)	0.374	1.13 (0.85-1.51)	0.397
2	80.0	1.29 (0.97-1.70)	0.078	1.30 (0.98-1.72)	0.067
3	84.6	1.36 (0.98-1.89)	0.065	**1.39 (1.01-1.90)**	**0.041**

Note: Multivariate regression models were adjusted for age and regular income when lifetime sexual violence and lifetime physical violence were the exposure variables; for age, ever married and duration in sex work when lifetime physical assault or arrest was the exposure variable; and for age and age at entry into sex work when number of types of violence experienced was the exposure variable (see Section 4.3.3 for further details). PR, prevalence ratio; CI – confidence interval; ICU, inconsistent condom use.

Table 4.4 Associations between violence and HIV/STI testing uptake outcomes

	OUTCOMES				
	HIV test past 12 months				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	86.8	1.00 (reference)		1.00 (reference)	
Yes	79.3	0.91 (0.82-1.02)	0.097	0.91 (0.82-1.01)	0.082
Lifetime physical violence					
No	86.4	1.00 (reference)		1.00 (reference)	
Yes	80.0	0.93 (0.84-1.02)	0.115	0.92 (0.83-1.01)	0.093
Lifetime police assault or arrest					
No	84.5	1.00 (reference)		1.00 (reference)	
Yes	84.8	1.00 (0.90-1.11)	0.957	0.98 (0.89-1.08)	0.701
No. of types of violence experienced					
0	86.7	1.00 (reference)		1.00 (reference)	
1	85.0	0.98 (0.89-1.09)	0.710	0.91 (0.82-1.01)	0.082
2	85.1	0.98 (0.87-1.11)	0.762	0.92 (0.83-1.01)	0.093
3	77.3	0.89 (0.75-1.06)	0.196	0.98 (0.89-1.08)	0.701
	HIV test past 3 months				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	60.7	1.00 (reference)		1.00 (reference)	
Yes	49.1	**0.81 (0.66-1.00)**	**0.046**	0.82 (0.66-1.01)	0.062
Lifetime physical violence					
No	60.3	1.00 (reference)		1.00 (reference)	
Yes	50.0	0.83 (0.68-1.01)	0.069	0.84 (0.68-1.03)	0.088
Lifetime police assault or arrest					
No	61.5	1.00 (reference)		1.00 (reference)	
Yes	52.0	0.85 (0.69-1.04)	0.112	0.84 (0.68-1.04)	0.103
No. of types of violence experienced					
0	65.2	1.00 (reference)		1.00 (reference)	
1	54.6	**0.82 (0.68-0.99)**	**0.039**	**0.79 (0.66-0.96)**	**0.018**
2	62.7	0.96 (0.78-1.19)	0.717	0.94 (0.76-1.17)	0.565
3	36.4	**0.56 (0.37-0.84)**	**0.006**	**0.56 (0.37-0.85)**	**0.007**
	Ever STI tested				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	35.0	1.00 (reference)		1.00 (reference)	
Yes	35.3	1.01 (0.75-1.35)	0.952	1.01 (0.76-1.35)	0.922
Lifetime physical violence					
No	34.3	1.00 (reference)		1.00 (reference)	
Yes	36.6	1.07 (0.80-1.42)	0.655	1.07 (0.81-1.40)	0.629
Lifetime police assault or arrest					
No	32.6	1.00 (reference)		1.00 (reference)	
Yes	37.7	1.16 (0.83-1.60)	0.379	1.16 (0.83-1.62)	0.376
No. of types of violence experienced					
0	31.4	1.00 (reference)		1.00 (reference)	
1	37.7	1.20 (0.85-1.69)	0.298	1.23 (0.85-1.78)	0.262
2	34.3	1.09 (0.72-1.65)	0.677	1.12 (0.72-1.72)	0.617
3	38.6	1.23 (0.74-2.04)	0.421	1.26 (0.74-2.17)	0.393
	STI test past 12 months				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	26.4	1.00 (reference)		1.00 (reference)	
Yes	26.7	1.01 (0.71-1.44)	0.937	1.01 (0.71-1.43)	0.968
Lifetime physical violence					
No	26.1	1.00 (reference)		1.00 (reference)	
Yes	27.3	1.05 (0.74-1.48)	0.799	1.02 (0.73-1.43)	0.893
Lifetime police assault or arrest					
No	25.6	1.00 (reference)		1.00 (reference)	
Yes	27.2	1.06 (0.76-1.49)	0.717	1.11 (0.76-1.61)	0.589
No. of types of violence experienced					
0	25.7	1.00 (reference)		1.00 (reference)	
1	27.1	1.05 (0.68-1.62)	0.816	1.06 (0.66-1.69)	0.806
2	22.4	0.87 (0.54-1.40)	0.567	0.90 (0.54-1.52)	0.696
3	31.8	1.24 (0.74-2.06)	0.415	1.27 (0.75-2.16)	0.377

Note: Multivariate regression models were adjusted for age and regular income when lifetime sexual violence and lifetime physical violence were the exposure variables; for age, ever married and duration in sex work when lifetime physical assault or arrest was the exposure variable; and for age and age at entry into sex work when number of types of violence experienced was the exposure variable (see Section 4.3.3 for further details). PR, prevalence ratio; CI – confidence interval.

4.4.3 Association between violence and HIV infection and mediating factors

YFSWs who reported ever experiencing physical violence, and who reported experiencing all three types of violence compared to no types of violence, were more likely to be HIV positive (adjusted PRs: 1.89 [95% CI: 1.15-4.10] and 2.65 [95% CI: 1.19-5.90], respectively) (Table 4.5). There were no significant associations between sexual violence and HIV infection, and police assault or arrest and HIV infection.

YFSWs who tested for HIV in the last year and who tested for HIV in the last 3 months were less likely to be HIV positive (unadjusted PRs: 0.44 [95% CI: 0.22-0.88] and 0.40 [95% CI: 0.20-0.77]) (Table 4.6). None of the other HIV prevention related outcomes were significantly associated with HIV infection.

HIV testing in the past 3 months was found to fully mediate the relationship between the number of types of violence experienced and HIV infection. When HIV testing in the last 3 months was included in this final multivariate model, there was no longer a significant association between experiencing 3 types of violence and HIV infection (adjusted PR: 1.80 [95% CI: 0.80-4.08], p-value=0.155), while the association between HIV testing in the last 3 months and HIV infection remained significant (adjusted PR: 0.36 [95% CI: 0.18-0.74]).

Table 4.5 Associations between violence and HIV infection

	HIV POSITIVE				
	%	**Crude PR (95% CI)**	**p-value**	**Adjusted PR (95% CI)**	**p-value**
Lifetime sexual violence					
No	8.3	1.00 (reference)		1.00 (reference)	
Yes	12.9	1.56 (0.89-2.72)	0.119	1.44 (0.81-2.56)	0.208
Lifetime physical violence					
No	7.5	1.00 (reference)		1.00 (reference)	
Yes	15.2	**2.04 (1.27-4.27)**	**0.003**	**1.89 (1.15-4.10)**	**0.013**
Lifetime police assault or arrest					
No	7.6	1.00 (reference)		1.00 (reference)	
Yes	12.2	1.61 (0.81-4.20)	0.176	1.61 (0.80-4.21)	0.178
No. of types of violence experienced					
0	9.5	1.00 (reference)		1.00 (reference)	
1	5.0	0.53 (0.19-1.49)	0.230	0.64 (0.24-1.71)	0.374
2	8.8	0.93 (0.39-2.19)	0.864	0.88 (0.33-2.32)	0.790
3	24.7	**2.51 (1.11-5.64)**	**0.027**	**2.65 (1.19-5.90)**	**0.017**

Note: Multivariate regression models were adjusted for age and regular income when lifetime sexual violence and lifetime physical violence were the exposure variables; for age, ever married and duration in sex work when lifetime physical assault or arrest was the exposure variable; and for age and age at entry into sex work when number of types of violence experienced was the exposure variable (see Section 4.3.3 for further details). PR, prevalence ratio; CI – confidence interval.

Table 4.6 Bivariate associations between potential mediators and HIV infection

	HIV POSITIVE		
POTENTIAL MEDIATORS	**%**	**Crude PR (95% CI)**	**p-value**
HIV prevention programme exposure			
Ever contacted by peers or staff from HIV prevention programmes			
No	9.8	1.00 (reference)	
Yes	10.6	1.09 (0.48-2.45)	0.835
Registered with a HIV prevention programme			
No	10.2	1.00 (reference)	
Yes	6.7	0.65 (0.18-2.32)	0.508
Ever seen a condom demonstration			
No	9.9	1.00 (reference)	
Yes	10.3	1.04 (0.41-2.63)	0.941
Ever used a HIV prevention programme clinic or drop-in centre			
No	9.6	1.00 (reference)	
Yes	14.3	1.39 (0.59-4.28)	0.449
Inconsistent condom use			
Inconsistent condom use with regular clients, last week			
No	11.0	1.00 (reference)	
Yes	12.5	1.13 (0.53-2.42)	0.749
Inconsistent condom use with new clients, last week			
No	7.8	1.00 (reference)	
Yes	5.9	0.75 (0.18-4.11)	0.695
Inconsistent condom use with transactional sex partners, last week			
No	4.7	1.00 (reference)	
Yes	4.0	0.65 (0.07-5.86)	0.697
Inconsistent condom use with intimate partners, last week			
No		1.00 (reference)	
Yes	7.1	0.98 (0.28-4.42)	0.970
HIV and STI testing uptake	7.0		
HIV test past 12 months			
No	19.2	1.00 (reference)	
Yes	8.4	**0.44 (0.22-0.88)**	**0.020**
HIV test past 3 months			
No	15.6	1.00 (reference)	
Yes	6.2	**0.40 (0.20-0.77)**	**0.007**
Ever STI tested			
No	8.7	1.00 (reference)	
Yes	12.0	1.37 (0.78-2.41)	0.274
STI test past 12 months			
No	8.0	1.00 (reference)	
Yes	12.1	1.50 (0.83-2.72)	0.175

PR, prevalence ratio; CI – confidence interval.

4.5 Discussion

In this chapter, I examined associations between three types of violence (sexual violence, physical violence and police assault/arrest) and HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection among YFSWs in Mombasa, Kenya.

4.5.1 Summary of key results

Figure 4.2 updates Figure 4.1 to summarise the general trends of associations that I found evidence for in this chapter, which will be discussed in further detail below.

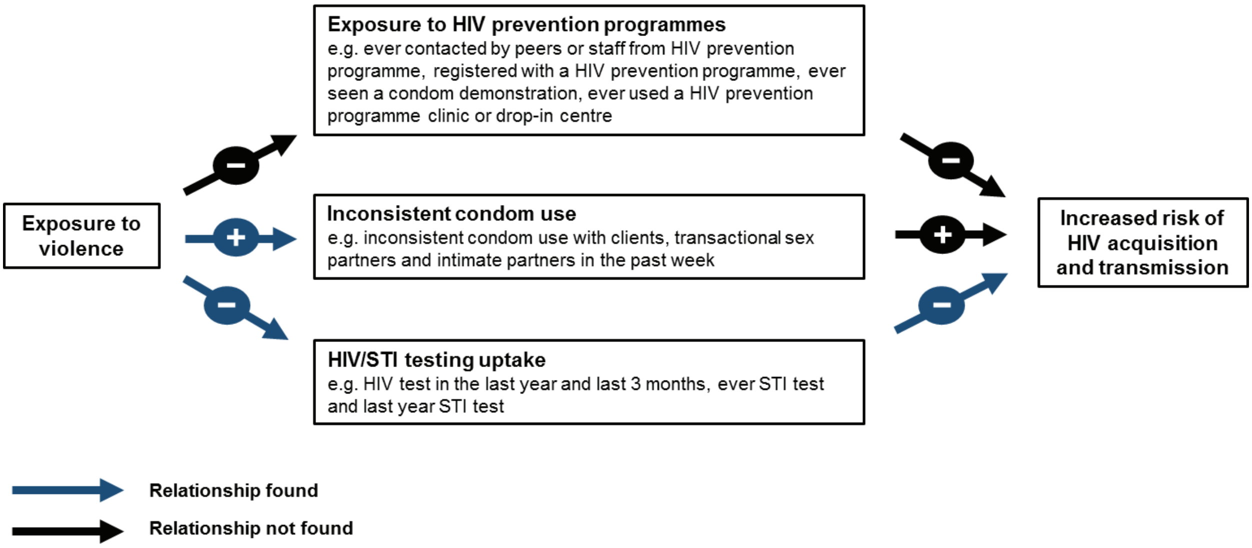


Figure 4.2. The relationships found between violence, exposure to HIV prevention programmes, inconsistent condom use (ICU), HIV/STI testing uptake and HIV.

I found that all three types of violence were associated with a higher prevalence of inconsistent condom use. YFSWs who had ever experienced sexual violence, physical violence or police assault or arrest were between 1.3 and 1.9 times more likely to inconsistently use condoms with new clients or intimate partners compared to those that had not experienced violence. The association between sexual and physical violence and inconsistent condom use with clients and intimate partners is consistent with other studies that have found higher rates of sexual and physical violence among FSWs to be associated with reduced condom use with these types of sexual partners [2,4,6,12,16,21-30]. Interestingly, police assault or arrest was not associated with inconsistent condom use with clients, but was associated with inconsistent condom use with intimate partners. Previous studies have found associations between police violence and policing strategies and condom use with clients, but none to date have reported an association between police assault or arrest and inconsistent condom use with intimate partners [31]. This finding suggests that experiences of police assault and/or arrest may be having a negative impact on

FSWs intimate partnerships, and FSWs ability to use condoms in these partnerships. Further research and qualitative studies are needed to better understand this relationship and how police interactions with YFSWs effect intimate partner relationships and vice versa. I also found a positive relationship between the number of different types of violence experienced and inconsistent condom use with new clients and intimate partners. YFSWs who had experienced two or three types of violence in their lifetime had the highest rates of inconsistent condom use with new clients or intimate partners and were between 1.3 and 4.0 times more likely to inconsistently use condoms with these types of sexual partners compared to those that reported no experiences of violence. Similar trends have been found in other studies that have looked at the association between the number of types of violence experienced by sex workers and frequency of inconsistent condom use or condom breakage [27,29,32]. This results suggests that there is an amplification of HIV risk among YFSWs exposed to multiple types of violence, and highlights the need to concurrently address multiple types of violence to reduce HIV risk among YFSWs.

In the analysis, I also found that violence was associated with reduced HIV testing uptake. YFSWs who experienced all three types of violence were 40% less likely to have HIV tested in the past 3 months compared to those that had not experienced any violence. This association could be due to violence having a negative impact on YFSWs psychological well-being and mental health, which may reduce their motivation or ability to access health services including HIV testing [3,33-37]. Although there were no other significant associations between violence and HIV testing uptake in multivariate analysis, there were a number of borderline associations between violence and HIV testing in the past year, which all had the same direction of association indicating that FSWs experiencing violence had lower uptake of HIV testing. Another study in China also found violence to be associated with reduced uptake of HIV testing among FSWs [37]. These findings would suggest that violence may be an important barrier to achieving the first of the UNAIDS 90-90-90 targets (i.e. 90% of HIV positive people to know their HIV status by 2020), and given that HIV testing is the main entry point to HIV treatment and care, this would also suggest that violence could have a negative impact on scaling up ART among FSWs [38]. Reduced HIV testing uptake due to violence could also result in reduced access to other primary HIV prevention programmes and services for those who are HIV-negative, as HIV testing is an important gateway to these types of programmes and services [38].

Similar to other studies, violence was found to be significantly associated with being HIV positive [2,6,23,28,29,39-41]. The risk of HIV infection was 1.9 and 2.9 fold higher for YFSWs who had ever experienced physical violence compared to those that had not and for YFSWs who had experienced all three types of violence compared to those that had experienced none, respectively. Mediation analysis was conducted to explore the pathways linking violence and HIV infection. Of the HIV programme exposure, inconsistent condom use and HIV/STI testing uptake variables examined as potential mediators, only HIV testing in the last 12 months and HIV testing in the last 3 months were associated with HIV infection. YFSWs that had tested for HIV in the past year or 3 months were about 60% less likely to be HIV positive. Another recent study in a Ugandan population of FSWs found a similar result, where FSWs who had never HIV tested were more likely to be HIV positive [42]. Although HIV testing itself cannot directly reduce HIV infection, YFSWs who engage in HIV testing may be more likely to engage in other health services, be more aware of HIV and HIV prevention, and engage in safer sexual practices, which reduces their risk of HIV infection. According to the findings, HIV testing uptake fully mediated the association between the number of types of violence experienced and HIV infection. This finding suggests that linking YFSWs who have experienced violence to HIV testing services could be an important step towards increasing awareness of HIV prevention and reducing HIV risk. No other pathways were assessed in mediation analysis due to lack of significant associations between violence exposures, potential mediators and HIV infection. Reduced condom use is a likely mediator between violence and HIV infection among FSWs [3]. However in this analysis, inconsistent condom use, which was associated with violence, was not associated with HIV infection. This could be due to a number of factors, including the small sample size when considering condom use by partner type, the small number of HIV positive YFSWs in the sample, the short time-period of the condom use measure (measured over the week preceding the survey), and biases related to reporting of inconsistent condom use (e.g. social desirability bias). Further study is needed to understand the pathways linking violence and HIV risk among YFSWs in Mombasa.

4.5.2 Implications

Taken together, the associations between experience of violence, increased inconsistent condom use, reduced uptake of HIV testing and HIV infection, highlight the importance of addressing and preventing violence in the HIV response for YFSWs in Kenya. Interventions to reduce and prevent violence against YFSWs could help to reduce HIV transmission. For example, a recent modelling study suggested that elimination of sexual violence against FSWs in Kenya could avert 17% of HIV infections among FSWs and their clients over the next 10 years through the immediate and sustained effect on non-condom use [2]. In the next chapter, I will also examine the impact of violence interventions on HIV transmission among FSWs and their clients in Mombasa, Kenya. As discussed in the previous chapter, interventions to reduce violence against YFSWs could include community empowerment, as well as sensitisation and education of the police force.

For YFSWs who have experienced violence, it is essential that they are linked to both violence prevention and response services, and to HIV/STI testing and prevention services. The findings indicate that YFSWs who experience multiple different types of violence have a higher risk of reduced condom use and HIV testing and are more likely to be HIV positive, which suggests that there is also a need to ensure and prioritise linkage of particularly vulnerable YFSWs who experience multiple types of violence to violence and HIV prevention and response services.

Although there were no associations between violence and HIV prevention programme exposure in this analysis, the findings did highlight a particularly concerning gap in access to HIV prevention programmes among the YFSWs in Mombasa, with very few YFSWs reporting having ever been contacted by peers or staff from HIV prevention programmes, being registered with HIV prevention programme, ever seeing a condom demonstration and ever using a HIV prevention programme clinic or drop-in centre. Uptake of STI testing among the YFSWs in the study was also very low. Further research is needed to understand the low access to HIV prevention programme and low uptake of STI testing, so that strategies can be implemented to reach and link YFSWs to HIV prevention programmes. Conversely, there was high uptake of HIV testing among YFSWs, which is encouraging in light of the first 90-90-90 goal (i.e. 90% of HIV positive people to know their HIV status by 2020) [43], although regular testing every 3 months, which is the national guideline in Kenya, is lower than was reported among FSWs in a recent national survey of key populations in Kenya [44]. Reduced uptake of regular HIV testing was also associated with a higher HIV prevalence in this analysis, so it is important that HIV prevention programmes expand and encourage regular HIV testing among YFSWs, although, given the cross-sectional nature of the study, it could also be that YFSWs who are HIV positive are less likely to be HIV tested. If this is the case, this would be an important issue for HIV prevention programmes trying to scale up HIV testing and linkage to treatment for HIV-infected FSWs, and would have important implications for the success of TasP. Similar to other studies, inconsistent condom use among the YFSWs was much higher with their intimate partners than with their clients [4,15,25,44-50], so strategies to address the low condom use within the intimate partnerships of YFSWs should be investigated.

4.5.3 Limitations and strengths

The findings from this analysis should be viewed within the context of several limitations. First, as the study is cross-sectional it is not possible to ascertain the causality and directions of associations between violence and condom use, violence and HIV testing uptake and violence and HIV infection. Further research using longitudinal data is needed to better understand the associations and pathways between violence and HIV infection among young sex workers in Kenya. Second, the smaller sample size when considering inconsistent condom use by type of sexual partner limited the statistical power of these analyses and may be partially responsible for a lack of significant findings concerning condom use and HIV infection and the borderline associations between violence and some of the inconsistent condom use measures examined. As previously discussed in Chapter 3, the data are all self-reported (with the exception of the biological HIV outcome), so the results may be affected by social-desirability bias, and there may have been underreporting of sensitive topics, such as violence, or over-reporting of other topics, such as condom use. In addition, the survey did not differentiate experiences of physical and sexual violence by type of perpetrator. Finally, the Transitions study focussed exclusively on young women aged between 14 and 24 years, so the results may not be generalizable to older FSWs. Despite these limitations, to the best of my knowledge this is one of the first studies to examine the associations between violence, HIV prevention, and HIV infection among FSWs in Kenya, and is the first in Kenya to exclusively focus on YFSWs, and to assess the potential pathways between violence and HIV infection.

4.5.4 Conclusions

In conclusion, the findings from this analysis provide evidence to suggest that different types of violence are associated with increased risk of inconsistent condom use, reduced uptake of HIV testing and being HIV positive among YFSWs in Mombasa, Kenya. This suggests that violence may be undermining existing HIV prevention efforts in Kenya. To protect the human rights and health of YFSWs in Kenya it will be crucial to address and prevent violence, and preventing violence against YFSWs could help to reduce HIV transmission. HIV prevention programmes should incorporate strategies and interventions that specifically target violence against YFSWs.

4.6 References

1. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
2. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
3. Dunkle KL, Decker MR. Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups. Am J Reprod Immunol. 2013 Feb;69:20-6
4. Beattie TSH, Bhattacharjee P, Ramesh BM, et al. Violence against female sex workers in Karnataka state, south India: impact on health, and reductions in violence following an intervention program. BMC Public Health. 2010 Aug 11;10
5. Berger BO, Grosso A, Adams D, et al. The Prevalence and Correlates of Physical and Sexual Violence Affecting Female Sex Workers in Swaziland. J Interpers Violence. 2016 Feb 12;12:12
6. Decker MR, Lyons C, Billong SC, et al. Gender-based violence against female sex workers in Cameroon: prevalence and associations with sexual HIV risk and access to health services and justice. Sex Transm Infect. 2016 Jun 8;8:8
7. Goldenberg SM, Deering K, Amram O, et al. Community mapping of sex work criminalization and violence: impacts on HIV treatment interruptions among marginalized women living with HIV in Vancouver, Canada. Int J STD AIDS. 2017 01 Sep;28(10):1001-9
8. Goldenberg SM, Montaner J, Duff P, et al. Structural Barriers to Antiretroviral Therapy Among Sex Workers Living with HIV: Findings of a Longitudinal Study in Vancouver, Canada. Aids Behav. 2016 May;20(5):977-86
9. Lyons CE, Grosso A, Drame FM, et al. Physical and sexual violence affecting female sex workers in Abidjan, cote d'ivoire: Prevalence, and the relationship with the work environment, HIV, and access to health services. J Acquir Immune Defic Syndr. 2017;75(1):9-17
10. Mendoza C, Barrington C, Donastorg Y, et al. Violence from a sexual partner is significantly associated with poor HIV care and treatment outcomes among female sex workers in the Dominican Republic. J Acquir Immune Defic Syndr. 2017 01 Mar;74(3):273-8
11. Sherwood JA, Grosso A, Decker MR, et al. Sexual violence against female sex workers in The Gambia: a cross-sectional examination of the associations between victimization and reproductive, sexual and mental health. BMC Public Health. 2015;15:270
12. Zhang C, Li X, Hong Y, Chen Y, Liu W, Zhou Y. Partner violence and HIV risk among female sex workers in China. Aids Behav. 2012 May;16(4):1020-30
13. National AIDS & STI Control Programme. National Guidelines For HIV/STI Programming With Key Populations. 2014.
14. NACC. Kenya AIDS Response Progress Report 2016.
15. Luchters S, Richter ML, Bosire W, et al. The Contribution of Emotional Partners to Sexual Risk Taking and Violence among Female Sex Workers in Mombasa, Kenya: A Cohort Study. PLoS ONE. 2013 07 Aug;8(8)
16. Wilson KS, Deya R, Yuhas K, et al. A Prospective Cohort Study of Intimate Partner Violence and Unprotected Sex in HIV-Positive Female Sex Workers in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2054-64
17. Baggaley R, Armstrong A, Dodd Z, Ngoksin E, Krug A. Young key populations and HIV: A special emphasis and consideration in the new WHO Consolidated Guidelines on HIV Prevention, Diagnosis, Treatment and Care for Key Populations. Journal of the International AIDS Society. 2015;18(2 Supplement 1):85-8
18. FHI. Young People Most at Risk of HIV: A Meeting Report and Discussion Paper from the Interagency Youth Working Group, U.S. Agency for International Development, the Joint

United Nations Programme on HIV/AIDS (UNAIDS) Inter-Agency Task Team on HIV and Young People, and FHI. 2010.
19. WHO. HIV and young people who sell sex: A technical brief. 2014.
20. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of personality and social psychology. 1986 Dec;51(6):1173-82
21. Beattie TS, Isac S, Bhattacharjee P, et al. Reducing violence and increasing condom use in the intimate partnerships of female sex workers: study protocol for Samvedana Plus, a cluster randomised controlled trial in Karnataka state, south India. BMC public health. 2016 29 Jul;16:660
22. Deering KN, Bhattacharjee P, Mohan HL, et al. Violence and HIV Risk Among Female Sex Workers in Southern India. Sex Transm Dis. 2013 Feb;40(2):168-74
23. Iakunchykova OP, Burlaka V. Correlates of HIV and Inconsistent Condom Use Among Female Sex Workers in Ukraine. Aids Behav. 2017 Aug;21(8):2306-15
24. Lang DL, Salazar LF, DiClemente RJ, Markosyan K. Gender based violence as a risk factor for HIV-associated risk behaviors among female sex workers in Armenia. Aids Behav. 2013 Feb;17(2):551-8
25. Mooney A, Kidanu A, Bradley HM, Kumoji EK, Kennedy CE, Kerrigan D. Work-related violence and inconsistent condom use with non-paying partners among female sex workers in Adama City, Ethiopia. BMC Public Health. 2013 Aug 23;13:771
26. Moret W. Economic Strengthening for Female Sex Workers: A Review of the Literature. ASPIRES, FHI 360: 2014.
27. Pando MA, Coloccini RS, Reynaga E, et al. Violence as a Barrier for HIV Prevention among Female Sex Workers in Argentina. Plos One. 2013 Jan 16;8(1)
28. Ramesh S, Ganju D, Mahapatra B, Mishra RM, Saggurti N. Relationship between mobility, violence and HIV/STI among female sex workers in Andhra Pradesh, India. Bmc Public Health. 2012 Sep 11;12
29. Tounkara FK, Diabate S, Guedou FA, et al. Violence, condom breakage, and HIV infection among female sex workers in Benin, West Africa. Sex Transm Dis. 2014 2014-May;41(5):312-8
30. Wirtz AL, Schwartz S, Ketende S, et al. Sexual violence, condom negotiation, and condom use in the context of sex work: results from two West African countries. Journal of acquired immune deficiency syndromes (1999). 2015 01 Mar;68:S171-S9
31. Footer KH, Silberzahn BE, Tormohlen KN, Sherman SG. Policing practices as a structural determinant for HIV among sex workers: a systematic review of empirical findings. J Int AIDS Soc. 2016;19(4 Suppl 3):20883
32. Erausquin JT, Reed E, Blankenship KM. Change over Time in Police Interactions and HIV Risk Behavior Among Female Sex Workers in Andhra Pradesh, India. Aids Behav. 2015 Jun;19(6):1108-15
33. Hong Y, Zhang C, Li X, Liu W, Zhou Y. Partner Violence and Psychosocial Distress among Female Sex Workers in China. Plos One. 2013 Apr 23;8(4)
34. Patel SK, Ganju D, Prabhakar P, Adhikary R. Relationship between mobility, violence and major depression among female sex workers: a cross-sectional study in southern India. BMJ open. 2016;6(9):e011439
35. Sagtani RA, Bhattarai S, Adhikari BR, Baral D, Yadav DK, Pokharel PK. Violence, HIV risk behaviour and depression among female sex workers of eastern Nepal. BMJ open. 2013;3(6):1-6
36. Yuen WWY, Tran L, Wong CKH, Holroyd E, Tang CSK, Wong WCW. Psychological health and HIV transmission among female sex workers: a systematic review and meta-analysis. AIDS Care. 2016 02 Jul;28(7):816-24
37. Zhang L, Li X, Wang B, et al. Violence, stigma and mental health among female sex workers in China: A structural equation modeling. Women Health. 2017 Jul;57(6):685-704

38. WHO. Consolidated guidelines on HIV prevention, diagnosis, treatment and care for key populations. WHO, Geneva, Switzerland: 2014.
39. Beattie TS, Bhattacharjee P, Isac S, et al. Declines in violence and police arrest among female sex workers in Karnataka state, south India, following a comprehensive HIV prevention programme. Journal of the International AIDS Society. 2015 16 Oct;18 (1) (no pagination)(20079)
40. Decker MR, Wirtz AL, Baral SD, et al. Injection drug use, sexual risk, violence and STI/HIV among Moscow female sex workers. Sex Transm Infect. 2012 Jun;88(4):278-83
41. Ulibarri MD, Strathdee SA, Ulloa EC, et al. Injection Drug Use as a Mediator Between Client-perpetrated Abuse and HIV Status Among Female Sex Workers in Two Mexico-US Border Cities. Aids Behav. 2011 Jan;15(1):179-85
42. Hladik W, Baughman AL, Serwadda D, et al. Burden and characteristics of HIV infection among female sex workers in Kampala, Uganda - a respondent-driven sampling survey. BMC Public Health. 2017 Jun 10;17(1):565
43. UNAIDS. 90-90-90 An ambitious treatment target to help end the AIDS epidemic. 2014.
44. Bhattacharjee P, McClarty LM, Musyoki H, et al. Monitoring HIV Prevention Programme Outcomes among Key Populations in Kenya: Findings from a National Survey. PLoS ONE [Electronic Resource]. 2015;10(8):e0137007
45. Deering KN, Lyons T, Feng CX, et al. Client demands for unsafe sex: The socioeconomic risk environment for HIV among street and off-street sex workers. J Acquir Immune Defic Syndr. 2013 August 1;63(4):522-31
46. Kayembe PK, Mapatano MA, Busangu AF, et al. Determinants of consistent condom use among female commercial sex workers in the Democratic Republic of Congo: implications for interventions. Sex Transm Infect. 2008 Jun;84(3):202-6
47. Luchters S, Chersich MF, Rinyiru A, et al. Impact of five years of peer-mediated interventions on sexual behavior and sexually transmitted infections among female sex workers in Mombasa, Kenya. BMC Public Health. 2008;8 (no pagination)(143)
48. Thomsen SC, Ombidi W, Toroitich-Ruto C, et al. A prospective study assessing the effects of introducing the female condom in a sex worker population in Mombasa, Kenya. Sex Transm Infect. 2006 October;82(5):397-402
49. Tucker JD, Peng H, Wang K, et al. Female sex worker social networks and STI/HIV prevention in South China. PLoS ONE. 2011 13 Sep;6(9)
50. Voeten HACM, Egesah OB, Varkevisser CM, Habbema JDF. Female sex workers and unsafe sex in urban and rural Nyanza, Kenya: Regular partners may contribute more to HIV transmission than clients. Tropical Medicine and International Health. 2007 February;12(2):174-82

Chapter 5: Modelling the potential impact of violence against FSWs and violence prevention on HIV transmission among FSWs and their clients in Mombasa, Kenya

5.1 Overview

In the previous two chapters I analysed data to examine the burden and determinants of violence among YFSWs in Mombasa, Kenya, and determine if these experiences of violence were associated with HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection. In this chapter, I utilise the findings from these prior data analyses, to develop, parameterise and calibrate a dynamic model of violence against FSWs and HIV transmission among FSWs and their clients in Mombasa, Kenya. I then use this model to explore the potential contribution of violence against FSWs to HIV transmission and the potential impact of violence prevention on HIV transmission among FSWs and their clients. Dr Marissa Becker (University of Manitoba) and Dr Sharmistha Mishra (University of Toronto) shared the Transitions study data which was utilised in this chapter.

5.2 Background and rationale

Although violence is recognised as an important structural risk factor for HIV among FSWs, there have been limited studies assessing the contribution of violence to HIV transmission at a population-level or evaluating the potential impact of violence prevention on HIV transmission at a population-level. In Kenya, FSWs have both a high HIV prevalence and a heavy burden of violence [1], so understanding the contribution of violence against FSWs to HIV transmission and the potential impact of violence prevention on reducing HIV transmission, will be critical to help guide HIV prevention efforts for FSWs in Kenya.

As previously described in Chapter 1, one recent modelling study examined the population-level impact of structural changes, including violence prevention, on HIV transmission among FSWs and their clients in three different setting with diverse HIV epidemics [2]. One of the settings modelled was Mombasa, Kenya, and the study found that eliminating client sexual violence and its negative effects on condom use could substantially avert HIV infections among FSWs and their clients. However, this first modelling study was limited by a lack of data specific to Mombasa on the impact of violence against FSWs on HIV risk factors, such as condom use, and as such data from the other settings was used to form model assumptions in this first exercise. In addition, this study only considered sexual violence against FSWs in Mombasa. This chapter extends this work by using data specific to Mombasa, and by also exploring the potential role of physical violence and police assault or arrest, which are also highly prevalent among FSWs in Mombasa, Kenya [3-7].

In Chapter 3, I found a heavy burden of violence among YFSWs in Mombasa, Kenya, with 29.6%, 30.3% and 45.5% reporting that they had ever experienced sexual violence, physical violence and police assault or arrest, respectively. In Chapter 4, I found that these experiences of violence were associated with increased inconsistent condom use with different types of sexual partners, reduced uptake of HIV testing, and being HIV positive among the YFSWs. In this chapter, I utilise the data and findings from these prior two analyses, to develop, parameterise and calibrate a dynamic model of violence against FSWs and HIV transmission among FSWs and their clients in Mombasa, Kenya. My objectives are: (1) to use this model to estimate the contribution of sexual violence, physical violence, and police assault or arrest to HIV transmission among FSWs and their clients in Mombasa, Kenya; and (2) to estimate the potential impact of different violence prevention strategies on HIV transmission among FSWs and their clients. In doing so, I aim to assess the importance of incorporating structural interventions addressing violence against FSWs into HIV prevention activities for FSWs in Mombasa, Kenya.

5.3 Methods

5.3.1 Model description

I developed a dynamic, deterministic, compartmental model of violence against FSWs and sexual HIV transmission among FSWs and their clients in Mombasa, Kenya. The model is defined by a set of coupled ordinary differential equations (ODEs) (see Text D1 in Appendix D), which were programmed in Matlab and solved numerically using the ode45 solver. Flowcharts representing the structure of the violence and HIV components of the model are shown in Figures 5.1 and 5.2, respectively, and Table 5.1 shows the model parameters. The model structure and its parameterisation were informed by the analyses of Transitions data for YFSWs in Mombasa, Kenya, presented in Chapters 3 and 4, and other data on FSWs and their clients in Mombasa and other Kenyan settings, identified from a review of the literature.

5.3.1.1 Model structure

The violence component of the model for FSWs in Mombasa (Figure 5.1), was adapted from the model structure presented in Chapter 2. Based on the available Transitions study data, three types of violence against FSWs were considered: sexual violence, physical violence, and police assault or arrest (see Chapter 3, Section 3.3.2.1 for further details on the definition of each type of violence). Each model compartment represents a different state of sexual violence, physical violence, and police assault or arrest, and the arrows represent the flow of FSWs between them (Figure 5.1). Based on Transitions survey instruments, each type of violence has three possible states: never experienced violence, recently experienced violence (within the last 6 months), and previously but not recently experienced violence (Figure 5.1). In the HIV component of the model for FSWs and their clients in Mombasa, 5 different stages of HIV infection are represented: susceptible to HIV, initial acute HIV infection, chronic HIV infection with CD4>350, chronic HIV infection with CD4 200-350, and chronic HIV infection with CD4 <200 cells/mm^3 (Figure 5.2). Three different HIV treatment states are also represented for those with chronic HIV infection: never been on ART, currently on ART, and stopped ART (Figure 5.2). The FSW population in the model was further stratified into two age groups: 14-24 years and ≥ 25 years (the terms 'young FSWs' and 'older FSWs' will be used to refer to each age group, respectively) (Figure 5.3). This age-group stratification was incorporated into the model structure because the primary source of data, the Transitions study, focused on YFSWs (aged 14-24 years), and to reflect differences in sexual behaviours, ART uptake, and experience of violence between young and older FSWs. There was a dearth of data on clients in Kenya (e.g. number of regular and new clients), so only one group of clients was represented.

The model represents an open but stable population. FSWs enter the modelled population through initiation of sex work, and exit the model through cessation of sex work, or due to HIV-related death. Clients enter the model when they start paying FSWs for sex, and exit the model through cessation of paying FSWs for sex, or due to HIV-related death. The total sizes of the FSW and client population sizes are assumed to be constant over time. To achieve this, the rate of entry into the model for each risk group (FSWs and clients) was adjusted to balance the rate of leaving the model (due to cessation of sex work/paying for sex and HIV-related death). The rates at which FSWs leave sex work vary by age, and the HIV-related death rate among FSWs and clients varies by HIV disease stage and ART status. New FSWs were assumed to enter the model as young, HIV-susceptible FSWs, with no prior experience of violence, and new clients were assumed to enter the model as HIV susceptible.

HIV-susceptible FSWs and clients can get infected at a force of infection, which depends on number of sexual partners and their associated HIV prevalence, number of sex acts in a FSW-client partnership and fraction of sex acts protected by condoms, and infectiousness (i.e. the probability of transmission per sex act from an infected contact, which varies by gender [8], HIV stage [8-10], ART status [11] and condom use [12-14]). Sexual mixing between FSWs and clients is assumed to be proportionate. Based on analyses presented in Chapter 4, violence is assumed to influence the force of HIV infection, through its impact on inconsistent condom use and HIV testing uptake among FSWs (see Table 5.1 and Section 5.3.1.2 for further details). Following a short period of acute HIV infection, HIV-infected individuals' progress through three different CD4 stages, with varying infectivity. HIV-infected individuals in the acute HIV infection stage and CD4<200 stage are most infectious [8-10]. HIV-infected individuals can initiate ART at a rate which varies with time, risk and age group, and takes into account changes in ART guidelines (see Section 5.3.1.2 for further details). FSWs and clients on ART are substantially less infectious than those not on ART [11], and are assumed to no longer progress through the HIV CD4 stages, and to have lower rates of HIV-related mortality [15,16]. It is assumed that there is no treatment initiation for individuals in acute HIV stage. FSWs and clients receiving ART can stop ART at a rate which reflects the proportion of FSWs and clients each year who discontinue treatment or are lost to follow-up and assumed to have discontinued treatment [17,18]. Individuals who have stopped ART are assumed to be as infectious as those who have never started ART, and to progress through the HIV disease stages at the same rate as those who have never started ART. These individuals can re-initiate ART at a fixed rate, which is equal across all CD4 stages (Table 5.1).

To stabilise the relative size of the FSW age groups and to reach equilibrium prevalence of violence before introducing HIV, the model was run for 100 years before the start of the HIV epidemic. To check that equilibrium prevalence of violence was reached I did a visual inspection of violence trends in preliminary model simulations to check that equilibrium prevalence of violence was reached after 100 years. The HIV epidemic was seeded by assuming that a small proportion (0.5-2%) of clients and FSWs in each age group were HIV infected with CD4>350 at the start of the HIV epidemic. The start of the HIV epidemic corresponds to 1970 as was specified in the Shannon *et al* modelling study [2].

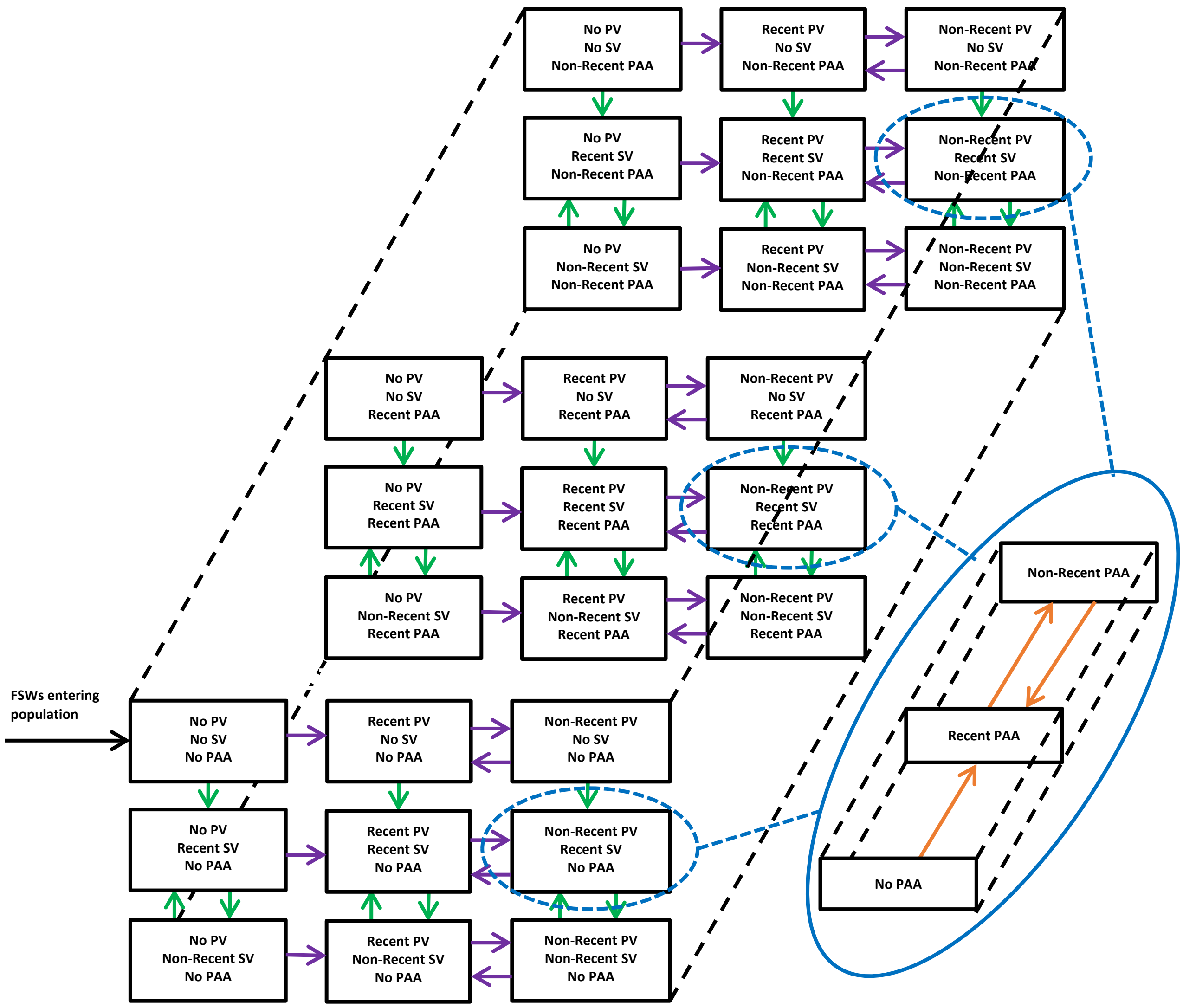


Figure 5.1 Structure of the violence model component. FSWs can progress through three different states of violence experience (none, recent or non-recent) for three different types of violence: police assault or arrest (PAA), orange arrows; physical violence (PV), purple arrows; and sexual violence (SV), green arrows. FSWs enter the model with no experience of any violence. Note that ceasing being a FSW, which can occur in each state, is not shown on this diagram for simplicity. FSW, female sex worker.

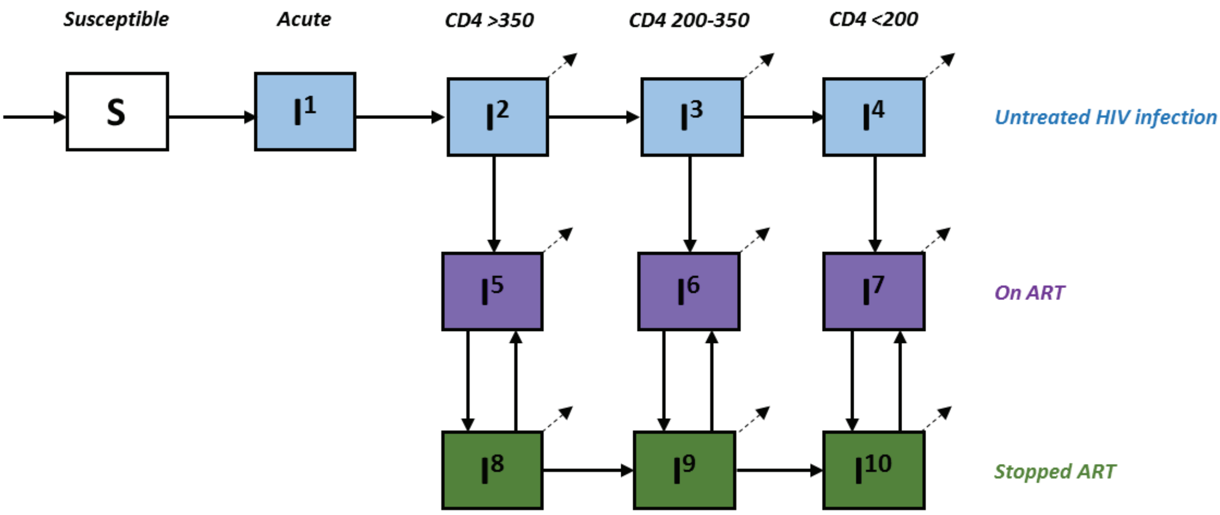


Figure 5.2 Structure of the HIV model component. Susceptible individuals (S) can become infected (I) and progress through different HIV stages (acute, CD4>350, CD4 200-350 and CD4<200). Infected individuals in each CD4 stage may be initiated onto ART, and those on ART may stop and re-initiate treatment. Dashed arrows represent mortality due to HIV which varies by HIV disease stage. All FSWs and clients enter the model as HIV susceptible.

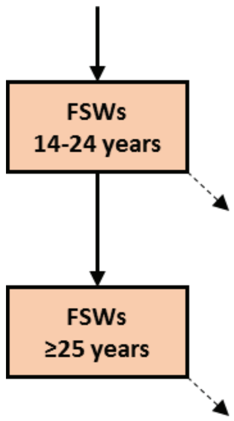


Figure 5.3 FSWs age-structure. FSWs enter the model aged 14-24 years and over time age into the older FSW group (≥ 25 years). Dashed arrows represent the cessation of sex work among each age group.

5.3.1.2 Model parameterisation and data

The following sections give further details on the parameters and data used in the model. Specifically I describe the population sizes and FSW/client transitions, violence, condom use, and HIV treatment.

5.3.1.2.1 Population sizes and FSW/client transitions

Based on mapping estimates for the size of the FSW population in Mombasa, Kenya in 2011-2012, the prior range for the total number of FSWs in the model was assumed to be 6920 to 11700 [19], and within a given run is taken to be constant over time. The number of clients in the model, which remains constant over time, was derived indirectly to balance the number of FSW-client partnerships in the model at the start of the simulation [20], by dividing the total number of partnerships on offer by all FSWs in a year by the number of FSWs visited by clients in a year. The simulated client population size in 2015 was compared against available data to ensure there was a reasonable client population size in the model (see Sections 5.3.2 and 5.4.1).

The rate of transition between FSW age groups depends on the time between starting sex work, estimated from the Transitions study (mean 17.6 years), and becoming 25 years old, corresponding to no longer being in the young age group (Table 5.1). Although the total FSW population is constant in the model, the relative size of each age group can vary over time in the presence of HIV, due to HIV-related death which results in FSWs leaving the model and being replaced by new young FSWs entering the model. To ensure that the model was simulating a reasonable FSW age-structure following the introduction of HIV, the relative size of each FSW age group in the model in 2015 was compared against recent unpublished FSW mapping estimates for the Transitions project, which suggest that approximately 50% of the FSW population in Mombasa are 14-24 years of age (see Sections 5.3.2 and 5.4.1). The number of FSWs visited by clients in a year was also adjusted over time to ensure that the number of FSW-client partnerships balanced over time.

The rate at which young and older FSWs leave sex work is based on the duration of time that FSWs sell sex, estimated from Transitions data and from existing surveys of FSWs in Mombasa, respectively, and adjusted for the fact that duration in sex work reported by FSWs still active is right-censored and therefore likely underestimates the average duration in sex work (Table 5.1). The years in sex work reported by active FSWs would on average be half the actual lifetime duration in sex work, so the data on duration selling sex was adjusted by a 2-fold factor. In the Transitions study, young FSWs leave the cohort either when they leave sex work or when they age out of the cohort. Therefore, for young FSWs the rate of leaving sex work was taken to be the estimated rate of leaving the Transitions cohort minus the rate of aging. As there was no specific data for this parameter among clients in Mombasa, a study of clients in Kenya's Nyanza province was used to estimate the average duration spent paying for sex (Table 5.1).

5.3.1.2.2 Violence

To generate prior ranges for the rates of first-time and repeat sexual violence, physical violence, and police assault or arrest (Table 5.1), the same approach taken in Chapter 2 was used, whereby I calculated the equilibrium for each type of violence, and compared this to the prevalence of violence in Transitions to estimate each rate of violence, assuming no interaction with other types of violence. Rates were calculated for young FSWs, but the same rates were assumed for older FSWs.

5.3.1.2.3 Condom use

Here, I describe the parameters governing condom use in the model. First, I describe how consistent condom use (CCU) varies over time in the absence of sexual violence. Then I describe how these trends in CCU are used to estimate trends in inconsistent condom use (ICU), and how ICU is influenced by violence. Finally, I describe how the trends in ICU are used to estimate the fraction of sex acts protected by condom, which influences the force of infection.

Trends in consistent condom use (CCU) with clients in the absence of sexual violence are assumed to follow a piecewise linear trend over time, which differs between young and older FSWs. Given the lack of historical data on condom use in Mombasa [2], consistent condom use in each age group is assumed to be zero early in the epidemic, and then increase linearly until a time when it reaches and remains at a constant level consistent with available data. Thus, consistent condom use in the absence of sexual violence varies over time as follows for young and older FSWs:

$$CCU_{youngFSW}(t) = \begin{cases} 0\,, & when\ t < \ t_{0cond} \\ (t - t_{0cond})/\,(t_{1cond} - t_{0cond}\,) * \ (1 - ICU_{youngFSW}), & when \quad t_{0cond} \le t < t_{1cond} \\ 1 - ICU_{youngFSW}, & when\, t \ \ge t_{1cond} \end{cases}$$

$$CCU_{olderFSW}(t) = \begin{cases} 0\,, & when\ t < \ t_{0con} \\ (t - t_{0cond})/\,(t_{1cond} - t_{0cond}\,) * \ (1 - ICU_{olderFSW}), & when \quad t_{0cond} \le t < t_{1cond} \\ 1 - ICU_{olderFSW}, & when\, t \ \ge t_{1cond} \end{cases}$$

where t_{0cond}, the time at which FSWs start using condoms, is assumed to be 1990, and t_{1cond}, the time at which condom use is assumed to plateau and remain constant, is assumed to be 2006 (these assumptions are the same as those used in the Shannon *et al* modelling study [2]). $ICU_{youngFSW}$ is the prevalence of inconsistent condom use among young FSWs from 2006 onwards, which is estimated from Transitions data, and $ICU_{olderFSW}$ is the prevalence of inconsistent condom use among older FSWs from 2006 onwards, which is estimated from recent studies of FSWs in

Mombasa (Table 5.1). Thus, the levels of consistent condom use reached when condom use is assumed to plateau and remain constant are 70-92% among young FSWs, and 55-86% among older FSWs (Table 5.1).

These levels of consistent condom use over time for young and older FSWs are then used to estimate the levels of inconsistent condom use (ICU) at time t for young and older FSWs, as follows:

$$ICU_{youngFSW}(t) = \begin{cases} \left(1 - CCU_{youngFSW}(t)\right), & \textit{if never experienced sexual violence} \\ \left(1 - CCU_{youngFSW}(t)\right) \text{ x } \mathrm{RR}_{cond_{SV}}, & \textit{if ever experienced sexual violence} \end{cases}$$

$$ICU_{olderFSW}(t) = \begin{cases} (1 - CCU_{olderFSW}(t)), & \textit{if never experienced sexual violence} \\ (1 - CCU_{olderFSW}(t)) \text{ x } \mathrm{RR}_{cond_{SV}}, & \textit{if ever experienced sexual violence} \end{cases}$$

where RR_{cond_SV} is the relative increase in inconsistent condom use among FSWs that have ever experienced sexual violence. The prior range for RR_{cond_SV} was based on the results for young FSWs in Mombasa presented in Chapter 4. Given the lack of studies examining the association between violence and condom use among older FSWs in Mombasa (or elsewhere in Kenya), it was assumed that older FSWs who experienced sexual violence would have the same increased risk of ICU as young FSWs.

Overall, the fraction of sex acts protected by condoms among young and older FSWs was then calculated as:

$$frac^{cond}_{young}(t) = \left(ICU_{youngFSW}(t) \text{ x } frac^{ICU}\right) + \left(\left(1 - ICU_{youngFSW}(t)\right) \text{ x } frac^{CCU} \right)$$

$$frac^{cond}_{older}(t) = (ICU_{olderFSW}(t) \text{ x } frac^{ICU}) + ((1 - ICU_{olderFSW}(t)) \text{ x } frac^{CCU})$$

where $frac^{ICU}$ is the fraction of sex acts that are protected when condoms are used inconsistently, and $frac^{CCU}$ is the fraction of sex acts that are protected when condoms are used consistently (see Table 5.1). The overall fraction of sex acts protected by condoms among young and older FSWs will thus differ among FSWs who have ever or never experienced sexual violence, as FSWs who have experienced sexual violence have higher levels of inconsistent condom use than FSWs who have never experienced sexual violence.

5.3.1.2.4 Treatment initiation

Roll-out of ART in Kenya started in 2003, with a scaled-up effort launched in 2004 [21]. At the start of the ART programme in 2003, the eligibility criteria for initiating ART was CD4 <200 cells/mm^3. Since then, the eligibility criteria changed to CD4<250 in 2007, CD4<350 in 2010, CD4<500 in 2014 and any CD4 count in 2016 [21-24]. These trends in ART eligibility criteria are reflected in the model, by switching on or off the annual rate of initiating ART in each CD4 category of the model in line with the ART eligibility criteria at time t. Since the model structure (CD4<200, CD4 200-350, and CD4>350) did not correspond exactly to the ART eligibility criterion CD4 <250 and CD4 <500, the annual rate of initiating ART among FSWs and clients between 2007 and 2010 in the CD4 stage 200-350 was reduced by 2/3 since approximately only 1/3 of individuals in that category would be eligible for treatment in that time-period, and the annual rate of ART uptake among FSWs and clients between 2010 and 2014 in the CD4 stage >350 was reduced by 1/2 to reflect that approximately 50% of individuals in that category would be eligible for treatment in that time-period [15].

The annual rate of initiating ART was parameterised separately for young FSWs, older FSWs and clients, as available data suggested different ART coverage (% of HIV positive on ART) across the three groups (see Tables D1 and D3 in Appendix D).

ART initiation in FSWs

The annual rate of initiating ART among FSWs depends on the annual fraction of FSWs HIV testing, which is influenced by violence, and the fraction of those HIV tested and diagnosed that initiate ART if eligible. It is assumed that people test independently of HIV status.

To reflect changes in the uptake of HIV testing over time in Kenya [25,26], HIV testing for all FSWs (in the absence of violence) ($fracTest^{base}$) was assumed to follow a piece-wise linear trend from the start of the ART programme in 2003. Given the lack of historical data on HIV testing among FSWs in Mombasa, and the evidence to suggest from Transitions and a recent study that HIV testing rates are similar among young and older FSWs from Mombasa (approximately 80-92% tested in the past year) (Table 5.1), the trend in HIV testing was assumed to be the same in young and older FSWs. The annual fraction of FSWs HIV testing was assumed to be 6% at the start of the ART programme roll-out in 2003 ($fracTest_{2003}$), in line with available data for women in the general population in Mombasa, Kenya [25], and then increase linearly from 2003 to reach 37-47% in 2008 ($fracTest_{2008}$), based on levels of HIV testing among women in Mombasa, Kenya and FSWs in Kisumu, Kenya [26,27]. From 2008, the annual fraction of FSWs HIV testing is then assumed to increase linearly to reach the recent HIV testing levels of FSWs in Mombasa in 2013 ($fracTest_{2013}$), where it then remains constant at this level (Table 5.1).

The annual fraction of FSWs HIV testing at time t was also influenced by FSWs experiences of violence. Sexual violence, physical violence and police assault or arrest were assumed to reduce uptake of HIV testing by factors RR_{test_SV}, RR_{test_PV}, *and* RR_{test_PAA}, respectively, based on the analyses on young FSWs presented in Chapter 4 (see Table 5.1). These factors were assumed to be the same among young and older FSWs, due to the lack of studies among older FSWs examining the association between violence and HIV testing in Mombasa (or elsewhere in Kenya). For FSWs experiencing multiple types of violence it was assumed that the relative reduction in uptake of HIV testing was a product of the risk associated with each type of violence experienced (e.g. RR_{test_SV} x RR_{test_PV} x RR_{test_PAA} for those who have experienced all three types of violence). This assumption was based on results from Chapter 4, which suggested a multiplicative effect of experiencing multiple types of violence on HIV testing uptake. Thus, the overall uptake of HIV testing ($fracTest^{cov}$) at time t when taking into account FSWs experiences of violence was defined as:

$$fracTest^{cov}\ (t)\ =\ fracTest^{base}\ (t)\ x\ RR_{test\_total}$$

where RR_{test_total} is the relative reduction in uptake of HIV testing due to FSWs experiences of violence, which is either one or a product of the factors RR_{test_SV}, RR_{test_PV}, and RR_{test_PAA} depending on a FSWs experience of violence.

The annual rate of ART uptake (τ) among young and older FSWs at time t, respectively, was then calculated as:

$$\tau_{young}\ (t) = \ fracTest^{cov}\ (t)\quad x\quad fracInitiate_{young}$$

$$\tau_{older}\ (t) = \ fracTest^{cov}\ (t)\quad x\quad fracInitiate_{older}$$

where, $fracInitiate_{young}$ *and* $fracInitiate_{older}$, are the fraction of young and older FSWs who are diagnosed after HIV testing that initiate treatment if they are eligible. Estimates of $fracInitiate_{young}$ *and* $fracInitiate_{older}$ were based on available data on the fraction of FSWs tested for HIV in the past year and the fraction of HIV positive FSWs who are currently on ART from Transitions study and a recent study of older FSWs, and also on available data from the general population in Mombasa on the fraction of ART-eligible women who initiate ART, and had wide prior ranges to reflect the uncertainty in this parameter (Table 5.1).

ART initiation in clients

In the absence of data for clients specifically, I simplified the annual rate of initiating ART into one component representing the fraction of ART-eligible clients who initiate treatment. Based on national-level male Kenya data, this parameter was assumed to follow a piece-wise linear trend over time, to reflect that the fraction of ART-eligible males in Kenya initiating ART was low at the start of the ART programme (about 3%), and then increased and remained relatively stable at approximately 55-65% from 2006 onwards [28].

5.3.1.2.5 Treatment discontinuation

Based on cohort data for FSWs in Mombasa on treatment discontinuation and loss to follow-up from ART, an annual ART drop-out rate of 9-24% was assumed for FSWs who had initiated ART [17]. Due to a lack of data on clients, 9-16% of clients were assumed to stop ART annually, based on data from the general population reported in the NASCOP 2010 Annual Health sector HIV report [18].

Table 5.1 Model parameters

Parameter	Symbol	Fixed value or prior range	References/Notes
Demographic parameters			
FSW population size in Mombasa in 2015	N_{FSW}	6920-11700	Odek *et al* 2014 [19]
Client population size in 2015	N_{client}	Number of clients is derived by multiplier method to balance number of FSW/client partnerships	Client population size is compared against Kenya data (see Section 5.3.1.2 for further details)
Individual FSW and dyad parameters			
Age at entry into sex work, years	*AgeEnter*	17.6	From Transitions data analysis
Rate of entry into older age group (≥ 25 years) for FSWs	*Rate_AgeTransition*	1/7.4 years	Based on the mean duration between entering sex work and becoming 25 years old (25 years-17.6 years = 7.4 years)
Rate of leaving sex work per year	μ_{young} μ_{older}	FSWs 14-24 years: 0.065-0.092 FSWs ≥ 25 years: 0.087-0.125	Estimated from Transitions data (further details in Section 5.3.1.2) Based on Luchters *et al* 2008 [29], Luchters *et al* 2013 [5], Parcesepe *et al* 2016 [30] and McClelland *et al* 2016 [31] (further details in Section 5.3.1.2)
Number of clients seen by FSWs per week	C_{young} C_{older}	FSWs 14-24 years: 5-6.4 FSWs ≥ 25 years: 4-7.4	From Transitions data analysis Based on Luchters *et al* 2013 [5] and Thomsen *et al* 2006 [32]
Number of sex acts per client	n^{Acts}	1-2	Based on Luchters *et al* 2013 [5]
Individual client and dyad parameters			
Number of FSWs visited per month	n^{FSW}	3-8	Based on Voeten *et al* 2002 [33]
Time spent buying sex in years	$1/\mu_{client}$	14	Based on Voeten *et al* 2002 [33]
Condom-use related parameters			
Time when condom use is assumed to start	t_{0cond}	1990	Assumption used in Shannon *et al* 2015 [2]
Time when condom use is assumed to plateau	t_{1cond}	2006	Assumption used in Shannon *et al* 2015 [2]
ICU from 2006 (i.e. when condom use is assumed to plateau)	$ICU_{youngFSW}$ $ICU_{olderFSW}$	FSWs 14-24 years: 10-28% FSWs ≥ 25 years: 14-45%	From Transitions data analysis Based on Parcasepe *et al* 2016 [30], Odek *et al* 2014 [19], Luchters *et al* 2013 [5], Tegang *et al* 2010 [34], Luchters *et al* 2008 [29]

% of sex acts which are protected when reporting ICU	$frac^{ICU}$	0%	Assumption used in Shannon *et al* 2015 [2]
% of sex acts which are protected when reporting CCU	$frac^{CCU}$	75-100%	Assumption used in Shannon *et al* 2015 [2]
Relative increase in ICU due to recent and non-recent sexual violence	RR_{cond_SV}	1.19-4.09	Analysis of Transitions data (see Chapter 4)
Violence parameters			
Annual per capita rate that FSWs experience first-time: - Sexual violence - Physical violence - Police assault or arrest	 α^{SV} α^{PV} α^{PAA}	 0.073-0.112 0.076-0.116 0.146-0.217	Estimated from Transitions data analysis (further details in Section 5.3.1.2)
Annual per capita rate that FSWs experience recurrent: - Sexual violence - Physical violence - Police assault or arrest	 ν^{SV} ν^{PV} ν^{PAA}	 0.687-1.768 1.518-3.474 0.882-1.772	
Time to non-recent sexual violence or physical violence or police assault or arrest from recent sexual violence, physical violence or police assault or arrest (years)	θ	0.5	Corresponds to 6 months, to be consistent with other survey questionnaires and reported violence data
HIV testing and ART related parameters			
Fraction of FSWs tested for HIV per year	$fracTest_{2003}$ $fracTest_{2008}$ $fracTest_{2013}$	2003: 6% 2008: 37-47% 2013 onwards: 80-92%	Kenya DHS 2003 report [25] Kenya DHS 2008-2009 report [26] and Vandenhoudt *et al* 2013 [27] Based on Transitions data analysis and Lafort *et al* 2016 [35] The 2013 time-point reflects approximately the mid-point between the time of recruitment in Transitions and Lafort *et al*.
Fraction of FSWs initiating ART if diagnosed	$fracInitiate_{young}$ $fracInitiate_{older}$	FSWs 14-24 years: 10-40% FSWs ≥ 25 years: 50-90%	Estimated from Transitions data analysis Based on Lafort *et al* 2016 [35] and NASCOP 2015 Kenya HIV estimates report [28]
Relative decrease in HIV testing among FSWs due to recent and non-recent: - Sexual violence - Physical violence - Police assault or arrest	 RR_{test_SV} RR_{test_PV} RR_{test_PAA}	 0.82-1.0 0.83-1.0 0.89-1.0	Prior ranges are based on analysis of Transitions data (see Chapter 4). Note that the range (i.e. 95%CI) from Chapter 4 analysis have been truncated slightly here, in order to have an upper limit of 1.0 in the model (i.e. the model assumption is that violence negatively impacts HIV testing)
Rate of ART uptake per year among ART-eligible clients	τ_{client}	2003: 3% 2006 onwards: 55-65%	NASCOP 2015 Kenya HIV estimates report [28]
Yearly rate of stopping ART among FSWs	κ_{FSW}	0.09-0.24	Based on Graham *et al* 2012 [17]
Yearly rate of stopping ART among clients	κ_{client}	0.09-0.16	Based on NASCOP 2010 Annual Health Sector HIV report [18]
Yearly rate of restarting ART if stopped/failed previously	ω	0.3	Assumption
Eligibility criteria for initiating ART (CD4 cell/mm^3) - Before 2007 - 2007-2010 - 2010-2014 - 2014-2016 - 2016 onwards	 C_1 C_2 C_3 C_4 C_5	 <200 <250 <350 <500 Any CD4 count	 Kenya AIDS epidemic update 2011 [21] Kenya AIDS epidemic update 2011 [21] Kenya treatment guidelines 2011 [23] Kenya treatment guidelines 2014 [22] Kenya treatment guidelines 2016 [24]
Biological parameters			
Probability of HIV transmission per sex act in asymptomatic stage (CD4>350) - Male-to-female - Female-to-male	 β_1 β_2	 0.0006-0.0011 0.0001-0.0014	 Boily *et al* 2009 [8] Boily *et al* 2009 [8]

Relative risk of HIV transmission (compared to CD4>350) - Acute - CD4 200-350 - CD4 <200	 RR_A $RR_{200-350}$ RR_{200}	 4.5-18.8 1.0-1.6 4.5-7.0	 Boily *et al* 2009 [8] Donnell *et al* 2010 [9], Hollingsworth *et al* 2008 [10] Boily *et al* 2009 [8], Donnell *et al* 2010 [9], Hollingsworth *et al* 2008 [10]
Duration in each HIV stage in the absence of ART (years) - Acute - CD4 >350 - CD4 200-350 - CD4 <200	 $1/\sigma_1$ $1/\sigma_2$ $1/\sigma_3$ dur^{200}	 0.1-0.5 4.0-4.8 3.6-4.6 1.4-2.8	 Hollingsworth *et al* 2008 [10] e-ART linc 2008 [36] e-ART linc 2008 [36], Lodi *et al* 2011 [37] Morgan *et al* 2000 [38], Kumarasamy *et al* 2003 [39], Lodi *et al* 2011 [37]
HIV-related mortality rate per year by HIV stage - Acute - CD4 >350 - CD4 200-350 - CD4 <200	 Φ_1 Φ_2 Φ_3 Φ_4	 0 0.01-0.022 0.022-0.038 $1/ dur^{200}$	 Assumption Lewden *et al* 2012 [40] Lewden *et al* 2012 [40], Anglaret *et al* 2012 [41]
Per-act condom efficacy against HIV transmission	Eff_{ART}	78-95%	Weller *et al* 2002 [14], Pinkerton *et al* 1997 [13], Hughes *et al* 2012 [12]
Per-act effectiveness of ART against HIV transmission	Eff_{cond}	79-96%	Reviewed by Baggaley *et al* 2013 [11]
Reduction in HIV-related mortality due to ART	Eff_{mort}	50%	The HIV-CAUSAL collaboration 2010 [42], Kitahata *et al* 2009 [43], Ghate *et al* 2011 [44], Kumarasamy *et al* 2003 [39]
Seed (% infected with HIV at the start of the HIV epidemic)	$seed_{1970}$	0.5-2%	Assumption

5.3.2 Model calibration

To take into account uncertainty in the model parameters, model calibration was done in a Bayesian framework, using Latin Hypercube Sampling (LHS) combined with a target fitting method, to obtain multiple parameter sets that simultaneously fit to various age and risk group specific data on HIV prevalence, ART coverage (% of HIV positive on ART) and prevalence of violence (see Table 5.2). The model calibration process is as follows: (1) uniform prior distributions are assigned to each of the model parameters with prior ranges (prior ranges and their sources are shown in Table 5.1); (2) LHS was used to randomly select a large number of parameter sets (4000) from the prior distributions of these parameters [45,46]; (3) parameter sets from step 2 were deemed to produce a "good fit", and accepted as a posterior parameter set, if the associated model predictions fell simultaneously within the pre-specified targets (ranges) of the HIV prevalence, ART coverage, and violence prevalence data defined in Table 5.2.

In addition, model predictions from the model fits were compared to additional observed data on HIV prevalence, ART coverage and prevalence of violence that were not used during the fitting procedure and that were directly comparable to model outcomes (see Tables D3-D5 in Appendix D). This was done to provide an additional visual check of how well the model projections match all other available HIV prevalence, ART coverage and violence prevalence data. As described above, demographic model outputs (FSW and client population sizes) were also compared to available data (see Section 5.3.1.2).

The majority of the observed data from the literature on FSWs in Mombasa are from studies which did not specifically recruit young FSWs, did not recruit FSWs as young as 14, and had a relatively small proportion of the study population that was 24 years or younger (typically less than 30%) (Tables D1 and D3-D4 in Appendix D), therefore estimates from these studies were considered to be more representative of older FSWs, and as such this data was used to fit and compare model outcomes among older FSWs in the model.

The posterior parameter sets represent the 'baseline calibrated scenario' used in the analyses to estimate the contribution of violence and the potential impact of eliminating future violence experiences on HIV transmission among FSWs and their clients.

Table 5.2 HIV prevalence, ART coverage and violence prevalence data used in model fitting

Model outcome	Population	Year	Target range		Sources for target range[1]
			Lower limit	Upper limit	
HIV prevalence	Older FSWs	2005	29.2%	40.0%	Chersich et al 2007 [47], Luchters et al 2008 [29], Luchters et al 2010 [48]
HIV prevalence	Young FSWs	2015	6.9%	13.5%	Transitions data
HIV prevalence	Clients	2005	5.0%	24.0%	PhD thesis, S. Mishra 2014 [49]
% HIV positive on ART	Young FSWs	2015	6.7%	35.0%	Transitions data
Prevalence of sexual violence (ever)	Young FSWs	2015	25.2%	34.3%	Transitions data
Prevalence of sexual violence (recent)	Young FSWs	2015	8.9%	15.6%	Transitions data
Prevalence of physical violence (ever)	Young FSWs	2015	25.9%	35.0%	Transitions data
Prevalence of physical violence (recent)	Young FSWs	2015	13.6%	21.2%	Transitions data
Prevalence of police assault or arrest (ever)	Young FSWs	2015	40.4%	50.3%	Transitions data
Prevalence of police assault or arrest (recent)	Young FSWs	2015	15.3%	23.6%	Transitions data

[1] Further details on the data used to specify the target ranges are in Tables D1 and D2 in Appendix D

5.3.3 Plan of analysis

5.3.3.1 Estimating the contribution of violence to HIV transmission among FSWs and their clients

The contribution of violence to HIV transmission among FSWs and their clients in Mombasa, Kenya was estimated using the Population Attributable Fraction (PAF) calculated over the 2015-2025 period. The PAF measures the proportion of cumulative new HIV infections in a population over a certain time period that were due (indirectly or directly) to given a risk factor (e.g. violence). The PAF of violence was defined as the relative difference in cumulative new HIV infections over the 2015-2025 period between the baseline calibrated scenario and a counterfactual scenario where violence has no effect on HIV.

I simulated a number of different counterfactual scenarios and estimated the PAF for each:

- First, I simulated a counterfactual scenario where the impact of violence on increasing ICU and/or reducing HIV testing was removed i.e. RR_{cond_SV}, RR_{test_SV} , RR_{test_PV}, and RR_{test_PAA} were all set to equal 1, while all other parameters remained the same as in the baseline calibrated scenario. This PAF takes into account the contribution of all three violence types to HIV transmission, and so is defined as the "full" PAF.
- Second, to examine the contribution of each type of violence alone to HIV transmission, I simulated further counterfactual scenarios where the impact of each type of violence on increasing ICU or reducing HIV testing was removed in turn (i.e. four counterfactual scenarios were run with RR_{cond_SV}, RR_{test_SV}, RR_{test_PV}, and RR_{test_PAA} sequentially set to equal 1).
- Third, to examine the contribution of recent versus non-recent violence to HIV transmission, I simulated two further counterfactual scenarios, one where RR_{cond_SV}, RR_{test_SV}, RR_{test_PV}, and RR_{test_PAA} were all set to equal 1 among FSWs who have recently experienced violence, and second where RR_{cond_SV}, RR_{test_SV}, RR_{test_PV}, and RR_{test_PAA} were all set to equal 1 among FSWs who have previously but not recently experienced violence.

All PAF estimates were calculated in the total population as well as by risk-group (i.e. young FSWs, older FSWs and clients), and are presented across two time-periods: 2015 to 2020 (i.e. a shorter-term 5-year PAF) and 2015-2025 (i.e. a longer-term 10-year PAF).

5.3.3.2 Estimating the potential impact of eliminating future violence experiences on HIV transmission among FSWs and their clients

The potential impact of violence elimination interventions on HIV transmission among FSWs and their clients in Mombasa, Kenya was estimated using the prevented fraction (i.e. the fraction of HIV infections averted by the intervention). The prevented fraction was defined as the relative reduction in cumulative new HIV infections over the 2015-2025 period between the baseline calibrated scenario and each intervention scenario.

Two intervention scenarios were examined:

- Intervention 1: Eliminate all future experiences of violence. This was modelled by setting the rates of first-time and recurrent violence to equal zero (i.e. α^{SV}=0, α^{PV}=0, α^{PAA}=0, ν^{SV}=0, ν^{PV}=0 and ν^{PAA}=0) from 2015 onwards.
- Intervention 2: Eliminate all future experiences of violence and remove the long-term negative effects of violence. This was modelled by setting the rates of first-time and recurrent

violence to equal zero, and also setting RR_{cond_SV}, RR_{test_SV} , RR_{test_PV}, and RR_{test_PAA} to equal 1 among those who have previously but not recently experienced violence, from 2015 onwards.

Prevented fraction estimates were calculated in the total population as well as by risk-group (i.e. young FSWs, older FSWs and clients), and are presented across two time-periods: 2015 to 2020 (i.e. a shorter-term 5-year projection) and 2015-2025 (i.e. a longer-term 10-year projection).

The impact of each intervention scenario on HIV prevalence and ART coverage (% of HIV positive on ART) was also assessed.

5.3.3.3 Sensitivity analyses

To explore the sensitivity of the PAF and prevented fractions to the uncertainty in the parameter values, partial rank correlation coefficients (PRCCs) were calculated to estimate the strength of association between the posterior parameter distributions and outcomes of interest (full PAF and prevented fractions in interventions 1 and 2). PRRC values nearer 0 indicate a weak association, and values nearer -1 and +1 indicate a strong association [45,50].

5.4. Results

5.4.1 Calibration results

From 4000 parameter sets, 70 parameter sets fit the fitting outcomes well and were retained as posterior parameter sets for further analysis. The baseline model projections of these posterior parameter sets produced a visually good fit to the age and risk group specific data on HIV prevalence, ART coverage (% of HIV positive on ART) and prevalence of violence shown in Table 5.2 (Figures 5.4-5.6).

The baseline model projections also corresponded reasonably well to the other available observed age and risk group specific comparison data on HIV prevalence and ART coverage not used in the model fitting process (Figures 5.4 and 5.5, and Figure D1 in Appendix D), although some early FSW HIV prevalence estimates were underestimated in the model projections, and some client HIV prevalence estimates were overestimated. Violence prevalence projections for young FSWs also matched reasonably well to additional comparison data from Transitions on prevalence of experiencing multiple types of violence that was not used in the fitting process (Figure 5.7), although the prevalence of experiencing both sexual violence and physical violence was slightly underestimated in the model projections. The prevalence projections of recent sexual violence among older FSWs were also consistent with other available comparison data from polling booth surveys of FSWs in Mombasa, Kenya in 2014 and 2015 (Figure 5.8). The prevalence projections of recent police assault or arrest among older FSWs were also similar to the 2014 polling booth survey comparison data, but underestimated the 2015 polling booth survey comparison data (Figure 5.8). The baseline model projections for demographic outcomes (FSW and client population sizes), were also consistent with their corresponding comparison data (Figure 5.9).

The posterior median of the relative risk of ICU due to sexual violence was 3.03 (95% CrI: 1.49-4.06), and the posterior median for the relative reduction in HIV testing uptake due to sexual violence, physical violence and police assault or arrest was 0.92 (95% CrI: 0.82-1.00), 0.89 (95% CrI: 0.83-0.99), and 0.94 (95% CrI: 0.89-1.00), respectively (see Table D7 in Appendix D). These posterior ranges were similar to their prior ranges.

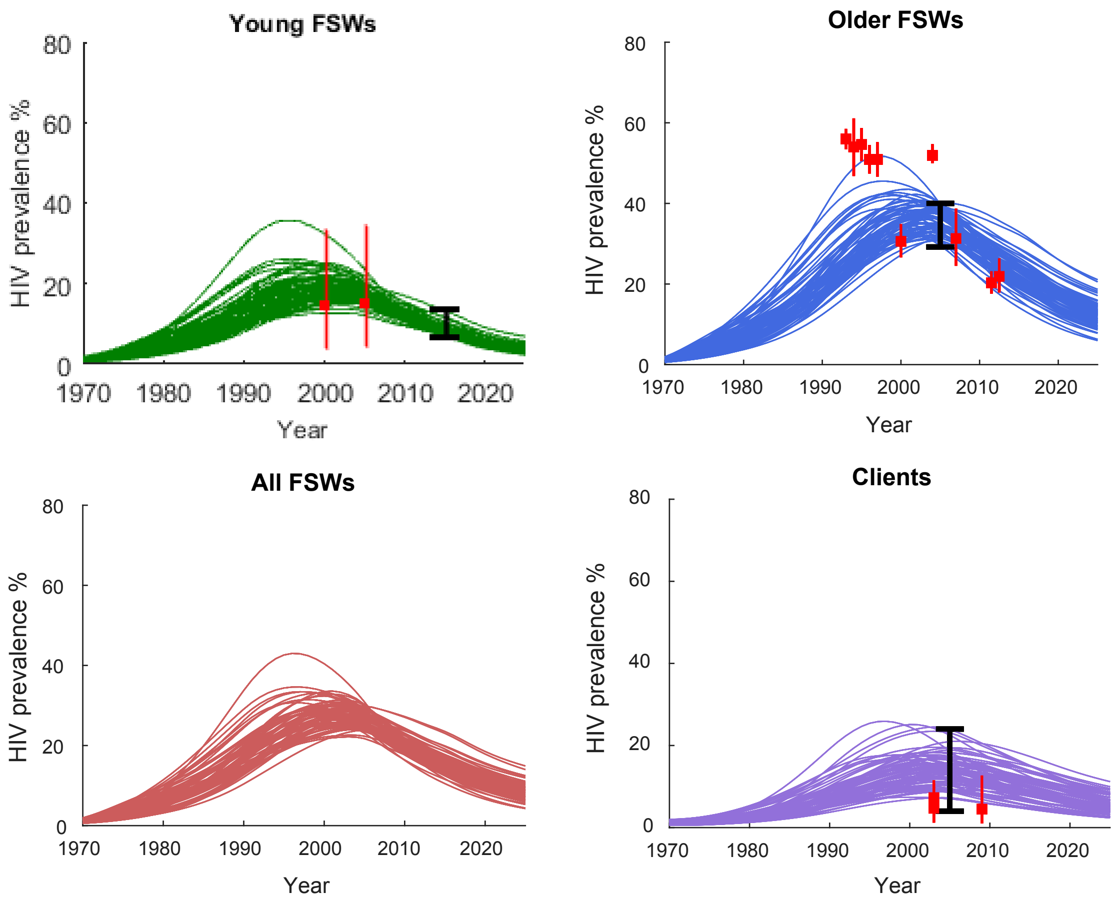


Figure 5.4 HIV prevalence trends in different risk groups across all the models fits. Black error bars show the target ranges used in the model fitting process. Red squares and error bars show the point estimates and 95% confidence intervals of other available comparison data not used in the fitting process.

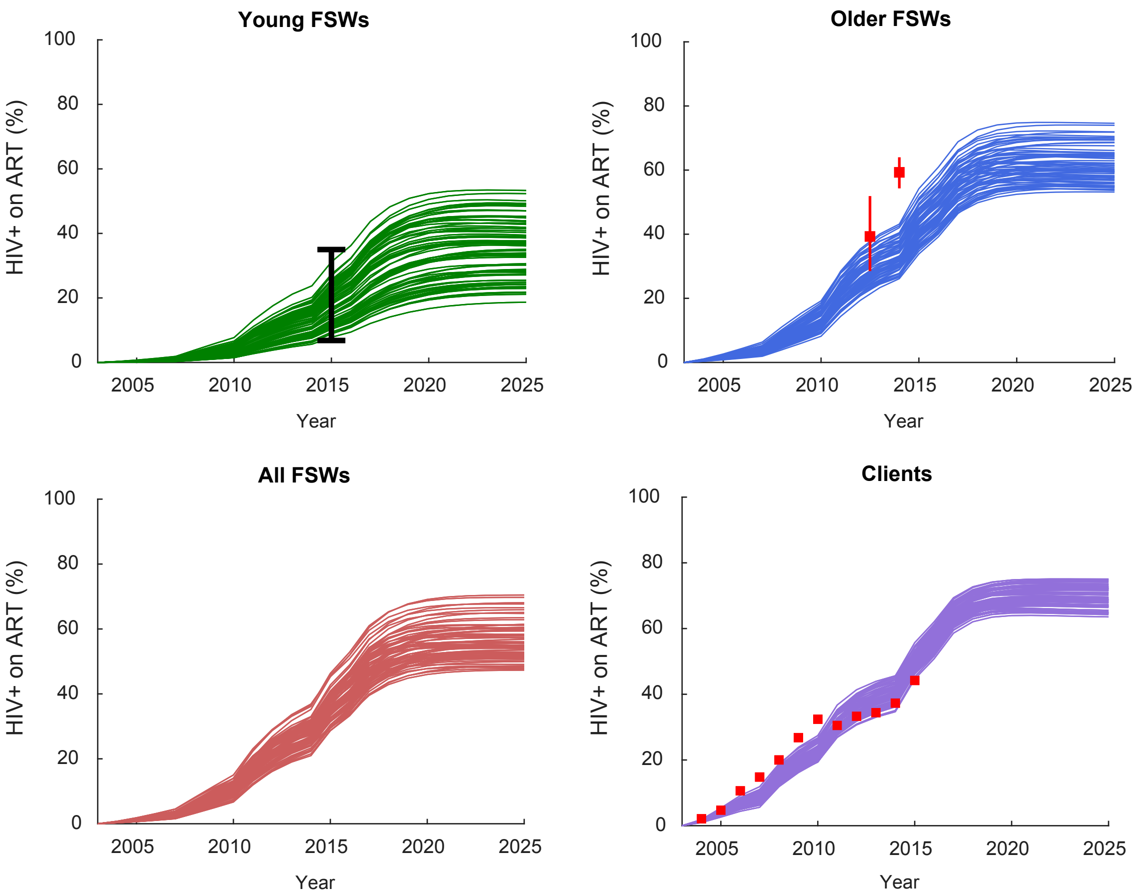


Figure 5.5. ART coverage (% of all HIV positive on ART) trends in different risk groups across all the models fits. Black error bars show the target ranges used in the model fitting process. Red squares and error bars show the point estimates and 95% confidence intervals of other available comparison data not used in the fitting process.

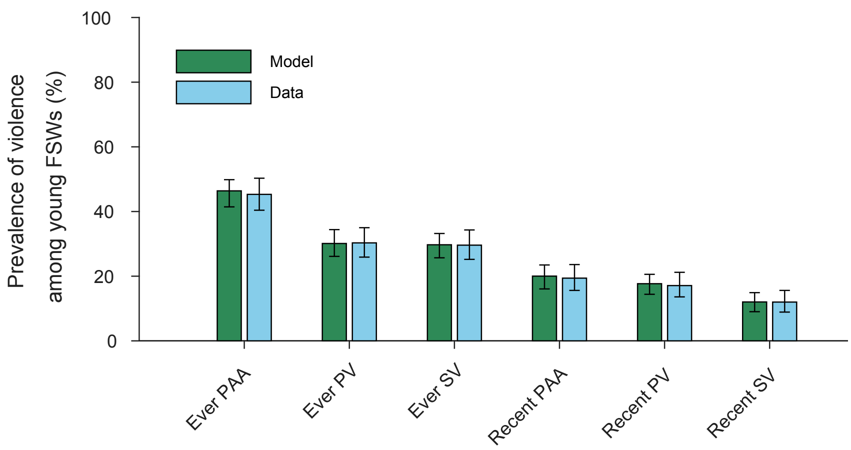


Figure 5.6. Prevalence of each type of violence among young FSWs in 2015: model projections compared to Transitions data used in the fitting process. Coloured bars represent the median value of the model fits or the point estimate from Transitions data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from Transitions data. PAA – police assault or arrest; PV – physical violence; SV – sexual violence.

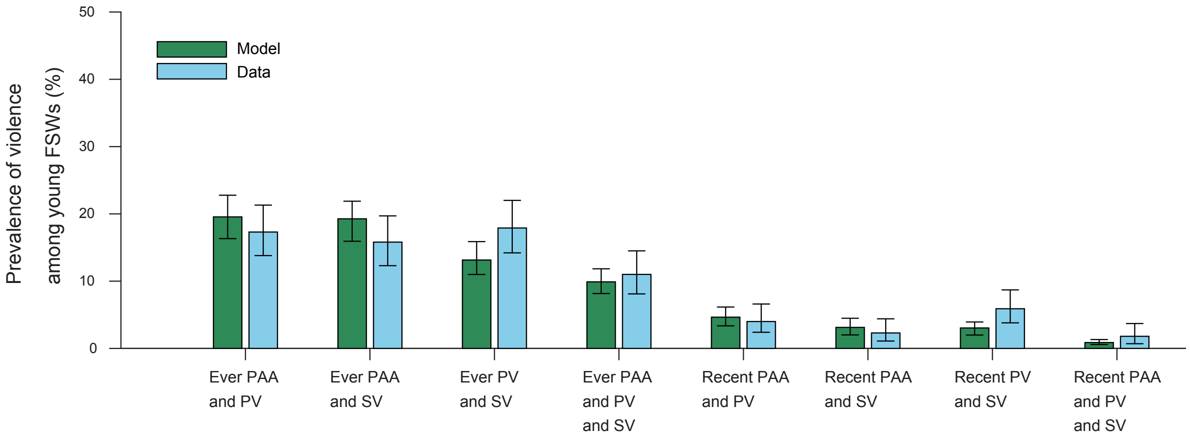
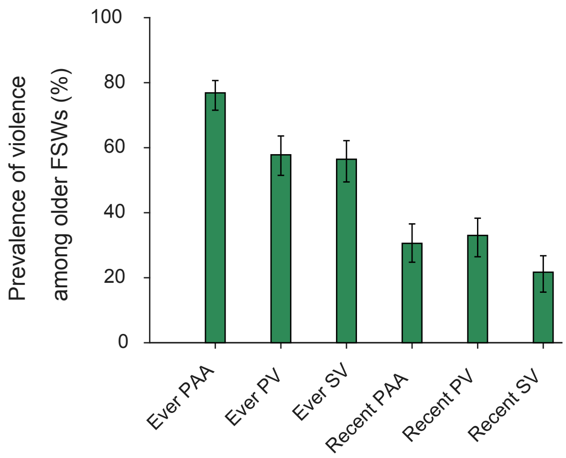


Figure 5.7. Prevalence of experiencing multiple types of violence among young FSWs in 2015: model projections compared to Transitions comparison data. Coloured bars represent the median value of the model fits or the point estimate from Transitions data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from Transitions data. PAA – police assault or arrest; PV – physical violence; SV – sexual violence.

(A)



(B)

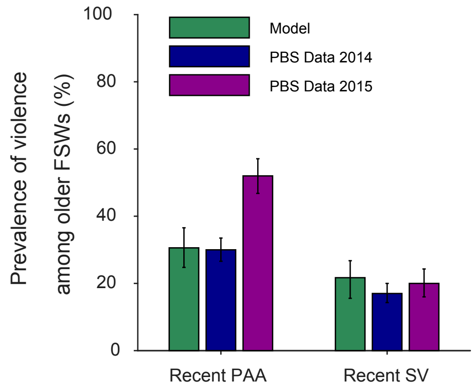


Figure 5.8 Prevalence of each type of violence among older FSWs. A) Model projections of violence prevalence among older FSWs in 2015. B) Violence prevalence model projections among older FSWs in 2015 compared to Mombasa polling booth survey (PBS) comparison data in 2014 and 2015 [3]. Coloured bars represent the median value of the model fits or the point estimate from the PBS data, and error bars represent the 95% credible interval of the model fits or the 95% confidence intervals of the PBS data. PAA – police assault or arrest; PV – physical violence; SV – sexual violence.

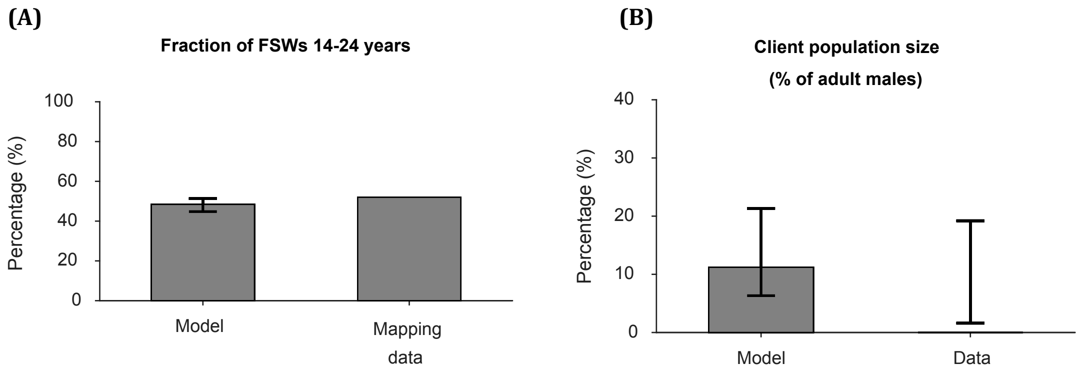
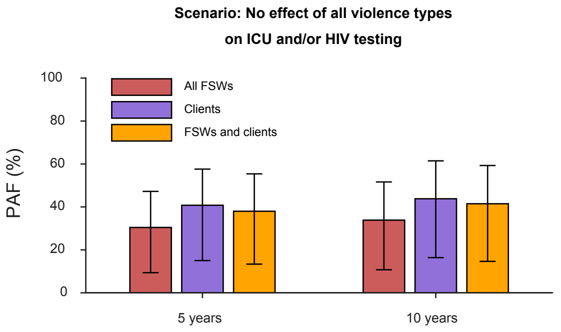


Figure 5.9. Demographic model projections compared to observed data. (A) Model and empirical estimates of the fraction of FSWs that are 14-24 years in 2015. Empirical estimates come from mapping estimates from the Transitions study (unpublished data). (B) Model and empirical estimates of the client population size (% of adult males) in 2015. Model estimates were calculated by dividing the number of clients projected in the model by the number of males in Mombasa in 2015, which was estimated from data reported in the 2016 Kenya HIV County Report [51]. Empirical estimates represent available national-level Kenya data for the % of the male population in Kenya who have ever or in the last 12 months exchanged payment, money, gifts or favours for sex [49,52]. Bars represent the median value of the model fits or the point estimates from the comparison data, and error bars represent the 95% credible interval of the model fits or the 95% confidence intervals of the comparison data.

5.4.2 Contribution of violence to HIV transmission

The model suggests that 41.5% (95% CrI: 14.6-59.3%) of all new HIV infections among FSWs and their clients in Mombasa, Kenya, over the 2015-2025 period, could be due to sexual violence, physical violence and police assault or arrest (Figure 5.10A). The full-PAF was highest for clients (43.8% [95% CrI: 16.4-61.5%]), followed by older FSWs (37.5% [95% CrI: 12.4-55.2%]), then young FSWs (28.9% [95% CrI: 8.5-47.7%]) (Figure D2 in Appendix D). Interestingly, as can be seen in Figure 5.10B, the substantial contribution of violence to HIV transmission among FSWs and their clients is mainly driven by sexual violence and its impact on ICU, with the PAF due to the impact of sexual violence on ICU estimated at 38.9% (95% CrI: 12.0-54.5%). The large magnitude of this PAF is due to there being a substantial decrease in ICU when the elevated risk in ICU due to sexual violence is removed; the weighted average ICU decreases from 47% at baseline in 2015 to 26% when the relative increase in ICU due to sexual violence is set to equal one from 2015. Figure 5.10C also suggest that the long-term negative impacts of previous non-recent violence experiences contribute more to HIV transmission than the short-term negative impacts of recent violence, although both PAFs were still considerable, with the PAF due to recent violence estimated at 17.2% (95% CrI: 6.0-30.1%), and the PAF due to non-recent violence estimated at 26.1% (95% CrI: 8.4-40.8%).

(A)



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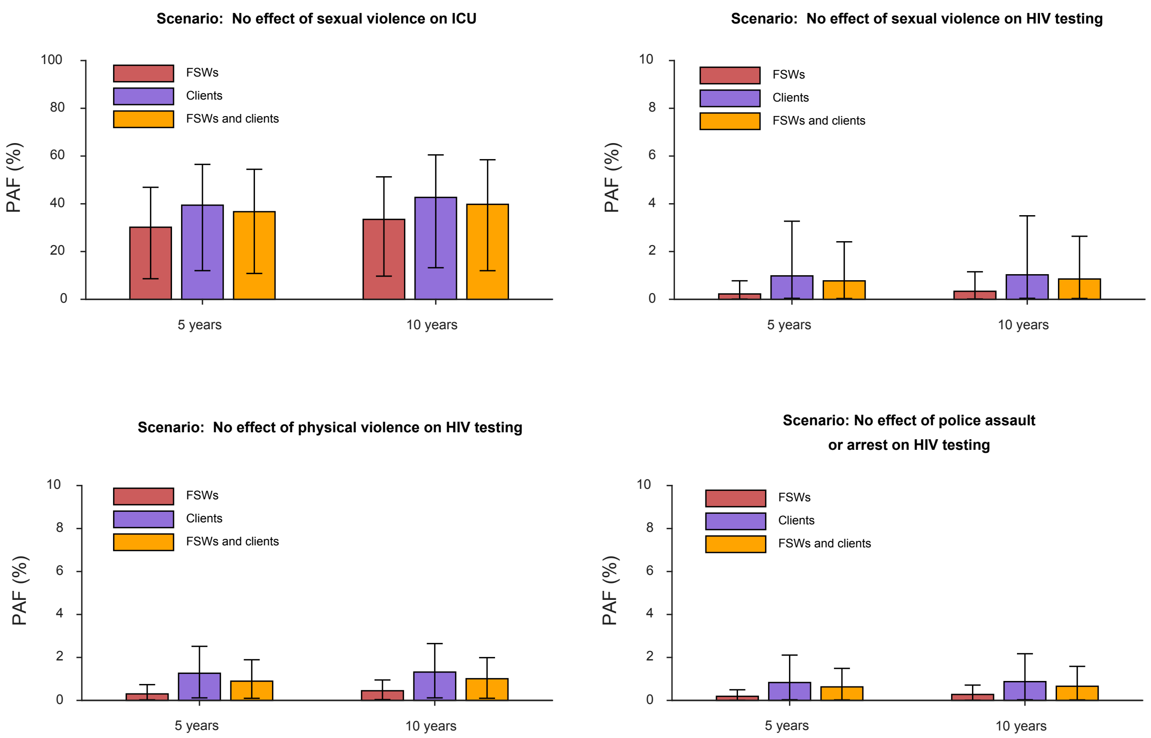


(C)

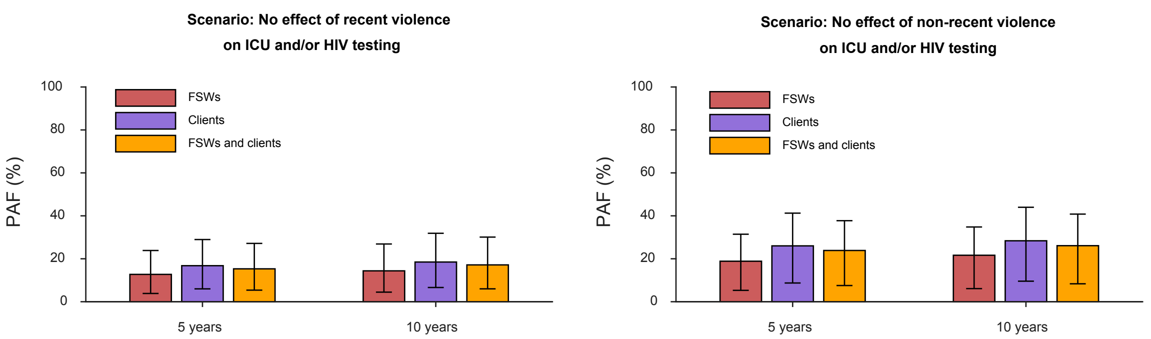


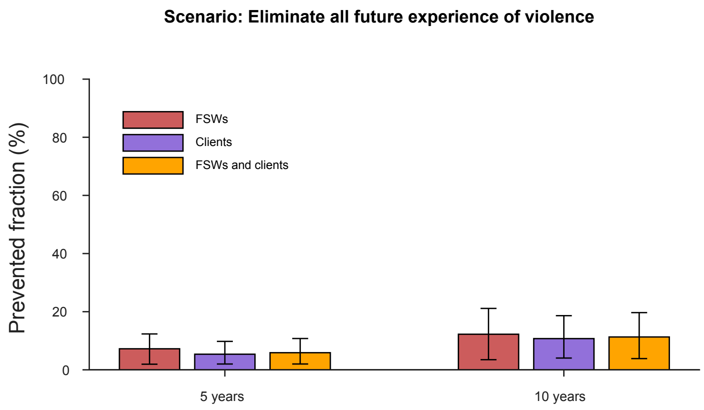
Figure 5.10 Population attributable fraction (PAF) of violence against FSWs over 2015-2020 and 2015-2025 (i.e. 5-year and 10-year PAF) in the following scenarios where various effects of violence are removed: (A) remove all effects of sexual violence, physical violence and police assault or arrest on ICU and/or HIV testing (i.e. full PAF); (B) remove effects of sexual violence, physical violence and police assault or arrest on ICU and/or HIV testing in turn; (C) remove effects of recent violence and non-recent violence on ICU and/or HIV testing in turn. The PAF calculated among female sex workers (FSWs), clients, and the whole population (i.e. FSWs and their clients) are shown. Coloured bars and error bars represent the median value of the model fits and the 95% credible interval of the model fits, respectively.

5.4.3 Impact of preventing violence

Model estimates of the potential fraction of HIV infections averted ('prevented fraction') by different violence interventions are presented in Figure 5.11. The model suggests that preventing all future experiences of violence from 2015 onwards (Intervention 1) could avert 5.9% (95% CrI: 2.0-10.8%) of all new HIV infections among FSWs and their clients over the first 5 years, and 11.3% (95% CrI: 3.9-19.7%) of all new HIV infections among FSWs and their clients over 10 years (Figure 5.11A). The prevented fractions were similar across risk groups (Figure D3 in Appendix D). As expected from PAF results, the majority of HIV infections averted were due to the impact of eliminating future experience of sexual violence (10-year prevented fraction for FSWs and clients = 11.2% [95% CrI: 3.5-19.5%]). If violence was eliminated and combined with additional support to reduce the long-term negative impacts of previous violence experiences (Intervention 2), then substantially more HIV infections could be averted among FSWs and their clients (10-year prevented fraction: 40.2% [95%CrI: 14.0-57.4%]) (Figure 5.11B). The prevented fraction of Intervention 2 is equivalent to the full-PAF estimate, as the intervention is essentially removing all the negative impacts of violence from 2015 onwards (i.e. it is a perfect intervention). For Intervention 2, the model predicted that a greater fraction of new HIV infections would be averted among clients than FSWs (10-year prevented fractions: 32.8% [95% CrI: 10.3-50.0%] among all FSWs, and 42.6% [95% CrI: 15.9-59.5%] among clients).

The model also suggests that with Intervention 2 (i.e. violence elimination + address long-term impacts of violence) there would be greater reductions in HIV prevalence among FSWs and their clients, and larger increases in ART coverage (% of HIV positive on ART) than with Intervention 1 (i.e. violence elimination alone) (see Figure 5.12, and Figures D4 and D5 in Appendix D). Preventing future experiences of violence from 2015 in combination with support to address the long term negative impact of violence (Intervention 2), could lead to a relative reduction in HIV prevalence among FSWs of 22.3% (95% CrI: 5.8-35.1%), and an increase in ART coverage among FSWs of 6.8% (95% CrI: 2.9-12.3%). Preventing future experiences of violence from 2015 without additional support to address the long-term negative impacts of violence (Intervention 1), could lead to a relative reduction in HIV prevalence among FSWs of 9.5% (95% CrI: 2.4-17.5%) and an increase in ART coverage among FSWs of 4.1% (95% CrI: 1.8-7.9%).

(A)



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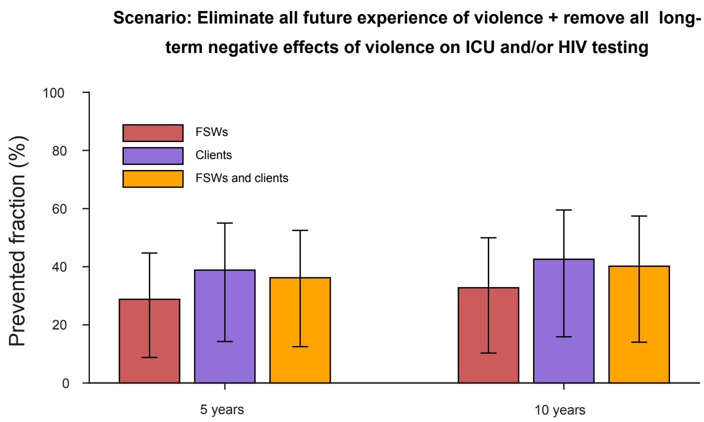

Figure 5.11 Prevented fraction (i.e. percentage of HIV infections potentially averted) among FSWs and their clients over 5 and 10 years due to the following intervention scenarios: Intervention 1 - Eliminate all future experiences of violence from 2015; Intervention 2 - Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured bars and error bars represent the median value of the model fits and the 95% credible interval of the model fits, respectively.

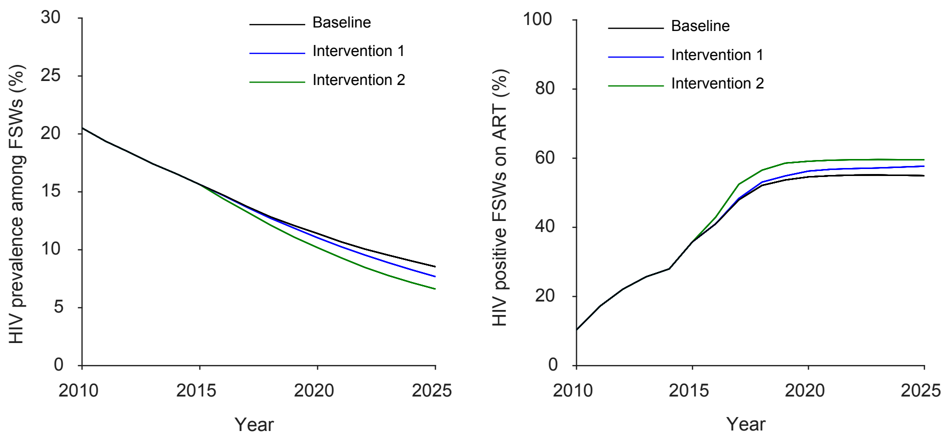

Figure 5.12 Impact of violence interventions on HIV prevalence and ART coverage (% of HIV positive on ART) among FSWs. Intervention 1 - Eliminate all future experiences of violence from 2015; Intervention 2 - Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured lines show the median of the model projections.

5.4.4 Sensitivity analysis

A PRCC analysis was conducted to identify which calibrated parameters had the most influence on the PAF and prevented fraction estimates. Table D8-D10 in Appendix D shows the PRCC values for the full-PAF and the prevented fraction for interventions 1 and 2. The strongest correlations were observed for the parameters that govern condom use in the model, and this finding was consistent across risk groups and outcomes. The relative risk of ICU due to sexual violence was the parameter most strongly positively associated with the full-PAF and prevented fractions, with the PRCC ranging between 0.8 and 0.9. Other condom use related parameters that were also strongly positively associated with each outcome (PRCC >0.5) were the fraction of young FSWs inconsistently using condoms (in the absence of sexual violence), the fraction of sex acts protected if condoms are used consistently, and the efficacy of condoms in reducing HIV transmission per sex act (Tables D8-D10).

5.5 Discussion

In this chapter, I developed a model of violence against FSWs and HIV transmission among FSWs and their clients in dynamic Mombasa, Kenya, and calibrated it to the available data from Mombasa. I used this model to explore the contribution of violence to HIV transmission and the potential impact of violence prevention on HIV transmission among FSWs and their clients.

5.5.1 Summary of key results

The modelling results suggest that about 40% of new HIV infections among FSWs and their clients between 2015 and 2025 could potentially be due to violence against FSWs, which is primarily due to the elevated risk of ICU due to sexual violence. A large fraction of new HIV infections were also attributed to non-recent experiences of violence, highlighting the important contribution of the long-term negative effects of violence on HIV transmission. As such, if violence is eliminated in combination with support to address the long-term negative effects of historical violence exposure, we would expect a substantial reduction in new HIV infections among FSWs and their clients between 2015 and 2025 (i.e. approximately 40%), and there could also be a 22% relative reduction in HIV prevalence among FSWs, and an 7% increase in the fraction of HIV positive FSWs on ART. Due to the sustained negative impact of sexual violence on condom use, much less impact is achieved by an intervention which prevents future violence but does not address the long-term consequences of historical exposure to violence. Nevertheless, preventing future experiences of violence, could still potentially avert about 11% of new HIV infections among FSWs and their clients between 2015 and 2025.

In contrast to ICU, the results suggested that the influence of violence on HIV testing uptake does not contribute significantly to HIV transmission. This is because HIV testing uptake among FSWs was already high, and because the fraction of FSWs HIV aware who initiate treatment was not that high, and was particularly low among YFSWs. This meant that eliminating the small reduced testing uptake associated with violence did not result in large increases in ART coverage, and so the indirect benefits of increasing the number of FSWs on ART, who are less likely to transmit HIV, was more limited.

Across risk groups, PAF estimates were largest for clients, and the intervention eliminating future violence combined with support to address the long-term negative effects of violence (Intervention 2), was predicted to avert more HIV infections among clients than FSWs (about 43% among clients versus about 33% among FSWs). This finding is partially due to the influence of violence on HIV testing uptake, and therefore ART coverage. When the reduced uptake of HIV testing due to violence is removed, more HIV positive FSWs can be initiated onto ART, and this indirectly benefits clients as FSWs on ART are less likely to transmit HIV to their clients. Furthermore, although removing the elevated risk of ICU due to sexual violence benefits both FSWs and their clients, the substantial improvement in condom use could have a greater influence on HIV acquisition among clients, as clients have fewer partners than FSWs, and so their hazard of infection may be reduced more than for FSWs who have a greater number of partners. The prevented fraction among FSWs and clients were more similar in the intervention which prevented future experiences of violence but did not address the long-term negative impacts of violence. This could partially be due to a slower increase in ART coverage among FSWs in this intervention (Figure 5.12), and the slower improvements in ICU that occur in this intervention (Figure D6 in Appendix D).

The model was able to reproduce well data on FSWs from the Transitions study and other available sources, providing plausible trends in HIV prevalence and ART coverage among each risk group, and matching well current estimates of violence prevalence among young FSWs. This would suggest that the model provides a reasonable representation of violence and HIV infection dynamics among FSWs and clients in Mombasa, Kenya. However, the model did slightly underestimate the prevalence of experiencing both sexual violence and physical violence among young FSWs. This has the potential to underestimate the PAF and prevented fraction if experiencing multiple types of violence compounds HIV risks, as was assumed for the reduced uptake in HIV testing due to violence. Nevertheless, as the negative effect of violence on HIV testing uptake contributed relatively little to HIV transmission, it is unlikely that this discrepancy between model and data would have a large impact on the results. In addition, data suggest that the prevalence projections for police harassment among older FSWs may be an underestimate.

However, given that the contribution of violence to HIV transmission was mainly driven by sexual violence, it is unlikely that this discrepancy would influence the model results. The model also underestimated some early FSW HIV prevalence estimates, but these empirical estimates may reflect a cluster of more high risk FSWs which may not be representative of all older FSWs at that time [53,54]. The model projections of client HIV prevalence were also higher in general than estimates from general population demographic health surveys (DHS), although DHS HIV prevalence estimates for clients could be underestimated due to social desirability bias [25,26,55].

5.5.2 Implications

Taken together, the results from this modelling analysis indicate that violence against FSWs is an important contributor to HIV transmission among FSWs and their clients in Mombasa, Kenya, and that structural interventions addressing violence and its negative impacts, particularly its negative impacts on condom use, will be crucial for the HIV prevention efforts in Kenya. This finding is consistent with the previous Shannon *et al* modelling study, which found that eliminating client sexual violence could avert a substantial fraction of HIV infections among FSWs and their clients (about 17%) due to its assumed negative impact on condom use [2]. However, the estimates from my analysis are larger than those estimated in this prior study, as in my analysis I assume that there is an elevated risk of ICU among FSWs who have recently and non-recently experienced sexual violence. In contrast, the prior study assumed no long-term negative effects of client sexual violence, as at the time in Kenya there was no available data on either the magnitude or duration of impact of client sexual violence on ICU. These results also potentially highlight the importance of providing support to FSWs who previously experienced violence in combination with interventions to prevent future violence. Due to the long-term negative impact of violence, preventing future violence alone without this additional support may have a more limited impact on HIV transmission, as many FSWs have already experienced violence and may continue to have elevated HIV risks unless support is provided to mitigate the negative effects of violence in the long-term. Given that the effect of violence on HIV transmission was mainly driven by the effect of violence on condom use, it is important that future studies and existing programmes with FSWs seek to better understand the relationship between violence and condom use and why condoms are not used, so that strategies can be implemented to reduce the elevated risk of ICU among those who have experienced violence. Interestingly, eliminating the small reduced testing uptake associated with violence did not result in large increases in ART coverage, which contradicts the hypothesis that addressing structural factors would be important for scaling up ART. However, as HIV testing was already high, it is likely that other stages in the HIV care cascade (e.g. linkage to HIV care once diagnosed) would need to be improved to increase

ART coverage among FSWs in this context. It will be important to conduct further studies to examine the effect of different types of violence in FSW's engagement across the entire continuum of HIV care and treatment.

5.5.3 Limitations and strengths

It is important to interpret these findings in light of several limitations. One limitation is that the model assumed a constant rate of violence. It is challenging, however, to determine if violence against FSWs has changed over time, due to the varying definitions, time periods and study populations of existing violence prevalence estimates among FSWs in Mombasa. Recent pooling booth surveys conducted in 2014 and 2015 indicate that prevalence of police assault or arrest may have increased, while the prevalence of sexual violence was similar in both years (Figure 5.8) [3], so future work could consider a non-constant rate of police violence. However, in the context of the findings in this study, incorporating a non-constant rate of police violence is unlikely to impact the results, as the assumed influence of police assault or arrest on HIV testing did not contribute significantly to HIV transmission. Further studies, that measure experiences of violence in the same way over time, could help to identify any trends in prevalence of violence, which could be incorporated into model projections.

Another limitation is that rates of violence and the magnitude and duration of effect of violence on ICU and HIV testing uptake among older FSWs were assumed to be the same as for young FSWs, due to a lack of comparable data among older FSWs in Mombasa from the existing literature. Further studies are needed to understand if there are differences in rates of experiencing violence and differences in HIV risks associated with violence among young and older FSWs. In particular, it is important to decrease uncertainty in the magnitude of elevated risk of ICU due to sexual violence, as my sensitivity analysis identified that this was the parameter most strongly associated with the PAF estimates and predicted prevention fraction of violence interventions. In addition, although it was assumed that there was elevated risk of ICU among all FSWs who had ever experienced sexual violence, there also remains uncertainty over the duration of elevated ICU risk due to sexual violence. A supplementary analysis of Transitions data suggested that there could be a delayed effect of sexual violence on ICU, as recent sexual violence was not significantly associated with ICU with clients among young FSWs (Table D11 in Appendix D). If this is the case, then these findings may overestimate the PAF due to violence. But even under this alternative assumption, the analyses presented suggest that the PAF due to sexual violence would still be substantial due to the long-term negative impact on ICU (Figure 5.10C). This hypothesis was confirmed in a supplementary sensitivity analysis, where I re-calibrated the model and re-estimated the PAF assuming that recent sexual violence did not elevate risk of ICU (Figure D7 in Appendix D). To reduce the uncertainty in model projections, further studies are needed to better understand the short and long-term impacts of violence on HIV risk, and if these differ between young and older FSWs.

It is also a limitation that the data used to parameterise the effect of violence on ICU and HIV testing uptake in the model was based on a cross-sectional study. Causality cannot be determined in cross-sectional study, but the model makes the assumption that there is a causal relationship. Longitudinal studies would be needed to strengthen the evidence for these directions of associations and hypothesised casual pathways between violence and HIV infection.

There are also limitations with the violence interventions modelled, as they make the assumption that future experiences of violence and the risks associated with violence are totally eliminated immediately at the start of the intervention. However, in reality reductions in violence and improvements in condom use and HIV testing are more likely to occur slowly, and it is unlikely that all violence will be totally eliminated or that all the long-term negative effects of violence will be completely removed. It may also be difficult to reach all FSWs who have experienced violence to provide support to reduce the negative effects of violence. Thus, the results may overestimate the impact of violence interventions. Nevertheless, the purpose of these intervention scenarios was to demonstrate the maximum potential benefits of violence prevention. Future work could consider more realistic violence reduction scenarios, which could be informed by evaluations of violence interventions.

Furthermore, this analysis only considers HIV transmission between FSWs and their clients, and does not take into account FSWs intimate partnerships. Violence by intimate partners is common among FSWs in Kenya, and a recent study found that recent violence from intimate partners was associated with unprotected sex among HIV positive FSWs in Mombasa [56]. In my analysis of Transitions data in Chapter 4, I also found that some forms of violence (physical violence and police assault or arrest) were associated with inconsistent condom use with intimate partners. Therefore, these modelling results may underestimate the contribution of violence to HIV transmission in Mombasa, and in particular are likely to underestimate the contribution of physical violence and police assault or arrest to HIV transmission. Future expansions of the model may benefit from incorporating additional risk groups in the model, such as intimate partners. It is also possible that violence may impact other HIV risk factors that were not examined in the prior analyses conducted, so further studies are needed to continue exploring the pathways through which violence against FSWs in Mombasa influences HIV risk and transmission. It may also be important to consider for inclusion in the model other factors which interact with violence to increase HIV risk. For example, supplementary analysis of Transitions data indicated that the association of violence with reduced HIV testing uptake may be influenced by FSWs alcohol use (Table D12 in Appendix D). However, given that the influence of violence on

HIV testing uptake was found not to contribute significantly to HIV transmission, the influence of this interaction on the model projections was not investigated further.

In my analysis of Transitions data in Chapter 3, I also found a significant association between sexual violence and physical violence, however I did not include any between-violence dynamics in the model. The absence of this violence dynamic could be why there was a slight discrepancy in prevalence of experiencing both sexual violence and physical violence, which as discussed previously has the potential to underestimate results when experiencing multiple types of violence compounds HIV risks. However, from the data it is challenging to determine more about the relationship between physical and sexual violence, and whether one type of violence proceeds another. Furthermore, I found in this data analysis that a number of FSWs had experienced sexual violence before their entry into sex work, but in my model I made the assumption that all FSWs entered sex work with no prior experience of violence. As my primary violence outcome of interest was prevalence of violence, which was fitted to the Transitions data, this assumption is unlikely to affect the results, but if incidence of violence was the primary outcome of interest this is an important limitation that would likely lead to an overestimate of incidence of violence. Nevertheless, it is difficult to accurately capture the start of entry into sex work, and thus difficult to fully understand FSWs experiences of violence before sex work from the data analysis.

A further limitation is that the model did not include migration of FSWs and their clients. FSW and client migration patterns, however, could influence HIV transmission and the impact of HIV interventions, because of the potential for changes in sexual behaviours and other HIV risks between home and migrant destinations [2,57-59]. Given that Mombasa is a major port city and transit stop in Kenya, which attracts many tourists and sex workers from elsewhere [6,60-62], it may be important in future work to develop a model that can consider the influence of FSW and client migration on model results. However, the links between migration and HIV and violence are complex [2,57,58,63,64], and currently there is a lack of quantitative data on sexual behaviours and experiences of violence among migrant FSWs and clients in Mombasa [5,65]. It is also a limitation of the model that FSWs stay in sex work for a specified duration, without movement in and out of sex work.

Lastly, the results from this analysis may not be generalizable to other settings, as the model was parameterised and calibrated to the context of sex work in Mombasa, Kenya. However, as the burden of violence is high in other settings, and other studies have also found that violence elevates risk of non-condom use [2,63], it is likely in other settings that violence against FSWs may also be contributing significantly to HIV transmission.

Despite the limitations described, this is one of the first modelling studies to investigate the contribution of violence against FSWs to HIV transmission and evaluate the potential impact that preventing violence against FSWs could have on the HIV epidemic. A key strength of this analysis is that the model development, parameterisation and calibration utilised novel context-specific estimates of violence and its effect on HIV risk among FSWs in Mombasa, Kenya. This improves upon the existing modelling study in Kenya [2], which did not use data specific to Mombasa on the impact of sexual violence on ICU among FSWs. This study further extends the prior work by considering multiple types of violence, and so is the first study to date in the Kenya to investigate the contribution of physical violence and police assault or arrest among FSWs to HIV transmission in Kenya. This study was also novel in that it considered the role of violence on HIV testing uptake and how this influences HIV transmission. Another strength of this analysis was that the model calibration approach allows the model results to take into account uncertainty in the data. Finally, a key strength is that the model was fitted and compared to multiple different types of outcomes.

5.5.4 Conclusion

In conclusion, these results provide evidence to highlight the important contribution of violence against FSWs to HIV transmission among FSWs and their clients in Mombasa, Kenya, and that structural interventions addressing violence and the long-term negative effects of violence on non-condom use will be crucial in ongoing HIV prevention efforts among FSWs in Kenya.

5.6 References

1. NASCOP. National Guidelines For HIV/STI Programming With Key Populations. 2014.
2. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
3. National AIDS & STI Control Programme MoH, Kenya. Second National Behavioural Assessment of Key Populations in Kenya: Polling Booth Survey Report. Nairobi: NASCOP: 2016.
4. Chersich MF, Bosire W, King'ola N, Temmerman M, Luchters S. Effects of hazardous and harmful alcohol use on HIV incidence and sexual behaviour: a cohort study of Kenyan female sex workers. Global health. 2014;10:22
5. Luchters S, Richter ML, Bosire W, et al. The Contribution of Emotional Partners to Sexual Risk Taking and Violence among Female Sex Workers in Mombasa, Kenya: A Cohort Study. PLoS ONE. 2013 07 Aug;8(8)
6. Pack AP, L'Engle K, Mwarogo P, Kingola N. Intimate partner violence against female sex workers in Mombasa, Kenya. Cult Health Sex. 2013 Dec 11;11:11
7. Parcesepe AM, KL LE, Martin SL, et al. The impact of an alcohol harm reduction intervention on interpersonal violence and engagement in sex work among female sex workers in Mombasa, Kenya: Results from a randomized controlled trial. Drug Alcohol Depend. 2016 Apr 1;161:21-8
8. Boily MC, Baggaley RF, Wang L, et al. Heterosexual risk of HIV-1 infection per sexual act: systematic review and meta-analysis of observational studies. The Lancet infectious diseases. 2009 February;9(2):118-29
9. Donnell D, Baeten JM, Kiarie J, et al. Heterosexual HIV-1 transmission after initiation of antiretroviral therapy: a prospective cohort analysis. Lancet. 2010;375(9731):2092-8
10. Hollingsworth TD, Anderson RM, Fraser C. HIV-1 transmission, by stage of infection. J Infect Dis. 2008 01 Sep;198(5):687-93
11. Baggaley RF, White RG, Hollingsworth TD, Boily MC. Heterosexual HIV-1 infectiousness and antiretroviral use: systematic review of prospective studies of discordant couples. Epidemiology (Cambridge, Mass). 2013 Jan;24(1):110-21
12. Hughes JP, Baeten JM, Lingappa JR, et al. Determinants of per-coital-act HIV-1 infectivity among African HIV-1-serodiscordant couples. The Journal of infectious diseases. 2012 Feb 1;205(3):358-65
13. Pinkerton SD, Abramson PR. Effectiveness of condoms in preventing HIV transmission. Social science & medicine (1982). 1997 May;44(9):1303-12
14. Weller S, Davis K. Condom effectiveness in reducing heterosexual HIV transmission. Cochrane database of systematic reviews (Online). 2002 (1):CD003255
15. Cori A, Ayles H, Beyers N, et al. HPTN 071 (PopART): a cluster-randomized trial of the population impact of an HIV combination prevention intervention including universal testing and treatment: mathematical model. PLoS One. 2014;9(1):e84511
16. Mishra S, Mountain E, Pickles M, et al. Exploring the population-level impact of antiretroviral treatment: the influence of baseline intervention context. Aids. 2014 Jan;28:S61-S72
17. Graham SM, Jalalian-Lechak Z, Shafi J, et al. Antiretroviral treatment interruptions predict female genital shedding of genotypically resistant HIV-1 RNA. J Acquir Immune Defic Syndr. 2012 15 Aug;60(5):511-8
18. NASCOP. Annual Health Sector HIV Report 2009. 2010.
19. Odek WO, Githuka GN, Avery L, et al. Estimating the size of the female sex worker population in Kenya to inform HIV prevention programming. PLoS ONE. 2014 03 Mar;9 (3) (no pagination)(e89180)
20. Pickles M, Boily MC, Vickerman P, et al. Assessment of the population-level effectiveness of the Avahan HIV-prevention programme in South India: a preplanned, causal-pathway-based modelling analysis. Lancet Glob Health. 2013 Nov;1(5):e289-99

21. NACC and NASCOP. Kenya AIDS Epidemic update 2011. Nairobi, Kenya: 2012.
22. Ministry of Health and NASCOP. Guidelines on Use of Antiretroviral Drugs for Treating and Preventing HIV Infection: A rapid advice, 2014. 2014.
23. NASCOP. Guidelines for antiretroviral therapy in Kenya. 2011.
24. Ministry of Health NASCP. Guidelines on Use of Antiretroviral Drugs for Treating and Preventing HIV Infections in Kenya. Nairobi, Kenya: 2016.
25. Central Bureau of Statistics [Kenya], Ministry of HEalth [Kenya], and ORC Macro. Demographic and Health Survey 2003. Calverton, Maryland: CBS, MOH, and ORC Macro: 2004.
26. Kenya National Bureau of Statistics and ICF Macro. Kenya Demographic and Health Survey 2008-09. Calverton, Maryland: KNBS and ICF Macro: 2010.
27. Vandenhoudt HM, Langat L, Menten J, et al. Prevalence of HIV and other sexually transmitted infections among female sex workers in Kisumu, Western Kenya, 1997 and 2008. PLoS ONE [Electronic Resource]. 2013;8(1):e54953
28. NASCOP and NACC. Kenya HIV Estimates 2015. 2016.
29. Luchters S, Chersich MF, Rinyiru A, et al. Impact of five years of peer-mediated interventions on sexual behavior and sexually transmitted infections among female sex workers in Mombasa, Kenya. BMC Public Health. 2008;8 (no pagination)(143)
30. Parcesepe AM, L'Engle KL, Martin SL, Green S, Suchindran C, Mwarogo P. Early Sex Work Initiation and Violence against Female Sex Workers in Mombasa, Kenya. J Urban Health. 2016 Dec;93(6):1010-26
31. McClelland RS, Richardson BA, Cherutich P, et al. A 15-year study of the impact of community antiretroviral therapy coverage on HIV incidence in Kenyan female sex workers. Aids. 2015 01 Nov;29(17):2279-86
32. Thomsen SC, Ombidi W, Toroitich-Ruto C, et al. A prospective study assessing the effects of introducing the female condom in a sex worker population in Mombasa, Kenya. Sex Transm Infect. 2006 October;82(5):397-402
33. Voeten HACM, Egesah OB, Ondiege MY, Varkevisser CM, Habbema JDF. Clients of female sex workers in Nyanza Province, Kenya: A core group in STD/HIV transmission. Sex Transm Dis. 2002;29(8):444-52
34. Tegang SP, Abdallah S, Emukule G, et al. Concurrent sexual and substance-use risk behaviours among female sex workers in Kenya's Coast Province: findings from a behavioural monitoring survey. Sahara J. 2010 Dec;7(4):10-6
35. Lafort Y, Greener R, Roy A, et al. HIV prevention and care-seeking behaviour among female sex workers in four cities in India, Kenya, Mozambique and South Africa. Tropical Medicine and International Health. 2016 01 Oct;21(10):1293-303
36. Zwahlen M. Duration from seroconversion to eligibility for antiretroviral therapy and from ART eligibility to death in adult HIV-infected patients from low and middle-income countries: Collaborative analysis of prospective studies: The eligibility for ART in lower income countries (eART-linc) collaboration. Sex Transm Infect. 2008 August;84(SUPPL. 1):i31-i6
37. Lodi S, Phillips A, Touloumi G, et al. Time from human immunodeficiency virus seroconversion to reaching CD4+ cell count thresholds <200, <350, and <500 Cells/mm³: Assessment of need following changes in treatment guidelines. Clinical Infectious Diseases. 2011 15 Oct;53(8):817-25
38. Morgan D, Malamba SS, Orem J, Mayanja B, Okongo M, Whitworth JAG. Survival by AIDS defining condition in rural Uganda. Sex Transm Infect. 2000;76(3):193-7
39. Kumarasamy N, Solomon S, Flanigan TP, Hemalatha R, Thyagarajan SP, Mayer KH. Natural history of human immunodeficiency virus disease in southern India. Clinical Infectious Diseases. 2003 01 Jan;36(1):79-85
40. Lewden C, Gabillard D, Minga A, et al. CD4-specific mortality rates among HIV-infected adults with high CD4 counts and no antiretroviral treatment in West Africa. []. JAIDS Journal of Acquired Immune Deficiency Syndromes. 2011;25

41. Anglaret X, Minga A, Gabillard D, et al. AIDS and non-AIDS morbidity and mortality across the spectrum of CD4 cell counts in HIV-infected adults before starting antiretroviral therapy in Cote d'Ivoire. Clinical Infectious Diseases. 2012 01 Mar;54(5):714-23
42. Hernan MA. The effect of combined antiretroviral therapy on the overall mortality of HIV-infected individuals. Aids. 2010 January;24(1):123-37
43. Kitahata MM, Gange SJ, Abraham AG, et al. Effect of early versus deferred antiretroviral therapy for HIV on survival. New England Journal of Medicine. 2009 30 Apr;360(18):1815-26
44. Ghate M, Deshpande S, Tripathy S, et al. Mortality in HIV infected individuals in Pune, India. Indian Journal of Medical Research. 2011 April;133(4):414-20
45. Blower SM, Dowlatabadi H. Sensitivity and Uncertainty Analysis of Complex Models of Disease Transmission: an HIV Model, as an Example. International Statistical Review. 1994;62(2):229-43
46. Pickles M, Foss AM, Vickerman P, et al. Interim modelling analysis to validate reported increases in condom use and assess HIV infections averted among female sex workers and clients in southern India following a targeted HIV prevention programme. Sex Transm Infect. 2010 February;86(SUPPL. 1):i33-i43
47. Chersich MF, Luchters SMF, Malonza IM, Mwarogo P, King'ola N, Temmerman M. Heavy episodic drinking among Kenyan female sex workers is associated with unsafe sex, sexual violence and sexually transmitted infections. Int J STD AIDS. 2007 Nov;18(11):764-9
48. Luchters SMF, Broeck DV, Chersich MF, et al. Association of HIV infection with distribution and viral load of HPV types in Kenya: A survey with 820 female sex workers. BMC Infectious Diseases. 2010 26 Jan;10 (no pagination)(18)
49. Mishra S. Using mathematical models to characterize HIV epidemics for the design of HIV prevention strategies (PhD thesis): Imperial College London; 2014.
50. Wu J, Dhingra R, Gambhir M, Remais JV. Sensitivity analysis of infectious disease models: methods, advances and their application. Journal of the Royal Society, Interface. 2013 Sep 6;10(86):20121018
51. NACC and NASCOP. Kenya HIV County Profiles. 2016.
52. Githuka G, Hladik W, Mwalili S, et al. Populations at increased risk for HIV infection in Kenya: Results from a national population-based household survey, 2012. J Acquir Immune Defic Syndr. 2014 01 May;66(SUPPL. 1):S46-S56
53. Baeten JM, Richardson BA, Martin Jr HL, et al. Trends in HIV-1 incidence in a cohort of prostitutes in Kenya: Implications for HIV-1 vaccine efficacy trials. J Acquir Immune Defic Syndr. 2000 15 Aug;24(5):458-64
54. Kavanaugh BE, Odem-Davis K, Jaoko W, et al. Prevalence and correlates of genital warts in kenyan female sex workers. Sex Transm Dis. 2012 November;39(11):902-5
55. Mishra S, Boily MC, Schwartz S, et al. Data and methods to characterize the role of sex work and to inform sex work programs in generalized HIV epidemics: evidence to challenge assumptions. Annals of Epidemiology. 2016 01 Aug;26(8):557-69
56. Wilson KS, Wanje G, Yuhas K, et al. A Prospective Study of Intimate Partner Violence as a Risk Factor for Detectable Plasma Viral Load in HIV-Positive Women Engaged in Transactional Sex in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2065-77
57. Cassels S, Jenness SM, Khanna AS. Conceptual framework and research methods for migration and HIV transmission dynamics. Aids Behav. 2014 01 Dec;18(12):2302-13
58. Deering KN, Vickerman P, Moses S, Ramesh BM, Blanchard JF, Boily MC. The impact of out-migrants and out-migration on the HIV/AIDS epidemic: a case study from south-west India. AIDS. 2008 Dec;22 Suppl 5:S165-81
59. Mishra S, Steen R, Gerbase A, Lo Y-R, Boily M-C. Impact of High-Risk Sex and Focused Interventions in Heterosexual HIV Epidemics: A Systematic Review of Mathematical Models. Plos One. 2012 Nov 30;7(11)
60. Hampanda KM. The social dynamics of selling sex in Mombasa, Kenya: a qualitative study contextualizing high risk sexual behaviour. Afr J Reprod Health. 2013 Jun;17(2):141-9

61. L'Engle KL, Mwarogo P, Kingola N, Sinkele W, Weiner DH. A randomized controlled trial of a brief intervention to reduce alcohol use among female sex workers in Mombasa, Kenya. J Acquir Immune Defic Syndr. 2014 Dec 1;67(4):446-53
62. Okal J, Chersich MF, Tsui S, Sutherland E, Temmerman M, Luchters S. Sexual and physical violence against female sex workers in Kenya: a qualitative enquiry. AIDS Care. 2011 May;23(5):612-8
63. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
64. Reed E, Gupta J, Biradavolu M, Blankenship KM. Migration/mobility and risk factors for HIV among female sex workers in Andhra Pradesh, India: Implications for HIV prevention. Int J STD AIDS. 2012 April;23(4):e7-e13
65. International Organization for Migration. Integrated biological and behavioural surveillance survey among migrant female sex workers in Nairobi, Kenya 2010. IOM, Nairobi, Kenya, 2011.

Chapter 6: Discussion

6.1 Overview

The work undertaken in this thesis has focussed on violence against FSWs and its links with HIV. Specifically, in Chapter 2, I developed a novel dynamic mathematical model to simulate experiences of workplace violence among FSWs in Vancouver, Canada, and utilised this model to characterise the dynamics of workplace violence, estimate incidence of workplace violence, and estimate the maximum impact of violence-related structural interventions on both workplace violence and inconsistent condom use among FSWs in Vancouver. In Chapter 3, I analysed data from a cross-sectional study of young women in Mombasa, to examine the burden and determinants of violence among YFSWs. Following on from this analysis, in Chapter 4, I examined whether violence against YFSWs is associated with HIV prevention programme exposure, inconsistent condom use, HIV/STI testing uptake and HIV infection. In Chapter 5, I developed, parameterised and calibrated a dynamic model of violence against FSWs and HIV transmission among FSWs and their clients in Mombasa, Kenya, utilising the findings from the data analyses conducted in Chapters 3 and 4. I then used this model to explore the contribution of violence against FSWs to HIV transmission and the maximum potential impact of violence prevention on HIV transmission among FSWs and their clients in Mombasa, Kenya. The analyses in these four chapters all contributed to addressing my overreaching thesis aims, which were:

1) To investigate the burden and determinants of violence against FSWs
    - Addressed in Chapters 2 and 3
2) To better understand the effects and contribution of violence against FSWs to HIV transmission
    - Addressed in Chapters 4 and 5
3) To estimate the potential impact of violence interventions for FSWs on HIV transmission
    - Addressed in Chapters 2 and 5

In undertaking this research, I hoped to help improve our understanding of the epidemiology and effects of violence against FSWs and the potential impact of violence interventions, and in doing so help inform the design and implementation of structural HIV prevention approaches and interventions for FSWs.

I have already discussed in detail my analyses and findings at the end of each relevant chapter. In this chapter I aim to provide a broad overview and synthesis of the key findings, strengths, limitations and implications of the work; and discuss future directions of the research. I also provide a framework for guiding future modelling studies of structural HIV determinants, and discuss the types of data needed for such modelling studies.

6.2 Synthesis of findings

There were a number of important findings for YFSWs in Mombasa, Kenya, that emerged from my data analyses conducted in Chapters 3 and 4. In particular, these analyses highlighted the many vulnerabilities of YFSWs in Mombasa, Kenya. By age 24, one in three YFSWs had experienced sexual violence, one in three had experienced physical violence, one in two had experienced police assault or arrest, and one in ten were HIV infected. In addition, a third drank alcohol almost every day or every day, over two-thirds did not use condoms consistently with intimate partners, and less than a fifth had been in contact with peers or staff from HIV prevention programmes. Conversely, and more encouragingly, the majority of young FSWs (over three-quarters) reported using condoms consistently with clients, and HIV testing uptake was high with over 80% reporting testing for HIV in the past year. When looking at determinants of violence in this population of YFSWs (Chapter 3), a key determinant of ever experiencing violence was heavy alcohol use, which was associated with a higher prevalence of lifetime physical violence and lifetime police assault or arrest. This finding was consistent with other studies in Kenya. Although, as the Transitions study is cross-sectional, alcohol use could be a coping mechanism among YFSWs who have experienced violence rather than a determinant factor. A novel finding of this analysis was that early experiences of violence influenced YFSW's likelihood of experiencing violence later on; specifically I found that YFSWs reporting a history of violence in the first month of sex work were more likely to report violence in the most recent month of sex work. Another important finding for YFSWs in Kenya, was that experiencing violence was associated with increased risk of ICU, reduced uptake of HIV testing and being HIV positive (Chapter 4), highlighting that violence could be undermining HIV prevention in Kenya.

Building on the findings from Chapter 4, which found associations between violence and HIV risk, prevention and infection, the modelling analyses in Chapter 5 indicated that the contribution (i.e. PAF) of violence against FSWs to HIV transmission could be considerable; with model estimates suggesting that 40% of all new HIV infections among FSWs and their clients in Mombasa, Kenya, between 2015 and 2025, could potentially be due to violence against FSWs. This large PAF was primarily driven by the short and long-term elevated risk of ICU due to experiencing sexual violence. In this analysis, the negative impact of violence on HIV testing uptake contributed marginally to HIV transmission. Taken together, these findings add to the growing evidence base that violence against FSWs is an important structural determinant and driver of HIV transmission [1,2], and that structural interventions addressing violence against FSWs will be crucial for HIV prevention.

A key theme emerging from my modelling analyses (Chapters 2 and 5) was the potential importance of addressing the long-term negative effects of violence against FSWs. In both settings (Vancouver and Mombasa), the largest impacts on HIV risks and/or HIV transmission (i.e. largest reductions in inconsistent condom use and/or HIV infections) were predicted by the model for violence interventions which coupled violence prevention with strategies that could reduce the long-term negative effects of violence on ICU. These findings concur with those from the recent Shannon *et al* modelling study, which estimated that elimination of police harassment and client violence alone in Vancouver would have a negligible impact on HIV infections averted over 10 years, whereas elimination of both police harassment and client violence, combined with support to address the sustained negative effects of violence on condom use, could avert 24% of HIV infections among FSWs and their clients over a decade [2].

Another important and novel finding from the modelling analysis in Vancouver (Chapter 2), was that due to the interaction between police harassment and client violence, structural interventions which eliminate police harassment could potentially reduce the prevalence of client physical violence and sexual violence by 20-30% over 5 years. This supports the growing calls to foster positive partnerships with police to help improve the safety of sex workers [3-5].

6.3. Strengths and unique contributions of work

A key strength of this thesis is the use of different and complementary approaches (statistical analysis and mathematical modelling) to understand violence against FSWs and its links with HIV.

The analyses undertaken in Chapters 3 and 4, provide the first quantitative data on the burden, determinants and effects of violence among YFSWs in Kenya, and also provide some of the first quantitative estimates of police assault and arrest of FSWs in Kenya. These data are particularly useful and important in light of the Kenya AIDS Strategic Framework 2014/15-18/19, which identifies young girls and women and sex workers as priority populations for the HIV response [6]. In January 2017, as part of the Transitions study team, I presented my findings from Chapter 3 at a dissemination workshop for the preliminary findings from the Transitions study. The workshop, which was held in Nairobi, Kenya, was held in partnership with the National AIDS and STI Control Programmes, the National AIDS Control Council, the International Centre for Reproductive Health Kenya, and the Centre for Global Public Health at the University of Manitoba, Canada, and was attended by Kenyan government officials, HIV prevention programmers, and other researchers. Thus, I have been able to directly disseminate some of my findings to key stakeholders involved in the HIV response in Kenya. A strength of this work and collaboration with the Transitions study team, is that as the study questionnaire was developed during the early stages of my PhD, I was able to provide input on questions relating to FSWs experiences of violence, sexual behaviours, work environment, alcohol use, and health care access (e.g. HIV testing uptake and ART use). This meant the questionnaire included items that would specifically address my research aims and be useful for parameterising mathematical models of violence and HIV transmission. More broadly, the data analyses I conducted also add to the limited literature on violence and HIV among YFSWs globally [7-10], as well as to the limited literature investigating the mediating factors between violence and HIV among FSWs.

The modelling analyses undertaken in Chapters 2 and 5 are some of the first modelling studies to investigate structural HIV determinants and structural HIV interventions in the context of sex work. The Vancouver modelling analysis is also the only study to date to utilise mathematical modelling to try and better understand and characterise violence dynamics, estimate incidence, and estimate the impact of structural interventions on other structural factors (i.e. impact of eliminating police harassment on client violence), while the Kenya modelling analysis is the first to estimate the PAF of different types of violence against FSWs. The Vancouver model I developed was a new model that imposed fewer restrictions on the dynamics of violence compared to the prior modelling study. This allowed me to explore additional research questions, and cross-validate the model to more outcomes. The Kenya modelling analysis improved upon the prior modelling work in the Kenyan context, by additionally considering physical violence and police assault or arrest, and by utilising data specific to Kenya on the impact of violence against FSW on HIV risks (i.e. condom use) and HIV prevention (i.e. HIV testing uptake) [2,11]. To the best of my knowledge, no other modelling studies to date in the sex work context have considered the role of structural factors on HIV testing uptake or other stages of the HIV care cascade.

Key strengths of my modelling analyses included that i) the models were developed, parameterised, and fit to context-specific data; ii) the models were calibrated within a Bayesian framework to take into account parameter uncertainties; iii) the models were fitted and compared to as much data and as many outcomes as was feasible, and iv) that sensitivity analyses were conducted to explore the influence of parameter uncertainty and model assumptions. An additional strength of the Vancouver modelling analysis is that longitudinal data was utilised to try and cross-validate some of the model outcomes.

There are also strengths with the key data utilised in this thesis. The AESHA cohort in Vancouver, is a large, open, longitudinal, community-based research cohort, that uses time-location sampling to help attain a representative sample of FSWs [12]. In the Transitions study, extensive mapping combined with a multi-stage probability-based cluster sampling approach was used to attain a representative sample of young women and sex workers. It is particularly rare for studies to have a representative sample of YFSWs.

6.4 Limitations

One of the main limitations of the thesis was the reliance on self-reported and cross-sectional data for the majority of the analyses in this thesis. There are many issues surrounding the quality and reliability of self-reported data on sexual behaviours and sensitive topics, such as violence. For example, social desirability bias and recall bias, could have led to under-reporting of some sensitive issues (e.g. violence), over-reporting of other issues (e.g. condom use), and inconsistent reporting of some behaviours and experiences (e.g. earlier violence experiences and age at start of sex work). The cross-sectional nature of the Transitions study also precluded assessments of causality in my data analyses. However, survey items in the Transitions study did provide some details on the life course and timing of violence (e.g. violence in the first and last month of sex work), which meant that I could conduct an analysis looking at re-victimisation. Furthermore, to address potential uncertainties in the data, my modelling analyses were conducted within a Bayesian framework, and sensitivity analyses were conducted to explore the influence of parameter values on the model results.

Data gaps were another key limitation for both the statistical and mathematical modelling analyses conducted. In the Transitions study, compromises had to be made on the amount and detail of data that could be collected on different topics of interest in the questionnaire, in order to ensure that the questionnaire was not too long. This meant that some potential questions of interest relating to violence against FSWs, could not be examined in my analyses. For example, as the Transitions survey only collected data on experiences of physical assault or arrest by law enforcement, other types of violence and abuse by law enforcement, such as harassment and extortion could not be assessed. This also means that there were potential determinants of violence that could not be examined (e.g. social cohesion, relationship power, or residential instability). Nevertheless, the data available and analyses conducted provide novel information that addresses a number of existing gaps in the literature. Data gaps were also a limiting factor in the design of the mathematical models, and meant that the models had to make a number of assumptions. For example, the Vancouver model was structured to reflect available data on prevalence of workplace violence ever and in the last 6 months, given the absence of frequency data, which results in a conservative model assumption that a maximum of one event of each type of workplace violence can occur in a 6 month period. In addition, due to limited data, it was assumed that FSWs remained in their given work environment and drug injecting status for the duration of sex work in the Vancouver model, which is unlikely to be an accurate representation of reality. In the Kenya model, a key assumption made due to limited data, was that rates of violence and the magnitude and duration of effect of violence on ICU and HIV testing uptake among older FSWs was the same as for young FSWs. There were also a limited amount of data for model fitting and comparison of baseline model projections to empirical estimates (e.g. HIV prevalence data among young FSWs, ART data for FSWs, and comparable violence data among older FSWs were all sparse). However, I fitted and compared the models to as many outcomes as was feasible, which is a strength of this analysis. This limitation also highlighted another broader issue relating to violence research, in that although there is a growing body of data on violence, the varying definitions and time-periods of violence make it difficult to make direct comparisons between studies. This was also an issue in Chapter 3 when comparing my descriptive analyses on violence to other available data in Kenya.

There are also methodological limitations with the interventions I modelled (Chapters 2 and 5), as they make the assumption that future experiences of violence and the risks associated with violence are totally eliminated immediately at the start of the intervention. In reality, complete elimination of violence is unlikely, and reductions in violence and improvements in condom use and HIV testing are more likely to occur slowly. Thus, the results are likely to be overestimates of the impact of structural interventions. Nevertheless, the purpose of these intervention scenarios was to provide estimates of the maximum potential impact of structural interventions.

It is also important to note that other methodological approaches for the mathematical modelling could have been taken, for example an individual-based model could have been used instead of a deterministic, compartmental model. Although individual-based models are more flexible than compartmental-based models and can incorporate more complexity, they also require lots of data, are more computationally demanding, and can be difficult to interpret and replicate. Given the current data limitations, I used deterministic compartmental models in my thesis. Furthermore, modelling violence and HIV transmission is complex, and models will not be able to capture all aspects of sex work, violence, HIV infection, treatment and care, and migration/mobility of FSWs and their clients. In my modelling, some structural aspects were kept as simple as possible (e.g. HIV infection and care cascade), and other assumptions were also made for model parsimony (e.g. no interactions between violence types, no experience of violence prior to sex work in the Kenya model, and no migration/mobility of FSWs and their clients). My aim was to ensure that the models were as simple as possible in order to effectively interpret and communicate results, while also being of adequate complexity to capture the key features of interest for the research question being addressed [13-15]. The potential influence of different simplifying assumptions made were discussed in detail in the relevant chapters.

Another broader limitation of this work, is that the findings in this thesis may not be generalisable to other settings, due to the context specific nature of structural HIV determinants. However, as there is a heavy burden of violence among FSWs in other settings, and these experiences of violence have been associated with a number of negative impacts, including reduced condom use

[2,16], it is likely that the PAF of violence would also be large in other settings. Furthermore, as highlighted in this thesis, the dynamic model of violence I developed can be adapted to different settings, so that the contribution of violence against FSWs and potential impact of violence interventions can be investigated elsewhere.

6.5 Implications and future research directions

6.5.1 Kenya

The work in this thesis has a number of important implications for the HIV response and for FSW programmes in the Kenyan setting. Taken together, the results highlight the need to prevent and address violence against FSWs as part of the HIV response in Kenya, in order to improve the health and safety of YFSWs. The heavy burden of violence and other vulnerabilities among young FSWs in Mombasa, emphasise the importance of reaching YFSWs and linking them to sex work programmes, violence prevention and response services, and other health, HIV prevention and care services. FSW programmes in Kenya will need to prioritise young sex workers, and enable them to understand violence, understand their rights and inform them about violence prevention and response services within and outside the programmes, and should have good assessment and screening processes in place (e.g. during their intake process) to ask YFSWs about their experiences of violence. YFSWs are at risk for violence and HIV, but are often a particularly hard population to reach, so future qualitative and quantitative work is needed to elucidate how best to reach YFSWs with the services and support they need. Violence prevention and response services themselves could provide an opportunity to identify YFSWs who have not yet been reached and enrolled in HIV programmes. The results also offered some insights for violence prevention strategies. For example, YFSWs with a regular source of income had a lower prevalence of violence, so implementing and targeting economic strengthening or empowerment interventions could help to reduce violence among YFSWs. Furthermore, the high prevalence of police physical assault and arrest reported highlights the importance of fostering positive partnerships with police as a key component of the HIV response for FSWs in Kenya. Prevention strategies that are targeted to and directly involve other perpetrators of violence, such as intimate partners and clients, should also be considered [17,18]. For example, in Karnataka, India, a multi-level intervention programme, called Samvedana Plus, works with intimate partners of FSWs, as well as with FSWs themselves, the sex worker community and the general population, with the aim of reducing violence and increasing condom use within FSWs intimate partner relationships [17]. The programme, which is being evaluated using a cluster RCT approach, involves shifting norms about beating as a form of discipline, challenging gender roles, and encouraging gender equity and respect in intimate partner relationships [17].

To understand the effectiveness of different strategies to reduce violence against YFSWs in Kenya, it will be important to undertake violence intervention trials and evaluate any new or existing violence prevention components of FSW programmes, utilising pre-designed surveys to examine how the burden of violence among YFSWs changes. To help hone the important questions and definitions of violence to use in monitoring surveys for trial and programme evaluations, additional quantitative and qualitative research is needed to provide more information on the types of violence affecting YFSWs, which is differentiated to look at specific types and perpetrators of violence in more detail.

The work also underscored the importance of addressing the long-term negative effects of violence for an effective HIV response. Particularly, it is important that future quantitative and qualitative work is undertaken to better understand the relationship between violence and condom use and why condoms are not used, so that strategies can be implemented to reduce the long-term elevated risks of ICU among YFSWs who have experienced violence.

Future quantitative and qualitative work should continue to further explore the effects of violence and the plausible mediating pathways between violence and HIV among YFSWs in Kenya, in order to identify priority areas and potential targets for HIV intervention programming. In particular it is important to further determine how violence influences YFSWs interactions with HIV prevention and care along the full HIV care cascade continuum. In my analyses, I found that violence was associated with reduced uptake of HIV testing, but I was unable to examine the influence of violence on linkage to care, uptake of ART, retention on and adherence to ART and viral suppression, as very few YFSWs in the Transitions study self-reported being HIV positive, and so very little data on the HIV treatment cascade could be collected. In a previous study of older HIV positive FSWs in Mombasa, Kenya, intimate partner violence was not found to be a barrier to ART adherence and was unexpectedly associated with significantly lower risk of detectable viral load [19]. Future work should continue to explore the impact of different types of violence, including workplace violence, on FSWs engagement in the HIV care cascade in Kenya. Interestingly, although I found that violence was associated with reduced uptake of HIV testing, my modelling analyses did not show a large increase in ART coverage when violence was eliminated, because of the already high levels of HIV testing among FSWs and the low initiation of ART once diagnosed, and suggested that the negative effect of violence on HIV testing uptake has a marginal contribution to HIV transmission. This contradicts the hypothesis that addressing structural factors would be important for scaling up ART. However, studies have highlighted that improving only one stage of the HIV care cascade may have negligible impacts on HIV outcomes and ART coverage [20,21]. Thus, it is likely that other deficiencies in the HIV care cascade of FSWs in Kenya must also be addressed to improve the coverage of HIV positive FSWs who are on ART and virally suppressed, and thereby reduce HIV transmission. Thus, it is important to understand how different types of violence influences the other stages of the HIV care cascade, and incorporate findings in future modelling work. Evaluation of violence prevention strategies in FSW programmes or trials (e.g. quantitative and qualitative surveys) should also seek to monitor their impact on HIV related risk and prevention outcomes, such as HIV prevalence, condom use, uptake of HIV testing and treatment, in addition to monitoring changes in the burden of violence.

The modelling work could also be extended to include other young women in Kenya and other non-client male sexual partners, in order to more broadly examine the influence of violence against young women on HIV transmission in Mombasa, Kenya. This would also allow the model to take into account my findings that some forms of violence (physical violence and police assault or arrest) were associated with higher levels of inconsistent condom use with intimate partners of FSWs. Currently, the model only considers FSW and client partnerships, and so is likely to underestimate the contribution of violence against FSWs to HIV transmission in Mombasa. Future modelling work could also benefit from considering additional intervention scenarios. For instance, it would be useful to simulate more realistic scenarios which instead of assuming all violence is eliminated reflect the impact that interventions have had on reducing violence. For example, in Karnataka, India, a structural intervention to address violence within a large-scale HIV prevention programme (Avahan), led to significant reductions in the proportion of FSWs being raped in the past year; reducing by two-thirds from 30% in 2007 to 10% in 2011 [22]. Furthermore, between the 2008 and 2011 follow-up surveys there were also reductions in police arrest in the last year (5.5% vs 3.0%) and physical violence by non-partners in the last year (8.4% vs 5.5%) [22]. A separate analysis of Avahan in Andhra Pradesh, India, also found that police arrests reduced significantly from 16.8% in 2006-2007 to 8.8% in 2009-2010 [23]. In Mombasa, Kenya, an alcohol harm reduction intervention among FSWs who were moderate risk drinkers, was also associated with significant reductions in violence [24,25]. For example, in the intervention group, physical violence from non-paying partners reduced from 32.0% at baseline to 9.4% after only 6 months post-intervention [25]. If other young women in Kenya and other non-client male sexual partners were included in the model, results from general population community mobilisation programmes, such as SASA!, in Uganda, which achieved significant reductions in women's experiences of intimate partner violence, could also potentially be useful in simulating realistic intervention scenarios for reductions in intimate partner violence among women in Mombasa, Kenya [26].

6.5.2 Vancouver

Taken together, my modelling results highlighted the importance of designing and implementing multi-component interventions that address multiple types of violence in Vancouver, Canada, while also ensuring that FSWs who have experienced client violence are identified and linked to comprehensive care and support services in order to address the long-term negative effects of violence on ICU. Importantly, this work also demonstrated the potential benefits that addressing police harassment could have on reducing client violence, which highlights the importance of working with police in Vancouver to improve FSWs safety. A number of the future directions of work described above for the Kenya modelling work would also be relevant to the Vancouver setting. For instance, the modelling work could be extended to consider the impact of violence and violence interventions on HIV care cascade outcomes [27]. Other structural factors which are associated with poor HIV prevention and care outcomes, could also be considered in future modelling work. For instance, a recent longitudinal analysis among sex workers in Vancouver, enrolled in AESHA, found that incarceration was independently correlated with experiencing gaps in ART use over a 2.5 year period [28]. More realistic intervention scenarios, could similarly be simulated in future work. Future modelling work could also consider simulating the impact of changes in client violence/and or police harassment due to the recent changes in policy and law enforcement approaches for sex work in Vancouver (e.g. Bill C-36, that criminalises clients of sex work) [29].

6.5.3 Mathematical modelling

The modelling analyses conducted had a number of setting specific implications and future directions, which were highlighted in the above sections. These analyses also provided some broader insights for future modelling studies of violence and HIV. For instance, sensitivity analyses I conducted highlighted that the model estimates for the magnitude of impact of violence interventions were particularly sensitive to the parameters and assumptions made on the effects of violence (e.g effect of violence on ICU in Vancouver and Kenya, and effect of police harassment on client violence in Vancouver). This highlights the importance of gathering more and better data to reduce the uncertainties and strengthen the evidence for the mediating pathways between violence and HIV, for example through longitudinal studies, and also emphasises the need to use data that is context specific in future modelling studies. This will be essential to more robustly estimate the potential effects of structural interventions using mathematical modelling, and in the absence of such data, highlights the need to conduct and report the results of sensitivity analyses in future modelling studies. The modelling results also highlight that further work is needed to explore whether dynamic mathematical models can be useful in estimating incidence of violence.

6.6 Modelling structural determinants of HIV in the sex work context: framework and data requirements

In the previous sections I discussed possible directions of further modelling work in each setting. Here, I provide a framework for thinking about how to model structural factors dynamically (Figure 6.1), using violence as a case example, in order to help guide the design of future modelling studies of structural factors and HIV in the sex work context. Insights from the modelling work in this thesis were used in the development of this framework. I also discuss the data needs and gaps in data for modelling studies of structural factors and HIV. Although focussed on the sex work context, this framework and issues discussed can be useful in modelling other structural HIV determinants for other key populations. The framework mainly considers structural factors that relate to discrete events (such as experiences of violence), but the principles could still be adapted and applied to structural factors which are more of a continual process, such as stigma. Modelling structural factors dynamically rather than statically is at the core of this framework. Modelling violence dynamically, as was done in this thesis, and as is recommended for future studies, allows you to capture changes in structural factors over time, recurrence of exposure to structural factors, and interactions between structural factors. Dynamic models can be compartmental or individual-based, but due to current data limitations, compartmental models will be used to illustrate the issues discussed in the following sections.

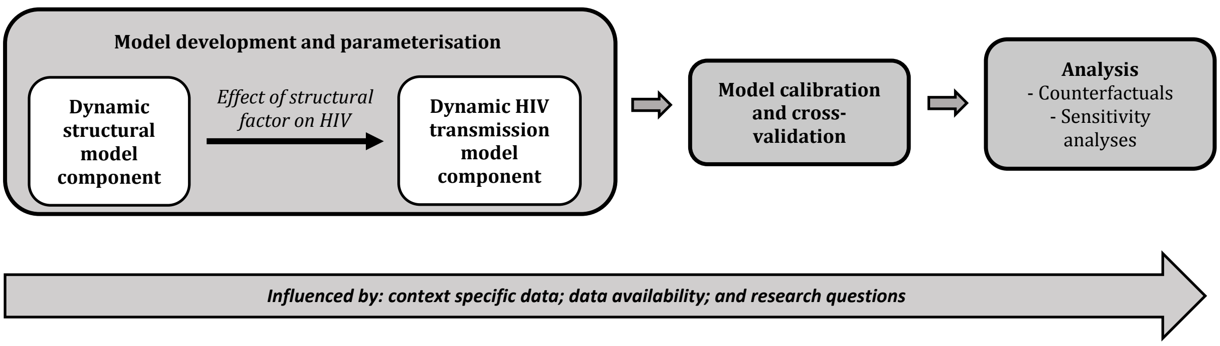

Figure 6.1 Framework for dynamically modelling structural determinants of HIV

6.6.1 Model development and parameterisation, using violence as a case example

Structural model component development

Similar to choosing an adequate structure when modelling the natural history of infectious diseases (e.g. SIR, SEIR), different model structures can be used to summarise the life course of exposure to a structural factor, such as violence, and their associated effects on risk of HIV acquisition and transmission among FSWs. In theory, the model can be divided into as many states as needed. However, in practice, this will be influenced primarily by data availability, the context specific patterns and effects of the structural factor and related interventions in the setting of interest, and the research questions of interest.

For example, as illustrated in Figure 6.2, the population of interest (i.e. FSWs) could be divided into states representing the frequency of exposure to the structural factor (e.g. never experienced violence, experienced violence once, experienced violence twice, and experienced violence three or more times) (Figure 6.2A), or states which represent different time-periods of exposure to the structural factor (e.g. never experienced violence, recent violence experience, and non-recent experience of violence) (Figure 6.2B). The first structure would be suitable for example if there was empirical evidence that the effects of the structural factor on HIV were compounded the more times a FSW had been exposed to that structural factor. The second structure would be suitable if empirical evidence suggests that the effects of the structural factor on HIV change with time since exposed (e.g. violence may elevate the risk of non-condom use in the short term but not the long-term [2]). Time-periods of exposure included in the model will depend on the structural factor of interest, survey items utilised (e.g. Have you ever been forced to have sex? Were you forced to have sex in the last 6 months?), and the associated risks in different time-periods.

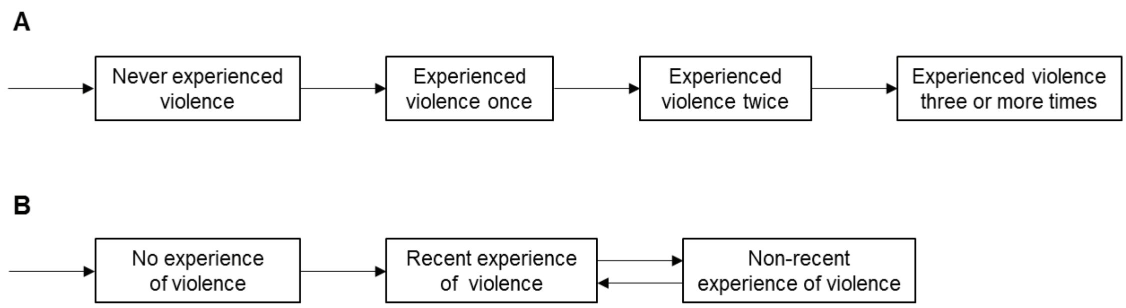

Figure 6.2 Example model structures for the violence component. The boxes represent each mutually exclusive state of violence exposure, and the arrows represent the rates of flow into and out of each state of violence.

The model could also be structured to summarise the life course and associated effects of multiple types of structural factors (e.g. different types of violence, or violence by different perpetrators) (Figure 6.3). Introducing multiple structural factors in the model can be done in two main ways. First, the most exhaustive way is to represent all combinations of the different structural factor exposures (as was done in Chapters 2 and 5), allowing full flexibility, and allowing the model to represent effects associated with exposure to multiple structural factors in the same time-period (Figure 6.3A). Second, a simpler model, which may be more hypothesis-driven (e.g. Shannon *et al* [2]), can be developed to represent separate states for the different structural factors (Figure 6.3B). Incorporating multiple structural factors can also allow the model to represent interactions between structural factors (e.g. effect of police harassment on increasing risk for client violence), and pathways between structural factors (e.g. client sexual violence being proceeded by client physical violence) [2]. Interactions can be incorporated in the rates of flow between the states of exposure (i.e. by specifying that the rates of flow for one type of structural factor (e.g. client violence) are higher among FSWs who have already been exposed to another type of structural factor (e.g. police harassment)). Pathways can be incorporated by placing constraints in the model where exposure to one type of structural factor only occurs after an individual has been exposed to another type of structural factor. It is important that these types of model elements are discussed with setting-specific experts when designing the structural model component.

Further layers could also be added to the model to incorporate other factors or interventions that shape the patterns of structural factors. For example, work environment has been found to be a key determinant of violence among FSWs (e.g. in Vancouver), so the states of violence in a model could be further stratified by FSWs work environment (e.g. indoor versus outdoor work environment) (Figure 6.4), and the rates of flow between the states of violence exposure would be specific to each work environment modelled in order to capture the heterogeneities in violence experiences (e.g. higher rates of violence in outdoor work environments compared to indoor work environments). Inclusion of these types of additional layers will chiefly depend on the context and research questions of interest. For example, work environment would be included to examine the impact of promoting safer work environments on violence, and hence HIV transmission [2].

However, if the model structure becomes too complex, with too many states, it would be important to consider using an individual-based model.

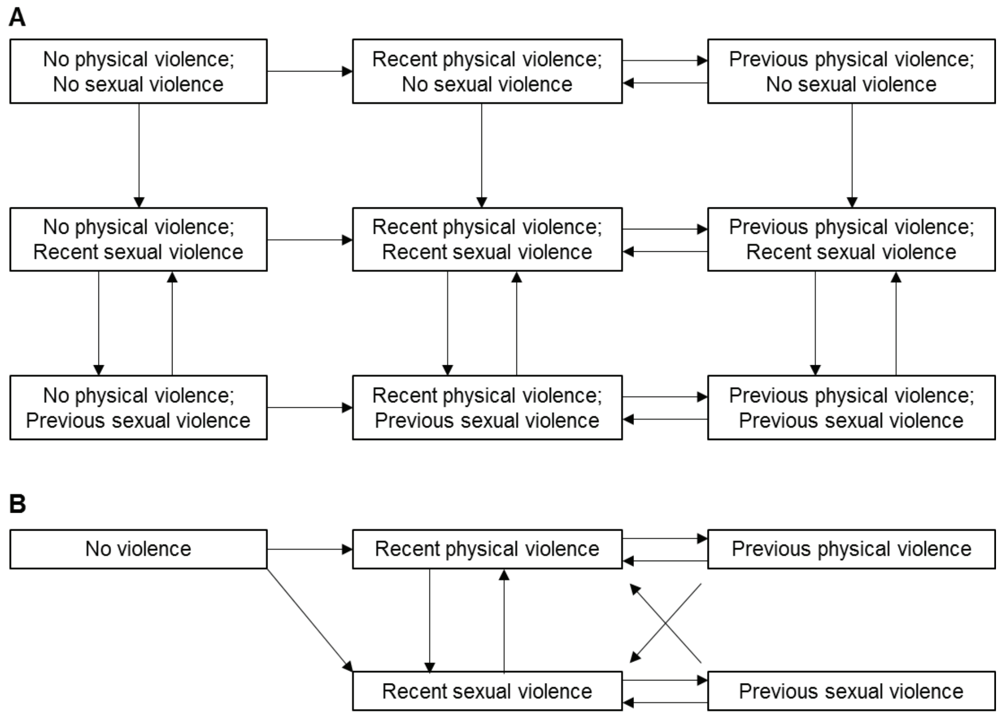

Figure 6.3 Example model structures when considering multiple types of violence. The boxes represent each mutually exclusive state of violence exposure, and the arrows represent the rates of flow into and out of each state of violence.

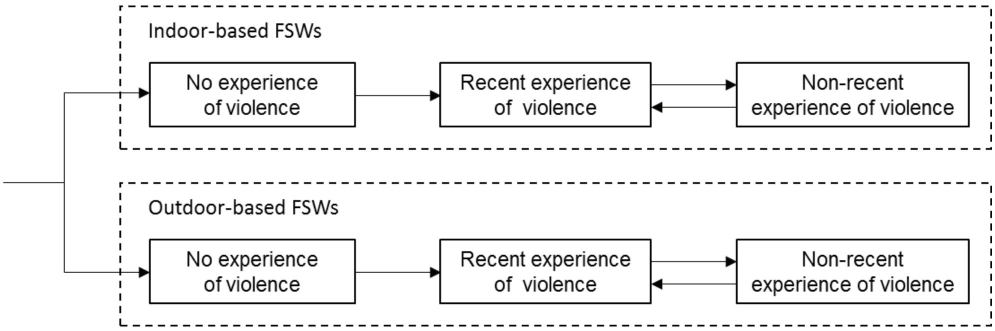

Figure 6.4 Example of model structure taking into account heterogeneous experiences of violence. The boxes represent each mutually exclusive state of violence exposure, and the arrows represent the rates of flow into and out of each state of violence.

HIV transmission component development

The HIV transmission component of the model will not be discussed in detail here. As with other models of HIV, or other infectious diseases, it should reflect key features of the natural history of HIV infection and HIV treatment, and the force of HIV infection should take into account key biological and behavioural factors that influence risk of HIV acquisition and transmission in a given setting. The key consideration here is how structural factors are assumed to influence the force of infection, as the model structure needs to allow these relationships to be incorporated e.g. if violence affects retention on ART, it would be important to have a more detailed representation of the HIV care cascade.

Effect of structural factors on HIV: model parameters

To model the effect of structural HIV determinants on HIV transmission among FSWs, the model must incorporate parameters that describe how different states of structural exposures in the structural model component affect HIV transmission (i.e. the force of HIV infection) in the HIV model component. This requires an understanding of the pathways and mechanisms through which different types of structural factors directly or indirectly impact on FSWs risk of HIV acquisition and transmission in both the short and long-term in a given setting. For example, as highlighted in Chapter 1, there are a number of pathways and mechanisms through which violence is thought to increase FSW's risk of HIV acquisitions and transmission, and these are summarised in Figure 6.5. Model inputs will need to specify how much each state of a structural exposure effects a particular component of the HIV transmission dynamics model (e.g. what is the relative risk [RR] of inconsistent condom use among FSWs who have recently experienced violence compared to those that have never experienced violence?). The model will assume a causal relationship between the structural factor and HIV, so it is important that the relationships modelled come from sound data (see Section 6.6.4 for further discussion on data needs).

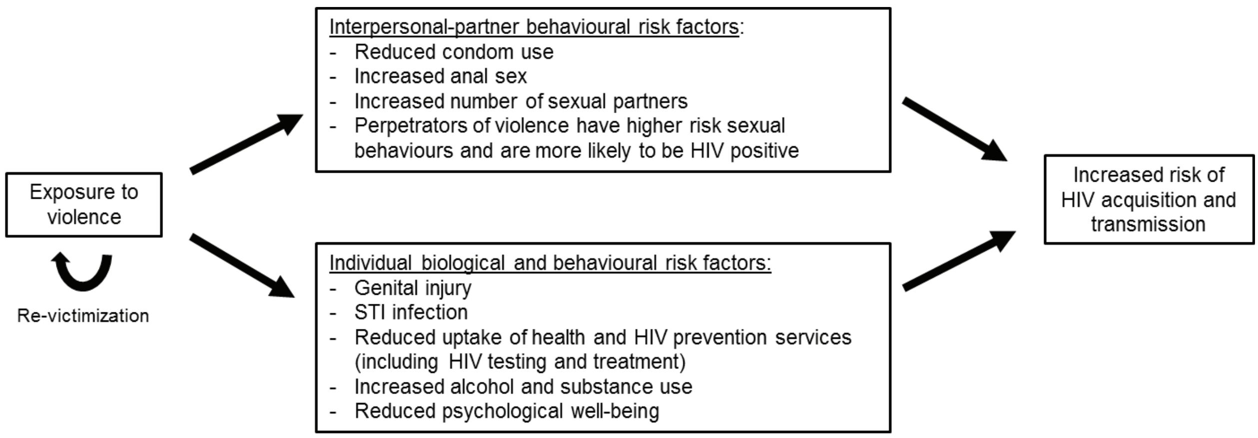

Figure 6.5 Illustration of pathways and mechanisms through which exposure to violence increases FSWs risk of HIV acquisition and transmission

6.6.2 Model calibration and cross-validation

Calibration to observed data is an important part of any modelling study. HIV transmission dynamics models are typically calibrated to data on HIV prevalence, HIV incidence, and/or coverage of existing HIV interventions such as uptake of ART, using different statistical techniques such as least-squared, or maximum likelihood methods [15]. To calibrate a dynamic model of structural HIV determinants and HIV transmission, similar approaches can be used. For example, in the case of violence, the model could be calibrated to data on the prevalence or incidence of violence among FSWs, and/or existing coverage of violence focussed structural interventions among FSWs. Calibrating the structural model component within a Bayesian framework, where multiple parameter sets that fit the data are identified and used for analyses [30], could be a particularly valuable approach when the model has complex structural factor dynamics and multiple uncertain structural-related parameters. When this is the case, using only one parameter set could lead to biased model estimates. Cross-validation to independent structural-related model outcomes is also important as a cross-check for the model predictions.

6.6.3 Model analysis

Counterfactual scenario considerations

In the context of structural HIV determinants and structural HIV interventions, counterfactual scenarios can provide estimates of model outcomes when the effects of the structural factor on HIV acquisition and transmission have been removed, which can be used in estimating the contribution of structural factors to HIV transmission and estimating the potential impact of structural interventions. This type of counterfactual scenario could be generated in two main ways. First, by eliminating exposure to the structural factor (e.g. setting the rates of exposure to the structural factor to zero), and second, by eliminating the associated effects of the structural factor (e.g. if in a baseline scenario there is an increased relative risk for inconsistent condom use among FSWs exposed to violence (i.e. RR > 1), this relative risk would be set to 1 in the counterfactual scenario (i.e. RR=1)). These different types of counterfactual scenarios (i.e. removing exposure to the structural factor compared to removing the associated effects of the structural exposure) can produce different model estimates that have different prevention implications. The choice of counterfactual scenario used will chiefly depend on the research question of interest (e.g. a scenario eliminating exposures to violence may be used to provide estimates of the potential impact of a violence prevention programme, or a scenario eliminating the long-term negative effects of violence on condom use may be used to provide estimates of the potential impact of an intervention focused on mitigating the impacts of violence on FSW's HIV risks). Depending on the research question of interest, other counterfactual scenarios could also be generated, for instance, where exposure to a structural factor is only partially removed, or where only one specific effect of a structural factor is removed.

Sensitivity analysis considerations

Given that modelling of violence and HIV transmission among FSWs is in its infancy, and that data on violence, the effect of violence on HIV transmission, and the impact of violence interventions on violence and HIV risk is often limited and uncertain, sensitivity and uncertainty analyses will be particularly important as this field of modelling emerges. Parametric sensitivity and uncertainty analyses are important for testing the robustness of results to uncertainties in parameter values and for highlighting which parameters contribute the most to uncertainty in the model outcomes, which parameters are most important to estimate and need more data, and which parameters are important to include in models [31,32]. Exploring structural uncertainty if possible is also important for determining if model complexity can be reduced while conserving sufficient accuracy in the model outputs [33]. Developing dynamic violence model components of varying levels of complexity and comparing the outputs from these models, could be a means of exploring the sensitivity of the models results to uncertainty in the model structure [33].

6.6.4 Data requirements

For dynamical models of structural HIV determinants, data related to the structural factors of interest are needed in the following four domains: i) burden of the structural factor/s, ii) interactions between structural factors, iii) effect of the structural factor/s on HIV risk and acquisition, and iv) intervention data. Table 6.1 gives an example of the data requirements for modelling violence.

i) *Burden of the structural factor:* At a minimum we need data on the prevalence of structural factors, which can be obtained from survey items in cross-sectional studies (e.g. were you forced to have sex in the last 6 months). Ideally, for some structural factors (e.g. violence) we also need frequency data, which could also be collected in cross-sectional studies (e.g. how many times in the last 6 months were you forced to have sex), or incidence data from longitudinal studies. Frequency and incidence data for structural factors are not often reported. Often with structural factors, such as violence, there may be issues with disclosure and recall bias, so asking precise questions over defined periods of time (e.g. by type of perpetrator, in the case of violence) could help to address these issues [34,35].

ii) *Interactions between structural factors*: Additional data is also needed to determine whether different types of structural factors interact (i.e. does exposure to one type of structural factor increase your risk for experiencing another type of structural factor). The type of data needed here (i.e. relative risks), would ideally be obtained from longitudinal studies, but can also be obtained from cross-sectional studies. It would also be important that experts are consulted about plausible interactions and directions of association to include in the model.

iii) *Effect of the structural factor on HIV acquisition and transmission*: At a minimum, we also need data on how a structural factor affects FSW's risk of HIV acquisition and transmission, and how this effect varies over time and/or by different exposure events. Similar to above (ii), the type of data needed here (i.e. relative risks), would ideally be obtained from longitudinal studies, but can also be obtained from cross-sectional studies. To date these types of data in the sex work context are most often from cross-sectional studies. Mediation analyses could also help to inform the key mediating factors to include in the model, and would help strengthen the evidence for causal pathways that may be assumed in the model.

iv) *Intervention impact and coverage*: Ideally data would be needed to understand the potential impact of a structural intervention on the structural factor of interest (e.g. for a scenario which simulates a realistic reduction in a structural factor), and on the effects associated with a structural factor (e.g. to what extent can the effects of structural factor be mitigated by a structural intervention, which again would be useful for generating more realistic counterfactual scenarios). These types of data could come from evaluations of existing and future structural and violence-related interventions, such as randomised controlled trials [17,24], and repeated cross-sectional surveys (e.g. Avahan [22,23]). Depending on the research question, data may also be needed on the coverage of an existing structural intervention (e.g. if the research question is to estimate the added benefit of scaling up the existing structural intervention), which could be obtained from specific intervention evaluations and also survey items in cross-sectional studies (e.g. survey items could ascertain FSW's exposure to community mobilisation [36,37]). Given the context-specific nature of structural interventions, the impact of structural interventions may be different across settings, so it is important that data used to inform certain types of counterfactual scenarios is as setting-specific as is feasible. In addition, there may be inconsistent and unintended adverse outcomes of structural interventions (e.g. measured levels of violence can initially go up following a violence intervention, due to negative reactions from clients and intimate partners and increased willingness and capability among FSWs to report incidents of violence [38-40]. It is important that inconsistent or adverse outcomes from structural interventions are monitored and understood, and taken into account when parameterising the model and defining counterfactuals to estimate the impact of structural interventions on HIV transmission among FSWs.

Currently, there is a dearth of data on the life course and effects of structural factors, and impact of structural interventions among FSWs. Gathering more data would help to improve the development and predictions of dynamic mathematical models [2,41,42]. As more data becomes available, this should be reflected in new models that are developed, and incorporated into existing models.

Table 6.1 Examples of data related to the structural factor of interest that are needed for dynamic models of structural HIV determinants, using violence as an example. In general, the examples in the table are not specific to any type or perpetrator of violence.

Type of data	Examples of types of information required and questions that could be used to collect required data (e.g. from observational studies, RCTs, bio behavioural surveys, routine data)	How might this data be used in the modelling process (i.e. to inform model development, model parameterisation, model calibration, and/or definition of counterfactual scenarios)
Burden and interactions		
Prevalence of violence	Have you ever experienced violence? Have you experienced violence in the past month/6 months/year?	Model development, parameterisation and calibration
Frequency of violence (or incidence)	How often did you experience violence in the past month/6 months/years? How many men forced you to have sex and/or physically hurt you in the past month/6 months/year?	Model development, parameterisation and calibration
Interactions between different types of violence	E.g. relative risk of client violence if recently experienced police harassment compared to not recently experiencing police harassment	Model development, parameterisation
Effect of violence on HIV acquisition and transmission		
Effect on interpersonal-partner behavioural HIV risk factors (short and/or long term effects)	E.g. relative risk of inconsistent condom use if ever or recently experienced violence	Model development, parameterisation and definition of counterfactual scenarios
Effect on individual biological and behavioural HIV risk factors (short and/or long term effects)	E.g. relative risk of ART interruptions if ever or recently experienced violence	Model development, parameterisation and definition of counterfactual scenarios
Impact and coverage of violence interventions		
Impact on violence experiences (short and/or long-term impacts)	E.g. reduction in proportion of FSWs experiencing violence	Model development, parameterisation and definition of counterfactual scenarios
Impact on HIV risks associated with violence experiences (short and/or long-term impacts)	E.g. reduction in inconsistent condom use associated with past experiences of violence	Model development, parameterisation and definition of counterfactual scenarios
Coverage	E.g. proportion of FSWs exposed to violence intervention	Model development, parameterisation and definition of counterfactual scenarios

6.7 Concluding remarks

To mitigate and ultimately end the HIV/AIDS epidemic it is crucial that there is an effective HIV response for priority and key populations. Given the important role of structural factors in HIV risk and transmission among FSWs, structural interventions and prevention approaches must be incorporated into HIV prevention programmes for FSWs. As such, there is a need to better understand the patterns and effects of structural HIV determinants, and the effectiveness of different types of structural interventions on reducing HIV transmission, in order to inform the design and implementation of effective structural HIV prevention approaches for FSWs. The work in this thesis responded to this need, by investigating violence against FSWs, a key and pervasive structural driver of HIV in the sex work context. This work adds to the limited literature on the burden and effects of violence among YFSW; extends the emerging field of modelling structural HIV determinants and structural HIV interventions in the sex work context; and provides insights and guidance for future modelling studies, to help understand the impact of structural factors and structural interventions on HIV transmission.

6.8 References

1. Footer KH, Silberzahn BE, Tormohlen KN, Sherman SG. Policing practices as a structural determinant for HIV among sex workers: a systematic review of empirical findings. J Int AIDS Soc. 2016;19(4 Suppl 3):20883
2. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
3. Crofts N, Patterson D. Police must join the fast track to end AIDS by 2030. Journal of the International AIDS Society. 2016 18 Jul;19 (Supplement 3) (no pagination)(21153)
4. Decker MR, Crago AL, Chu SKH, et al. Human rights violations against sex workers: Burden and effect on HIV. Lancet. 2015 10 Jan;385(9963):186-99
5. Tenni B, Carpenter J, Thomson N. Arresting HIV: Fostering Partnerships between Sex Workers and Police to Reduce HIV Risk and Promote Professionalization within Policing Institutions: A Realist Review. PLoS ONE [Electronic Resource]. 2015;10(10):e0134900
6. National AIDS Control Council. Kenya AIDS strategic framework 2014/2015 - 2018/2019. National AIDS Control Council, Nairobi, Kenya.
7. Baggaley R, Armstrong A, Dodd Z, Ngoksin E, Krug A. Young key populations and HIV: A special emphasis and consideration in the new WHO Consolidated Guidelines on HIV Prevention, Diagnosis, Treatment and Care for Key Populations. Journal of the International AIDS Society. 2015;18(2 Supplement 1):85-8
8. Cowan FM, Delany-Moretlwe S. Promise and pitfalls of pre-exposure prophylaxis for female sex workers. Current Opinion in HIV and AIDS. 2016 01 Jan;11(1):27-34
9. FHI. Young People Most at Risk of HIV: A Meeting Report and Discussion Paper from the Interagency Youth Working Group, U.S. Agency for International Development, the Joint United Nations Programme on HIV/AIDS (UNAIDS) Inter-Agency Task Team on HIV and Young People, and FHI. 2010.
10. WHO. HIV and young people who sell sex: A technical brief. 2014.
11. Decker MR, Wirtz AL, Pretorius C, et al. Estimating the Impact of Reducing Violence Against Female Sex Workers on HIV Epidemics in Kenya and Ukraine: A Policy Modeling Exercise. Am J Reprod Immunol. 2013 Feb;69:122-32
12. Duff P, Goldenberg S, Deering K, et al. Barriers to Viral Suppression among Female Sex Workers: Role of Structural and Intimate Partner Dynamics. J Acquir Immune Defic Syndr. 2016 01 Sep;73(1):83-90
13. Grassly NC, Fraser C. Mathematical models of infectious disease transmission. Nature Reviews Microbiology. 2008 June;6(6):477-87
14. Keeling MJ, Danon L. Mathematical modelling of infectious diseases. British Medical Bulletin. 2009 Dec;92(1):33-42
15. Mishra S, Fisman DN, Boily MC. The ABC of terms used in mathematical models of infectious diseases. J Epidemiol Community Health. 2011 Jan;65(1):87-94
16. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54
17. Beattie TS, Isac S, Bhattacharjee P, et al. Reducing violence and increasing condom use in the intimate partnerships of female sex workers: study protocol for Samvedana Plus, a cluster randomised controlled trial in Karnataka state, south India. BMC public health. 2016 29 Jul;16:660
18. Jewkes R, Flood M, Lang J. From work with men and boys to changes of social norms and reduction of inequities in gender relations: a conceptual shift in prevention of violence against women and girls. Lancet. 2015 18 Apr;385(9977):1580-9
19. Wilson KS, Wanje G, Yuhas K, et al. A Prospective Study of Intimate Partner Violence as a Risk Factor for Detectable Plasma Viral Load in HIV-Positive Women Engaged in Transactional Sex in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2065-77
20. Mountain E, Pickles M, Mishra S, Vickerman P, Alary M, Boily MC. The HIV care cascade and antiretroviral therapy in female sex workers: Implications for HIV prevention. Expert Review of Anti-Infective Therapy. 2014 01 Oct;12(10):1203-19

21. Olney JJ, Braitstein P, Eaton JW, et al. Evaluating strategies to improve HIV care outcomes in Kenya: a modelling study. The Lancet HIV. 2016 01 Dec;3(12):e592-e600
22. Beattie TS, Bhattacharjee P, Isac S, et al. Declines in violence and police arrest among female sex workers in Karnataka state, south India, following a comprehensive HIV prevention programme. Journal of the International AIDS Society. 2015 16 Oct;18 (1) (no pagination)(20079)
23. Erausquin JT, Reed E, Blankenship KM. Change over Time in Police Interactions and HIV Risk Behavior Among Female Sex Workers in Andhra Pradesh, India. Aids Behav. 2015 Jun;19(6):1108-15
24. L'Engle KL, Mwarogo P, Kingola N, Sinkele W, Weiner DH. A randomized controlled trial of a brief intervention to reduce alcohol use among female sex workers in Mombasa, Kenya. J Acquir Immune Defic Syndr. 2014 Dec 1;67(4):446-53
25. Parcesepe AM, KL LE, Martin SL, et al. The impact of an alcohol harm reduction intervention on interpersonal violence and engagement in sex work among female sex workers in Mombasa, Kenya: Results from a randomized controlled trial. Drug Alcohol Depend. 2016 Apr 1;161:21-8
26. STRIVE. Greentree II Report - Violence against Women and Girls, and HIV. 2016.
27. Goldenberg SM, Deering K, Amram O, et al. Community mapping of sex work criminalization and violence: impacts on HIV treatment interruptions among marginalized women living with HIV in Vancouver, Canada. Int J STD AIDS. 2017 01 Sep;28(10):1001-9
28. Goldenberg SM, Montaner J, Duff P, et al. Structural Barriers to Antiretroviral Therapy Among Sex Workers Living with HIV: Findings of a Longitudinal Study in Vancouver, Canada. Aids Behav. 2016 May;20(5):977-86
29. Landsberg A, Shannon K, Krusi A, et al. Criminalizing Sex Work Clients and Rushed Negotiations among Sex Workers Who Use Drugs in a Canadian Setting. J Urban Health. 2017 Aug;94(4):563-71
30. Boily MC, Lowndes CM, Vickerman P, et al. Evaluating large-scale HIV prevention interventions: Study design for an integrated mathematical modelling approach. Sex Transm Infect. 2007 December;83(7):582-9
31. Boily MC, Masse B. Mathematical models of disease transmission: A precious tool for the study of sexually transmitted diseases. Canadian Journal of Public Health. 1997 July/August;88(4):255-65
32. Garnett GP, Cousens S, Hallett TB, Steketee R, Walker N. Mathematical models in the evaluation of health programmes. The Lancet. 2011 August 6-12;378(9790):515-25
33. Foss AM, Vickerman PT, Chalabi Z, Mayaud P, Alary M, Watts CH. Dynamic modeling of herpes simplex virus type-2 (HSV-2) transmission: Issues in structural uncertainty. Bulletin of Mathematical Biology. 2009 April;71(3):720-49
34. Baggaley RF, Dimitrov D, Owen BN, et al. Heterosexual Anal Intercourse: A Neglected Risk Factor for HIV? Am J Reprod Immunol. 2013 Feb;69:95-105
35. WHO. WHO Multi-country Study on Women's Health and Domestic Violence against Women. WHO, Geneva, Switzerland. 2005
36. Beattie TS, Mohan HL, Bhattacharjee P, et al. Community mobilization and empowerment of female sex workers in Karnataka State, South India: associations with HIV and sexually transmitted infection risk. Am J Public Health. 2014 Aug;104(8):1516-25
37. Vassall A, Chandrashekar S, Pickles M, et al. Community mobilisation and empowerment interventions as part of HIV prevention for female sex workers in southern india: A cost-effectiveness analysis. PLoS ONE. 2014;9 (10) (no pagination)(e110562)
38. Beattie TSH, Bhattacharjee P, Ramesh BM, et al. Violence against female sex workers in Karnataka state, south India: impact on health, and reductions in violence following an intervention program. BMC Public Health. 2010 Aug 11;10
39. Gurnani V, Beattie TS, Bhattacharjee P, et al. An integrated structural intervention to reduce vulnerability to HIV and sexually transmitted infections among female sex workers in Karnataka state, south India. Bmc Public Health. 2011 Oct 2;11

40. Reza-Paul S, Lorway R, O'Brien N, et al. Sex worker-led structural interventions in India: a case study on addressing violence in HIV prevention through the Ashodaya Samithi collective in Mysore. Indian Journal of Medical Research. 2012 Jan;135(1):98-106
41. Kerrigan DL, Fonner VA, Stromdahl S, Kennedy CE. Community Empowerment Among Female Sex Workers is an Effective HIV Prevention Intervention: A Systematic Review of the Peer-Reviewed Evidence from Low- and Middle-Income Countries. Aids Behav. 2013 Jul;17(6):1926-40
42. Wechsberg WM, Luseno WK, Lam WKK, Parry CDH, Morojele NK. Substance use, sexual risk, and violence: HIV prevention intervention with sex workers in Pretoria. Aids Behav. 2006 Mar;10(2):131-7

Appendix A: Published papers

Mountain E, Mishra S, Vickerman P, Pickles M, Gilks C, et al. (2014) Antiretroviral Therapy Uptake, Attrition, Adherence and Outcomes among HIV-Infected Female Sex Workers: A Systematic Review and Meta-Analysis. PLoS ONE 9(9): e105645. doi:10.1371/journal.pone.0105645

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Antiretroviral Therapy Uptake, Attrition, Adherence and Outcomes among HIV-Infected Female Sex Workers: A Systematic Review and Meta-Analysis

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Abstract

Purpose: We aimed to characterize the antiretroviral therapy (ART) cascade among female sex workers (FSWs) globally.

Methods: We systematically searched PubMed, Embase and MEDLINE in March 2014 to identify studies reporting on ART uptake, attrition, adherence, and outcomes (viral suppression or CD4 count improvements) among HIV-infected FSWs globally. When possible, available estimates were pooled using random effects meta-analyses (with heterogeneity assessed using Cochran's Q test and I^2 statistic).

Results: 39 studies, reporting on 21 different FSW study populations in Asia, Africa, North America, South America, and Central America and the Caribbean, were included. Current ART use among HIV-infected FSWs was 38% (95% CI: 29%–48%, $I^2 = 96\%$, 15 studies), and estimates were similar between high-, and low- and middle-income countries. Ever ART use among HIV-infected FSWs was greater in high-income countries (80%; 95% CI: 48%–94%, $I^2 = 70\%$, 2 studies) compared to low- and middle-income countries (36%; 95% CI: 7%–81%, $I^2 = 99\%$, 3 studies). Loss to follow-up after ART initiation was 6% (95% CI: 3%–11%, $I^2 = 0\%$, 3 studies) and death after ART initiation was 6% (95% CI: 3%–11%, $I^2 = 0\%$, 3 studies). The fraction adherent to ≥95% of prescribed pills was 76% (95% CI: 68%–83%, $I^2 = 36\%$, 4 studies), and 57% (95% CI: 46%–68%, $I^2 = 82\%$, 4 studies) of FSWs on ART were virally suppressed. Median gains in CD4 count after 6 to 36 months on ART, ranged between 103 and 241 cells/mm^3 (4 studies).

Conclusions: Despite global increases in ART coverage, there is a concerning lack of published data on HIV treatment for FSWs. Available data suggest that FSWs can achieve levels of ART uptake, retention, adherence, and treatment response comparable to that seen among women in the general population, but these data are from only a few research settings. More routine programme data on HIV treatment among FSWs across settings should be collected and disseminated.

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Introduction

By reducing HIV viral load and helping to restore immune function, antiretroviral therapy (ART) has led to substantial reductions in HIV-attributable mortality and morbidity and has greatly improved the quality of life for people living with HIV. Evidence also indicates that individuals on effective ART are less likely to transmit HIV [1–5]. This evidence has sparked great interest in ART-based HIV prevention approaches, including 'Treatment as Prevention' (TasP), which aims to expand ART coverage among HIV-infected individuals in order to help reduce HIV transmission at a population level [6].

Successful treatment can sustain viral suppression and lead to immunological improvement among those that are HIV-infected, but requires that individuals engage and remain in the HIV care cascade. This cascade involves a series of actions, starting with HIV screening/testing, and followed by linkage to HIV care after HIV diagnosis, retention in pre-ART care prior to ART initiation, initiation of ART once eligible for treatment, retention on treatment once ART is started, and then maintenance of good ART adherence in order to achieve viral suppression and immunological improvement [7–9]. However, evidence indicates that many individuals are lost at each stage of the cascade, and many individuals are diagnosed late, only initiating ART at the onset of symptoms [8–11].

Female sex workers (FSWs) are a population at high risk of acquiring and transmitting HIV infection, and in many HIV epidemics bear a disproportionately larger burden of HIV [12–14]. Worldwide, the HIV prevalence among FSWs is 12%, ranging between 1.7% in the Middle East and North Africa to 36.9% in Sub-Saharan Africa, and FSWs have a pooled odds ratio of HIV infection compared to women in the general population of 14 [13]. Thus, FSWs remain a key population for HIV prevention strategies. Ensuring high levels of ART uptake, adherence and retention among FSWs, would provide not only individual benefits to HIV-infected FSWs, but could also help reduce HIV transmission at the population level [15,16].

With the high burden of HIV among FSWs and the potential merits of expanding ART in populations at high risk of transmitting HIV [15,17], it is crucial to understand the extent to which FSWs currently access ART, and continue ART with good adherence. We conducted a systematic review to summarise the existing information on the following events in the HIV care cascade among FSWs globally: ART uptake, ART attrition, adherence, and treatment response (viral suppression and CD4 count improvements).

Methods

Our systematic review and meta-analysis was conducted and reported in accordance with PRISMA and MOOSE guidelines (see Checklist S1) [18,19].

Search Strategy

Our search strategy was conducted in three stages. First, we searched PubMed, Embase and MEDLINE for studies published up until 10th March 2014. The search terms (keywords and medical subject heading terms) reflected three key domains: HIV/AIDS, FSWs and ART (see Table 1 for combinations of search terms used). There were no language restrictions. Following removal of duplicate references, abstracts were screened for exclusion. If studies were not excluded after abstract screening, the full text of the article was retrieved and evaluated for eligibility. Second, we hand-searched the reference lists of all eligible studies and relevant review articles identified in the database search for additional publications. Finally, for completion, whenever an eligible study analysed data from a specific FSW cohort, a supplementary database search was conducted, using the name and location of the FSW cohort and corresponding author names as search terms, to find any additional publications. Authors were contacted for additional information and supplementary data when needed. One reviewer conducted the search, reviewed abstracts, and evaluated full text articles for eligibility. Any queries on article eligibility were discussed and resolved with other team members.

Inclusion and Exclusion Criteria

We included observational or intervention studies with a sample size of at least 10 FSWs that reported estimates or sufficient data to derive the following ART cascade outcomes: ART uptake (specifically the fraction of all HIV-infected individuals or the fraction of all ART-eligible individuals, who either initiated ART within a specified follow-up period, currently use ART, or ever used ART (no time-frame for ART initiation specified)), ART attrition (specifically the fraction using ART who were either lost-to-follow-up, died or discontinued ART, or the fraction of treatment-experienced individuals no longer on ART), ART adherence (specifically the fraction achieving a predefined threshold of adherence e.g. $\geq$90%, $\geq$95%, 100%), viral suppression (specifically the fraction with undetectable plasma viral load following ART initiation), and CD4 counts at and/or after ART initiation (specifically the median CD4 count, median CD4 count gain, or fraction with CD4 counts $<$200, 200–499 or $>$500 cells/mm^3). We included studies which reported on the same study population if the studies provided estimates of different ART cascade outcomes for that study population or provided estimates for that study population on the same ART cascade outcome over different time periods.

We included studies that enrolled active or former FSWs, women who engage in sex work or transactional sex, or women who exchange sex for money, drugs or gifts. "Active" FSWs were defined as women who either reported sex work as their employment at enrolment, or within the previous 6 months. "Former" FSWs were those that either reported sex work as a former occupation at enrolment, reported transactional sex more than 6 months ago, or were no longer sexually active. We excluded review articles, mathematical modelling studies, qualitative studies and conference/oral/poster abstracts.

Data Extraction

One reviewer extracted data from included articles, and any queries during data extraction were discussed and resolved with other team members. Variables extracted included study characteristics (e.g. study design, study period and sample size of FSWs), participant characteristics (e.g. HIV status and illicit drug use), outcome estimates (or the data to calculate them), and the time period over which estimates were measured. Exact binomial confidence intervals (CI) for proportions were derived when not provided. Each study could provide information on multiple ART cascade outcomes and/or on the same ART cascade outcome over different time periods. Multiple studies could provide different ART cascade estimates for the same study population.

We also extracted information on ART initiation criteria and ART administration in order to provide a background to the local context for included studies. To assess risk of bias in included

Table 1. Search Terms Used For Search Strategy.

Domain	Search Terms
HIV	"HIV" OR "human immunodeficiency virus" OR "AIDS" OR "acquired immune deficiency syndrome"
	AND
FSWs	"FSW" OR "FSWs" OR "CSW" OR "CSWs" OR "commercial sex" OR "female sex worker*" OR "commercial sex work*" OR "sex-work*" OR "sexwork*" OR "sex work*" OR "prostitute*" OR "prostitution" OR "transactional sex" OR "paid sex" OR "money for sex" OR "sex for money" OR "paid for sex" OR "sex in exchange for money" OR (("core group" OR "high risk" OR "high-risk" OR highrisk") AND ("female*" OR "women" or "woman"))
	AND
ART	"ART" OR "antiretroviral*" OR "anti-retroviral*" OR "HAART" OR "highly active antiretroviral therapy" OR "cART" OR "combined antiretroviral therapy"

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studies, we also extracted the following study characteristics: study setting and recruitment, type of sampling, and outcome measurement methods. No studies were excluded from the systematic review or meta-analysis on the basis of this assessment, but the potential impact of these characteristics on study results was considered when interpreting overall findings.

Data Analysis

We firstly describe key characteristics of all included studies and the total number that provide estimates for the different ART cascade outcomes. We then summarise the results from different studies for each outcome. Given that several studies could provide information on the same study population, we give both the number of studies (N_s) and the number of independent study populations (N_p) when summarising the study characteristics and ART cascade outcome estimates.

All available study estimates are presented on forest plots in the main text and are also reported in Tables S1–S5. On all forest plots, study estimates are grouped by country income (high-income (HI) versus low- and middle-income (LMI)), and ordered by study-period, follow-up period, or time on ART.

For each outcome with at least 2 study estimates available from different study populations, we calculated an overall pooled estimate, and when possible performed sub-group meta-analyses by country income (i.e. HI versus LMI). These results are reported in the main text and are also presented on forest plots. As time period of data collection could influence HIV treatment outcomes, in particular ART uptake outcomes, we did additional sub-group analyses for ART uptake outcomes in order to address this issue. If the time period of data collection for any estimates of ART uptake spanned the pre-HAART and HAART era, sub-group meta-analyses were performed if possible by year of data collection (i.e. data collected in the pre-HAART to HAART era versus data collected in the HAART era) for that ART uptake outcome. These results are reported in the main text. We did not pool study estimates for outcomes relating to median CD4 count. For all other outcomes, we pooled study estimates using a DerSimonian and Laird random effects model on the logit scale, and then back-transformed the overall pooled estimate to the original scale. We assessed heterogeneity across study-estimates using the Cochran Q homogeneity test, which assesses whether differences in study estimates are due to chance alone (typically a p-value <0.1 or <0.05 indicates heterogeneity between study estimates), and the I^2 statistic, which measures the percentage of variation across study estimates that is due to heterogeneity rather than chance (the higher the I^2 value the greater the heterogeneity between study estimates) [20,21]. Meta-analyses were conducted using the 'meta' package in R (Version 3.0.0).

When pooling estimates, we only included study estimates with sample sizes of at least 10 FSWs. Study estimates with an unknown numerator and denominator were not included in any pooled estimates, and for ART uptake outcomes any study estimates with an unknown study period were not included in pooled estimates. If a study provided estimates of an outcome over different time-periods, we only used one estimate (the most recent estimate from each study) for pooling. If more than one study reported estimates of a given outcome for the same study population, we only used one estimate per study population (the study estimate with the largest sample size) for pooling. Study estimates that were included in overall or subgroup pooled estimates are indicated in forest plots and tables with a star symbol (*).

Results

Search Results and Study Characteristics

The search strategy and process of article selection is described in Figure 1. Of 3081 unique publications identified in our original search, 28 met the inclusion criteria (Figure 1). Additional studies were then identified from the supplementary database search ($N_s = 9$) and reference lists ($N_s = 2$) (Figure 1). In total, 39 studies ($N_s = 39$) identified in the search were eligible to be included in our review (Figure 1), providing data on 21 independent FSW study populations ($N_p = 21$) and at least 4,700 HIV-infected FSWs [22–60]. Table 2 summarises the key characteristics of the 39 included studies and their reported outcomes. Figure 2 shows the geographical location of the study settings. Study characteristics that were extracted to help assess risk of bias are shown in Table S6.

The majority of the 39 included studies were prospective cohort ($N_s = 24$, $N_p = 11$) or cross-sectional ($N_s = N_p = 12$) studies. There were also a small number of intervention ($N_s = N_p = 2$) and retrospective case-control ($N_s = N_p = 1$) studies. Twenty-four studies were conducted in five African countries: Benin ($N_s = N_p = 1$), Burkina Faso ($N_s = 5$, $N_p = 1$), Kenya ($N_s = 16$, $N_p = 3$), Rwanda ($N_s = N_p = 1$), and Zimbabwe ($N_s = N_p = 1$). Six studies were conducted in two North American countries: Canada ($N_s = 4$, $N_p = 3$) and United States ($N_s = N_p = 2$). Six studies were conducted in four Asian countries: India ($N_s = N_p = 3$), Russia ($N_s = N_p = 1$), Thailand ($N_s = N_p = 1$), and Vietnam ($N_s = N_p = 1$). Two studies were conducted in two Central America and Caribbean countries: Dominican Republic ($N_s = N_p = 1$), and El Salvador ($N_s = N_p = 1$), and one study was conducted in South America: Brazil ($N_s = N_p = 1$). Twenty-four studies (62%) had fewer than 150 HIV-infected FSW participants, and four studies enrolled HIV-infected FSWs who were also injecting drug users (IDUs) (Table 2).

Of the 39 eligible studies included, 26 reported ART uptake outcomes, 10 reported ART attrition outcomes, 9 reported on adherence to ART, 6 reported on viral suppression, and 17 reported on CD4 counts at and/or after ART initiation (Table 2 and Tables S1–S5). Criteria for ART initiation were reported by only 16 studies, the majority of which reported a CD4 count threshold for ART initiation of 200 cells/mm^3 ($N_s = 11$) [28–30,32,37–39,44,46,51,54]. Other CD4 count thresholds used for ART initiation were CD4 count <250 cells/mm^3 ($N_s = 2$), CD4 count <350 cells/mm^3 ($N_s = 1$), and any CD4 count ($N_s = 1$) [23,42,48,60], and in one other study the ART initiation criteria changed from CD4 count <200 cells/mm^3 to CD4 count <350 cells/mm^3 during the study period ($N_s = 1$) [56]. Other details on ART administration were provided in some studies. For example, studies in Rwanda and India report that ART has been provided free of charge to those with HIV through government ART programmes and ART centres, since 2003 and 2004, respectively [40,42,46]. Studies in Canada also report that ART is provided free of charge through provincial drug treatment programmes, and in the United States, free ART is provided to all those living with HIV [23,45,48]. In 2005, an ART programme was initiated in the Nairobi FSW cohort in Kenya, as part of the U.S. Presidents Emergency Plan for AIDS Relief (PEPFAR), and FSWs received ART through the research clinic [34]. From 2004, FSWs enrolled in the Mombasa FSW cohort in Kenya received ART through either the study research clinic or other clinics in the area, and FSWs enrolled in the Yérélon FSW cohort in Burkina Faso received ART through either the study research clinic or the Bobo-Dioulasso University Teaching Hospital [29,32,33,37–39,49,51,54,56,57]. In another study in Mombasa, FSWs received

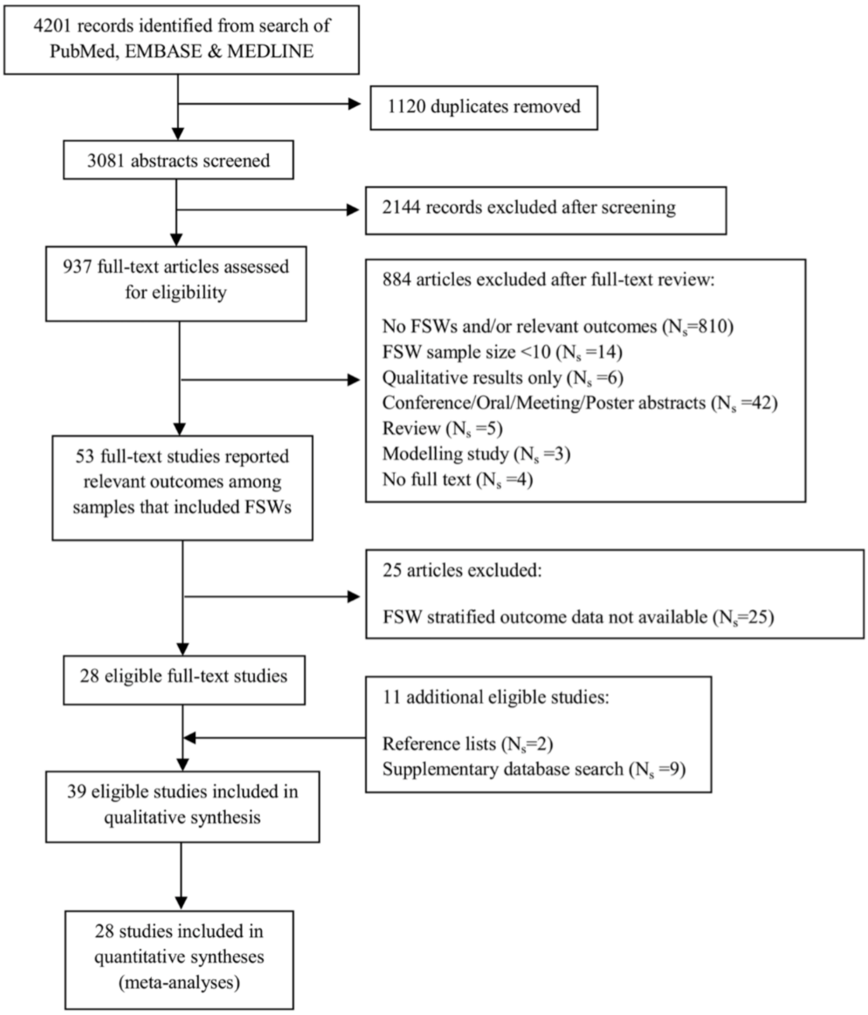

Figure 1. Flow diagram of search strategy and study selection process. FSW = female sex worker, ART = antiretroviral therapy, N_s = number of studies.
doi:10.1371/journal.pone.0105645.g001

ART at the study research clinic, whilst in Benin FSWs accessed ART at a medical center dedicated to FSWs [44,60].

ART Uptake

Estimates of ART uptake (either ART initiation within specified follow-up periods, current ART use, or ever use of ART (no time-frame for ART initiation specified)), among ART-eligible or all HIV-infected FSWs, were available from 26 studies reporting on 20 independent study populations in Asia, Africa, North America, South America, and Central America and the Caribbean [22,24,32–34,36–38,40–43,45–50,52–55,57–60] (Figures 3, 4, 5, Table S1). CD4 count criteria for ART initiation were reported by only 8 of these studies (CD4 count ≤200 cells/mm^3 (N_s = 5), CD4 count ≤250 cells/mm^3 (N_s = 1), CD4 count <350 cells/mm^3 (N_s = 1) and any CD4 count (N_s = 1)) (Table S1).

Estimates of ART initiation among all HIV-infected FSWs were provided by 6 studies reporting on 4 independent study populations in Asia and Africa (N_s = 6, N_p = 4) (Figure 3A, Table S1A). Across these 6 studies, 0.4% to 48% of HIV-infected FSWs initiated ART, during follow-up periods which varied between 4 months to 16 years (N_s = 6, N_p = 4) (Figure 3A, Table S1A). The overall pooled estimate for ART initiation among HIV-infected FSWs, when pooling only one estimate per study population, was 19% (95%CI: 10%–35%, I^2 = 96%, N_s = N_p = 4) (Figure 3A). Pooled estimates were lower for studies which collected data on HIV-infected FSWs between the pre-HAART and HAART era (6%; 95%CI: 0%–51%, I^2 = 96%, N_s = N_p = 2) than for studies which collected data on HIV-infected FSWs in the HAART era alone (37%; 95%CI: 20%–58%, I^2 = 91%, N_s = N_p = 2).

One study in Rwanda provided estimates of ART initiation among ART-eligible FSWs (Figure 3B, Table S1B). In this study,

Table 2. Study Characteristics and Outcomes Reported.

Study Population	Country/ Population Code	Study [Reference]	Study Design	Study Period	FSW Sample Size	FSW Characteristics	ART Cascade Outcomes				
							Uptake	Attrition	Adherence	VS	CD4
Abriendo Puertas Intervention Project	Dominican Republic 1	Donastorg *et al*, 2014 [53][a]	CS	2012–2013	268	Active, HIV +ve, Drug use (24%)	✓	✓	✓	✓	
ACCESS cohort	Canada 1	Reddon *et al*, 2011 [45][c]	PC	2005–2011	88	Active, HIV +ve, IDU	✓				
Canadian Co-infection Cohort	Canada 2	Cox *et al*, 2014 [58][a]	PC	2003–2013	43	Active, HIV +ve, IDU or crack	✓				
Chiang Rai Health Club FSW Cohort	Thailand 1	Kilmarx *et al*, 2000 [22]	PC	1991–1998	194	Active, HIV +ve	✓				
El Salvador FSW and MSM Study	El Salvador 1	Dennis *et al*, 2013 [52]	CS	2008	848	Active, HIV +ve (5%)	✓				
FSW and GP Comparative Study	Benin 1	Diabaté *et al*, 2011 [44]	PC	2008–2010	53	Active, HIV +ve, On ART					✓
FSW Focus Group Study	India 1	Chakrapani *et al*, 2009 [46][a]	CS	2007	19	Active, HIV +ve	✓				
HERMITAGE RCT Cohort	Russia 1	Tyurina *et al*, 2013 [59][a]	PC	2007–2011	42	Active, HIV +ve, Risky drinkers	✓				
Maka Project Partnership/WISH Drop-In Centre Society	Canada 3	Deering *et al*, 2009 [23][a]	PDI	2007–2008	20	Active + Former, HIV +ve, IDU (40%)			✓		
		Shannon *et al*, 2005 [24]	CS	2003	159	Active + Former, HIV +ve (21%), IDU (57%)	✓	✓			
Karnataka Multi-District FSW Study	India 2	Jadhav *et al*, 2013 [55]	CS	2011	603	Active, HIV +ve	✓				
Mombasa FSW cohort	Kenya 1	Balkus *et al*, 2013 [49]	PC	1993–2010	282	Active, HIV +ve, T.*vaginalis* infection	✓				
		Day et al, 2013 [51]	PC	2004–2010	159	Active, HIV +ve, On ART		✓			✓
		Graham *et al*, 2013 [54]	PC	1993–2009	306	Active, HIV +ve	✓				
		Graham *et al*, 2012 [29][b]	PC	2005–2009	102	Active + Former, HIV +ve, On ART		✓			✓
		Graham *et al*, 2011 [26]	PC	2004–2008	36	Active, HIV +ve, On ART, Genital ulcers					✓
		Masese *et al*, 2011[25]	PC	2004–2008	41	Active, HIV +ve, On ART, T.*vaginalis* infection		✓	✓		✓
		McClelland *et al*, 2011 [33][c]	CS	1993–2006	571	Active, HIV +ve	✓				

Table 2. Cont.

Study Population	Country/ Population Code	Study [Reference]	Study Design	Study Period	FSW Sample Size	FSW Characteristics	ART Cascade Outcomes				
							Uptake	Attrition	Adherence	VS	CD4
		Gitau *et al*, 2010 [31]	PC	2004–2008	30	Active, HIV +ve, On ART, Cervicitis infection					✓
		Graham *et al*, 2010 [28][b]	PC	2005–2008	102	Active + Former, HIV +ve, On ART		✓		✓	✓
		McClelland *et al*, 2010 [32][a]	PC	1993–2008	966	Active, HIV +ve	✓				✓
		Graham *et al*, 2009 [27]	PC	2004–2008	134	Active, HIV +ve, On ART					✓
		Graham *et al*, 2007 [30][a]	PC	2004	21	Active, HIV +ve, On ART			✓		✓
Multicentre Vietnam Study	Vietnam 1	Dean *et al*, 2011 [43][a]	CS	2008–2009	147	Active, HIV +ve	✓			✓	
Multicity Study of YPLH	USA 1	Comulada *et al*, 2003 [48][a]	CS	1999–2000	21	Active + Former, HIV +ve	✓	✓	✓		
Multisite Zimbabwe FSW Study	Zimbabwe 1	Cowan *et al*, 2013 [50]	CS	2009	836	Active, HIV +ve (57%)	✓				
Nairobi FSW cohort	Kenya 2	Mawji *et al*, 2012 [35][a]	RCC	2001–2006	62	Active, HIV +ve, On ART					✓
		McKinnon *et al*, 2010 [34][a]	PC	1986–2009	607	Active, HIV +ve	✓				✓
		Lester *et al*, 2009 [36]	CS	Not reported	57	Active, HIV +ve	✓				
North Mombasa Clinic Cohort	Kenya 3	Graham *et al*, 2013 [60][a]	PC	2005–2011	108	Active, HIV +ve	✓	✓	✓		
Payana FSW Cohort	India 3	Becker *et al*, 2012 [40][a]	PC	2008–2009	45	Active, HIV +ve, Died during follow-up	✓				
Port of Imbutiba Sex Worker Study	Brazil 1	Schuelter-Trevisol *et al*, 2007 [47]	CS	2003–2004	90	Active, HIV +ve (4%), Illicit Drug Users (52%)	✓				
Project HOPE	USA 2	Kalokhe *et al*, 2012 [41][c]	CS	2006–2010	46	Active, HIV +ve, Crack cocaine use	✓				
Project Ubuzima FSW HIV incidence study	Rwanda 1	Braunstein *et al*, 2011 [42]	PC	2006–2008	141	Active + Former, HIV +ve	✓		✓		✓
Yerelon FSW Cohort	Burkina Faso 1	Low et al, 2014 [56]	PC	2004–2011	199	Active, HIV +ve, On ART				✓	✓
		Low et al, 2014 [57]	PC	2007–2011	258	Active, HIV +ve	✓				

Table 2. Cont.

Study Population	Country/ Population Code	Study [Reference]	Study Design	Study Period	FSW Sample Size	FSW Characteristics	ART Cascade Outcomes				
							Uptake	Attrition	Adherence	VS	CD4
		Huet *et al*, 2011 [39]	PC	2003–2007	47	Active, HIV +ve, On ART		✓	✓	✓	✓
		Konate *et al*, 2011 [38]	PDI	2003–2005	658	Active, HIV +ve	✓	✓	✓	✓	✓
		Low *et al*, 2011 [37]	PC	2003–2006	767	Active, HIV +ve	✓				✓

FSW – female sex worker, ART – antiretroviral therapy, HIV – human immunodeficiency virus, VS – viral suppression, MSM – men who have sex with men, GP – general population, IDU – injecting drug user, PC – prospective cohort, CS – cross-sectional, RCT – randomised controlled trial, RCC – retrospective case-control, PDI – peer driven intervention, YPLH – young people living with HIV, HERMITAGE – HIV's Evolution in Russia – Mitigating Infection Transmission and Alcoholism in a Growing Epidemic, WISH – Women's Information and Safe House, HOPE – Hospital visit is an Opportunity for Prevention and Engagement, ACCESS – AIDS Care Cohort to evaluate Exposure to Survival Services.

[a] Additional data or clarifications were provided by corresponding author/s.

[b] Corresponding author confirmed that participants were FSWs from the Mombasa FSW cohort.

[c] Outcome data is based on entire cohort rather than subset of participants in referenced study; in some cases this data was provided by study authors.

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87% of ART-eligible (CD4 <350 cells/mm^3) FSWs enrolled in HIV care reported initiating ART within 12 to 36 months of their HIV diagnosis [42] (Figure 3B, Table S1B).

Estimates of current ART use among all HIV-infected FSWs were provided by 18 studies reporting on 16 independent study populations in Asia, Africa, North America, South America, and Central America and the Caribbean ($N_s = 18$, $N_p = 16$) (Figure 4, Table S1A). Across these 18 studies, the fraction of HIV-infected FSWs currently using ART ranged between 0% and 72% ($N_s = 18$, $N_p = 16$) (Figure 4, Table S1A). The overall pooled estimate for current ART use among HIV-infected FSWs, when pooling only one estimate per study population and pooling only those estimates with a known time period of data collection measured among at least 10 FSWs, was 38% (95% CI: 29%–48%, $I^2 = 96\%$, $N_s = N_p = 15$) (Figure 4). Pooled estimates were similar for LMI countries (39%; 95% CI: 27%–53%, $I^2 = 97\%$, $N_s = N_p = 9$) and HI countries (35%; 95% CI: 20%–55%, $I^2 = 87\%$, $N_s = N_p = 6$) (Figure 4). Removing the one LMI country estimate where data on HIV-infected FSWs was collected between the pre-HAART and HAART era had a marginal impact on the pooled estimate for LMI countries (42%; 95% CI: 29%–57%, $I^2 = 97\%$, $N_s = N_p = 8$).

Estimates of ever ART use (i.e. no time-frame for ART initiation specified) among HIV-infected FSWs were provided by five studies reporting on 5 independent study populations in Asia, Africa, North America, and Central America and the Caribbean. Across these 5 studies, the fraction of HIV-infected FSWs who had ever used ART ranged between 14% and 91% ($N_s = N_p = 5$) (Figure 5, Table S1A). The overall pooled estimate of ever ART use among HIV-infected FSWs was 54% (95% CI: 21%–84%, $I^2 = 98\%$, $N_s = N_p = 5$). Pooled estimates were lower for LMI countries (36%; 95% CI: 7%–81%, $I^2 = 99\%$, $N_s = N_p = 3$) than HI countries (80%; 95% CI: 48%–94%, $I^2 = 70\%$, $N_s = N_p = 2$) (Figure 5).

Treatment Attrition

Estimates of treatment attrition (either treatment discontinuation, loss-to-follow-up on ART, death on ART, or ART-experienced but no longer on ART), were available from 10 studies reporting on 6 independent study populations in Africa, North America, and Central America and the Caribbean [24,25,28,29,38,39,48,51,53,60] (Figure 6, Table S2).

Treatment discontinuation was reported by 2 studies reporting on the same study population in Kenya ($N_s = 2$, $N_p = 1$) (Figure 6A, Table S2). In this Kenyan cohort, estimates of treatment discontinuation among FSWs starting ART, increased from 4% at 6 months to 10% at 12 months [28,29] (Figure 6A, Table S2).

Estimates of loss-to-follow-up among FSWs on ART were provided by 6 studies reporting on 3 independent study populations in Kenya and Burkina Faso ($N_s = 6$, $N_p = 3$) (Figure 6B, Table S2). Across the three different study populations, estimates of loss-to-follow-up after ART initiation were similar, ranging between 3% and 10% after varying times on ART ($N_s = 6$, $N_p = 3$) (Figure 6B, Table S2). In one of the Kenyan cohorts, loss-to-follow-up increased from 3% after 3 months to 6% after 12 months on ART [28,29], whilst in the Burkina Faso cohort 4% were lost-to-follow-up after 32 months on ART [38,39]. The overall pooled estimate of loss-to-follow-up on ART, when pooling the most recent study estimate per study population, was 6% (95% CI: 3%–11%, $I^2 = 0\%$, $N_s = N_p = 3$) (Figure 6B).

Estimates of death among FSWs on ART were provided by 6 studies reporting on 3 independent study populations in Kenya and Burkina Faso ($N_s = 6$, $N_p = 3$) (Figure 6C, Table S2). Across

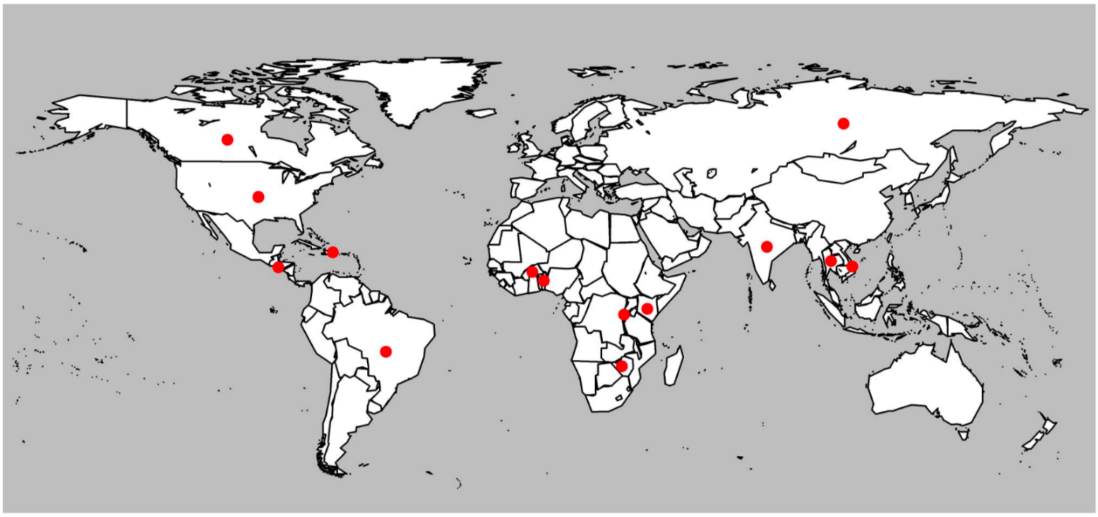

Figure 2. Map of Study Locations. Red dots highlight the countries where included studies were conducted.
doi:10.1371/journal.pone.0105645.g002

the three different study populations, the fraction of FSWs who died after varying times on ART ranged between 0% and 8.5% ($N_s = 6$, $N_p = 3$) (Figure 6C, Table S2). In two of the study populations in Kenya and Burkina Faso the fraction of FSWs who died whilst on ART increased over time [28,29,38,39,51] (Figure 6C, Table S2). The overall pooled estimate of death on ART, when pooling the most recent study estimate per study population, was 6% (95% CI: 3%–11%, $I^2 = 0\%$, $N_s = N_p = 3$) (Figure 6C). In one of the Kenyan cohorts, total attrition from ART, due to treatment discontinuation, loss-to-follow-up and

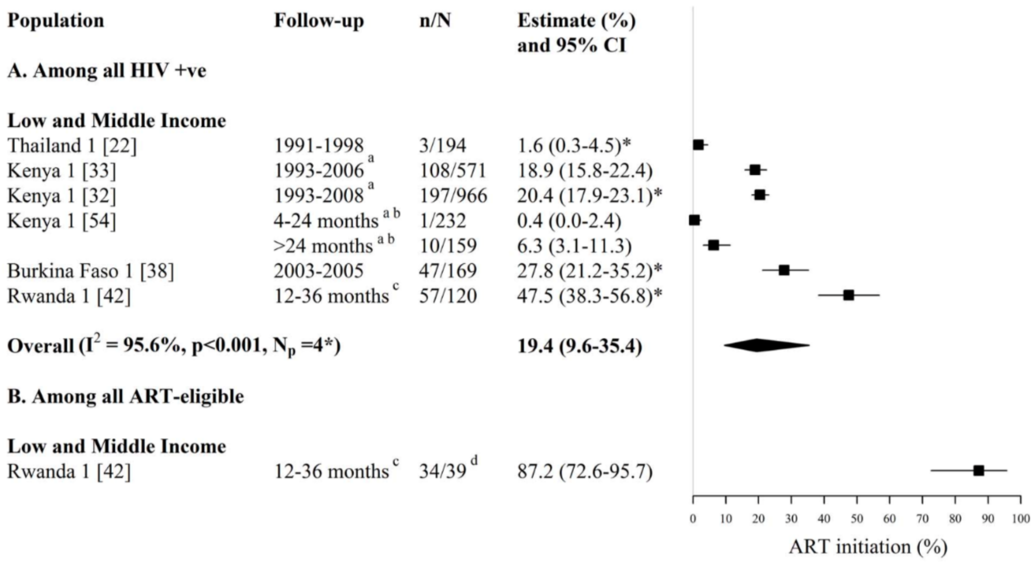

Figure 3. Forest plot of ART initiation among (A) all HIV-infected FSWs and (B) all ART-eligible FSWs. Study estimates are grouped by country income and ordered by follow-up period. The star symbol (*) highlights the individual study estimates (one per study population) included in the pooled overall estimate. I^2 and p-values are the measures of heterogeneity used. [a] ART was provided to FSWs in the Kenyan cohort from 2004, [b] Follow-up refers to months since HIV-diagnosis, study recruitment occurred between 1993 and 2009, [c] Follow-up refers to months since HIV-diagnosis, study recruitment occurred between 2006 and 2008. [d] N refers to HIV-infected ART-eligible FSWs who had enrolled in HIV care following HIV diagnosis. ART = antiretroviral therapy, FSW = female sex workers, CI = confidence interval, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations.
doi:10.1371/journal.pone.0105645.g003

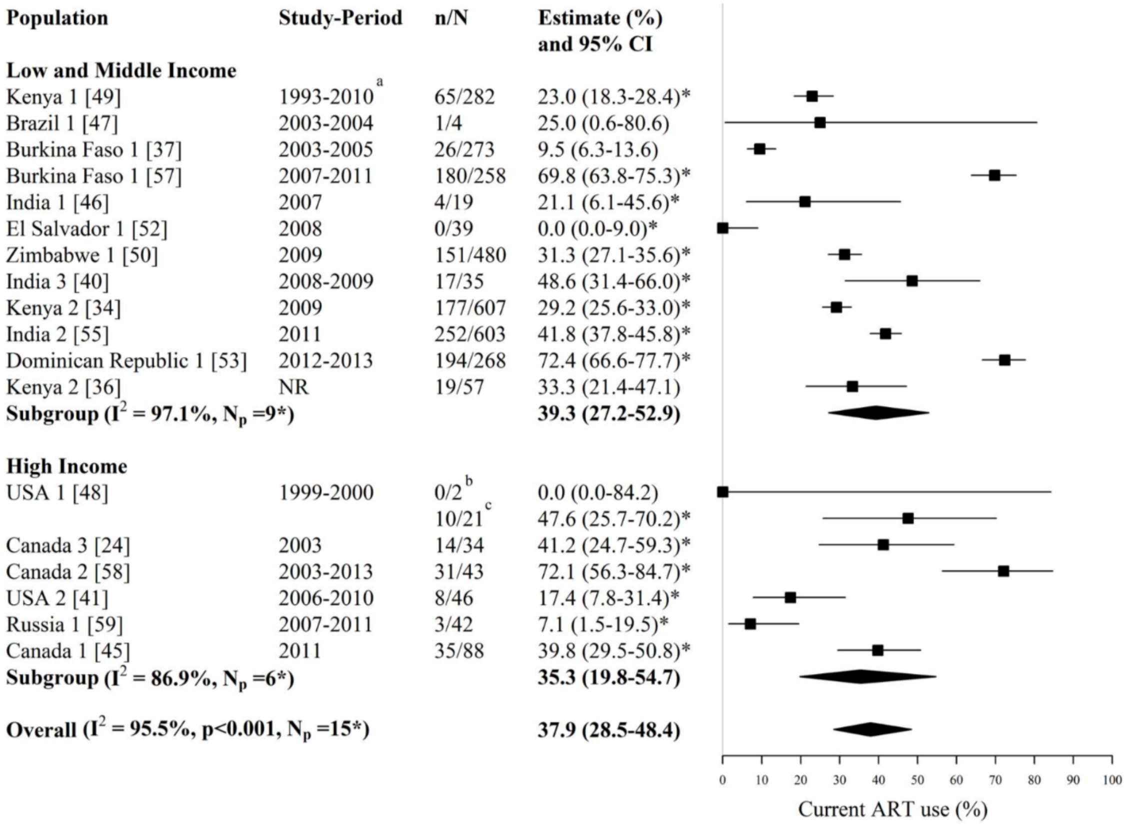

Figure 4. Forest plot of current ART use among HIV-infected FSWs. Study estimates are grouped by country income and ordered by study-period. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall or subgroup estimates. Only study estimates with a known time period of data collection which were measured among at least 10 FSWs were used for pooling. I^2 and p-values are the measures of heterogeneity used. [a] ART was provided to FSWs in the Kenyan cohort from 2004, [b] Sample is 'active' FSWs, [c] Sample is 'active' and 'former' FSWs. ART = antiretroviral therapy, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations.
doi:10.1371/journal.pone.0105645.g004

mortality, was 10% and 21%, after 6 and 12 months on ART, respectively [28,29].

Estimates of the number of treatment-experienced FSWs that reported no longer receiving ART, were provided by 3 studies reporting on 3 independent study populations in Canada, USA and Dominican Republic ($N_s = 3$, $N_p = 3$) (Figure 6D, Table S2). Across these three studies, the fraction of treatment-experienced FSWs that reported no longer receiving ART ranged between 8% and 47%, with an overall pooled estimate of 26% (95% CI: 6%–65%, $I^2 = 93.3\%$, $N_s = N_p = 3$) (Figure 6D). The pooled estimate for HI countries (43%; 95% CI: 29%–58%, $I^2 = 0\%$, $N_s = N_p = 2$), was higher than the single LMI country estimate (8%, 95% CI: 4%–12%, $N_s = N_p = 1$) (Figure 6D, Table S2).

Adherence

Estimates of adherence (i.e. the fraction achieving a predefined threshold of adherence) were available from 9 studies, reporting on 7 independent study population in Africa, North America, and Central America and the Caribbean [23,25,30,38,39,42,48,53,60] (Figure 7, Table S3). Among these 9 studies, three reported the availability of adherence counselling [23,38,39], one study reported the use of directly observed therapy [30], and one study reported that monthly support groups were used to promote adherence [60] (Table S3). The fraction of FSWs adherent to treatment was consistently high, ranging from 67% to 100% ($N_s = 9$, $N_p = 7$), across the varying time periods, adherence thresholds (≥90%, ≥95% and 100%), recall periods (past 3 days, past 4 days, past week, past 30 days, past month, and since ART initiation), and methods of assessment (self-report, pill count and visual analog scale) (Figure 7, Table S3). Estimates of the fraction of FSWs 100% adherent to ART were highest shortly after starting directly observed therapy (91% after 28 days on ART [30]) and at the end of a peer-driven intervention (90.4% [23]) (Figure 7, Table S3). Estimates of the fraction of FSWs ≥95% adherent to ART increased from 83% after 6 months on ART to 100% after 36 months on ART in a cohort in Burkina Faso [38,39] (Figure 7, Table S3). For LMI countries, the pooled estimate of adherence, when pooling only one estimate per study population and pooling only those estimates with a known numerator and denominator, was 76% (95% CI: 68%–83%, $I^2 = 36\%$, $N_s = N_p = 4$) (Figure 7).

Viral Suppression

Estimates of viral suppression (i.e. the fraction on ART with undetectable plasma viral load), were available from 6 studies

Population	Time-Period	n/N	Estimate (%) and 95% CI
Low and Middle Income			
Vietnam 1 [43]	2008-2009	29/131	22.1 (15.4-30.2)*
Kenya 3 [60]	2005-2011	15/108	13.9 (8.0-21.9)*
Dominican Republic 1 [53]	2012-2013	210/268	78.4 (72.9-83.1)*
Subgroup (I^2 = 98.7%, N_p =3*)			**35.7 (6.7-81.1)**
High Income			
USA 1 [48]	1999-2000	1/2 [a]	50.0 (1.3-98.7)
		19/21 [b]	90.5 (69.6-98.8)*
Canada 3 [24]	2003	23/34	67.6 (49.5-82.6)*
Subgroup (I^2 = 70.0%, N_p =2*)			**79.5 (47.5-94.4)**
Overall (I^2 = 97.6%, p<0.0001, N_p =5*)			**54.4 (21.3-84.0)**

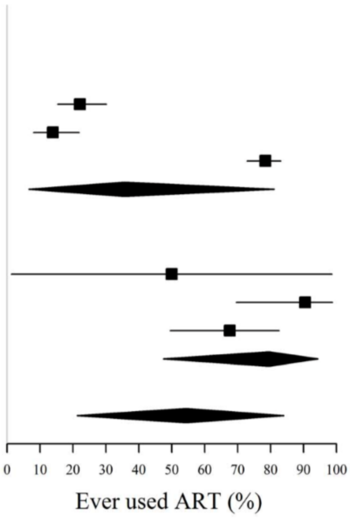

Figure 5. Forest plot of ever ART use among HIV-infected FSWs. Study estimates are grouped by country income and ordered by time-period. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall or subgroup estimates. I^2 and p-values are the measures of heterogeneity used. [a] Sample is 'active' FSWs, [b] Sample is 'active' and 'former' FSWs. ART = antiretroviral therapy, FSW = female sex workers, CI = confidence interval, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations.
doi:10.1371/journal.pone.0105645.g005

reporting on 4 independent study populations in Asia, Africa, and Central America and the Caribbean [28,38,39,43,53,56] (Figure 8, Table S4). The fraction of FSWs on ART virally suppressed, ranged between 40%–82% (N_s = 6, N_p = 4), across varying time periods and definitions of viral suppression (≤50 copies/mm^3, ≤100 copies/mm^3, ≤180 copies/mm^3, ≤300 copies/mm^3) (Figure 8, Table S4). The lowest study estimate of viral suppression (40%) was reported in the Kenyan study population after 3 months on ART [28], which increased to 73% after 6 months on ART [28] (Figure 8, Table S4). In the Burkina Faso study population, the high fraction of FSWs virally suppressed (79%–88%) after 6 to 36 months on ART, corresponded to similarly high levels of treatment adherence seen over the same time periods for these FSWs (Figure 7 & 8, Tables S3 & S4) [38,39]. The overall pooled estimate of viral suppression, when pooling one estimate per study population, was 57% (95% CI: 46%–68%, I^2 = 82%, N_s = N_p = 4) (Figure 8).

CD4 Counts at and/or after ART Initiation

Information on CD4 counts at and/or after ART initiation (either median CD4 count, median CD4 count gain, or fraction with CD4 counts >500, 200–499 or <200 cells/mm^3), were available from 17 studies reporting on 5 independent study populations in Africa [25–32,34,35,37–39,42,44,51,56] (Figures 9 &10, Table S5). Across the studies, the CD4 count criteria for ART initiation was either ≤200 cells/mm^3 or not reported, with one study reporting a change in ART initiation criteria from CD4 count <200 cells/mm^3 to CD4 count <350 cells/mm^3 (Table S5).

Median CD4 counts at and/or after ART initiation were provided by 14 studies reporting on 5 independent study populations in Benin, Kenya, Burkina Faso, and Rwanda (N_s = 14, N_p = 5) (Figure 9A & 9B, Table S5A). Across 4 of these study populations, the median CD4 count ranged between 121 and 205 cells/mm^3 at ART initiation (N_s = 12, N_p = 4), and 204 to 343 cells/mm^3 after 1 to 36 months on ART (N_s = 9, N_p = 4) (Figure 9A & 9B, Table S5A).

Median gains in CD4 count following ART initiation, were provided by 5 studies reporting on 4 independent study populations in Benin, Kenya, Burkina Faso, and Rwanda (N_s = 5, N_p = 4) (Figure 9C, Table S5A). Across 3 of these study populations, median gains in CD4 counts after 6 to 36 months on ART, ranged between 103 and 241 cells/mm^3 (N_s = 4, N_p = 3) (Figure 9C, Table S5A).

Estimates of the fraction of FSWs with CD4 counts <200, 200–499 or >500 cells/mm^3 at and/or after ART initiation were provided by 2 studies reporting on 2 independent study populations in Kenya and Burkina Faso (N_s = 2, N_p = 2) (Figure 10, Table S5B). In the Kenyan study, the fraction of FSWs with CD4 counts ≤200 cells/mm^3, decreased from 90% at ART initiation to 11% after 24 months on ART [32] (Figure 10A, Table S5B). When pooling the most recent study estimates from the 2 study populations, the overall pooled fractions of FSWs on ART with CD4 counts <200 cells/mm^3, 200–499 cells/mm^3, and >500 cells/mm^3, were 22% (95% CI: 5%–66%, I^2 = 88%, N_s = N_p = 2), 63% (95% CI: 28%–89%, I^2 = 89%, N_s = N_p = 2), and 13% (95% CI: 7%–22%, I^2 = 0%, N_s = N_p = 2), respectively [32,37] (Figure 10).

Discussion

Despite the recent momentum to scale-up ART coverage worldwide, there is a concerning lack of published data on HIV treatment among FSWs [61]. We found only thirty-nine studies, from fourteen different countries in Africa, Asia, North America, South America, and Central America and the Caribbean that reported information on the ART cascade among FSWs (Figure 2). Of these studies, the majority reported estimates of either current ART use or median CD4 counts at and/or after

Population	Time on ART	n/N	Estimate (%) and 95% CI
A. Treatment Discontinuation			
Low and Middle Income			
Kenya 1 [28]	6 months	4/102	3.9 (1.1-9.7)
Kenya 1 [29]	12 months	10/102	9.8 (4.8-17.3)
B. LFU on ART			
Low and Middle Income			
Kenya 1 [28,29]	3 months	3/102	2.9 (0.6-8.4)
	6 months	4/102	3.9 (0.1-9.7)
	12 months	6/102	5.9 (2.2-12.4)*
Kenya 1 [25]	10 months (m)	2/41	4.9 (0.6-16.5)
Burkina Faso 1 [38,39]	32 months (m)	2/47	4.3 (0.5-14.5)*
Kenya 3 [60]	NR	1/10	10.0 (0.3-44.5)*
Overall (I^2 = 0%, p=0.77, N_p =3*)			**5.8 (3.0-10.8)**
C. Deaths on ART			
Low and Middle Income			
Kenya 1 [28,29]	3 months	2/102	2.0 (0.2-6.9)
	6 months	2/102	2.0 (0.2-6.9)
	12 months	5/102	4.9 (1.6-11.1)*
Kenya 1 [51]	41 months (m)	7/159	4.4 (1.8-8.9)
Burkina Faso 1 [38,39]	12 months	3/47	6.4 (1.3-17.5)
	36 months	4/47	8.5 (2.4-20.4)*
Kenya 3 [60]	NR	0/10	0.0 (0.0-30.9)*
Overall (I^2 = 0%, p=0.67, N_p =3*)			**6.2 (3.3-11.2)**
D. No Longer on ART			
Low and Middle Income			
Dominican Republic 1 [53]	NR	16/210	7.6 (4.4-12.1)*
High Income			
Canada 3 [24]	NR	9/23	39.1 (19.7-61.5)*
USA 1 [48]	NR	9/19	47.4 (24.5-71.1)*
Subgroup (I^2 = 0%, p=0.59, N_p =2*)			**42.9 (28.9-58.1)**
Overall (I^2 = 93.3%, p<0.0001, N_p =3*)			**26.0 (6.4-64.6)**

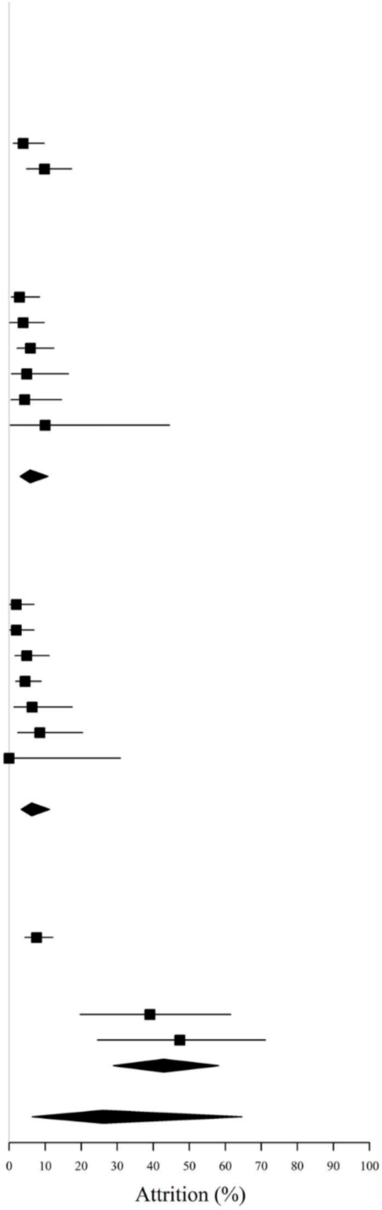

Figure 6. Forest plot of treatment attrition among HIV-infected FSWs, including (A) treatment discontinuation (B) loss to follow-up on ART (C) death on ART and (D) ART-experienced but no longer on ART. Study estimates are grouped by country income and ordered by time on ART. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall or subgroup estimates. For studies providing estimates over multiple time-periods, only one estimate was used for pooling (the most recent estimate from that study). I^2 and p-values are the measures of heterogeneity used. ART = antiretroviral therapy, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations, m = median, LFU = lost to follow-up.
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ART initiation, with very few providing estimates of treatment attrition, adherence and viral suppression among FSWs.

ART uptake among HIV-infected FSWs was particularly variable across the different studies and settings. Pooled estimates of ART initiation in HIV-infected FSWs were higher among studies which collected data on HIV-infected FSWs exclusively in the HAART era versus studies which collected data spanning the pre-HAART and HAART eras, and pooled estimates of ever

Population	Time on ART	Threshold, Method Assessed, Recall Period	n/N	Estimate (%) and 95% CI
Low and Middle Income				
Kenya 1 [30]	28 days	100%, PC, month	19/21	90.5 (69.6-98.8)
Kenya 1 [25]	10 months (m)	95%, PC, month	21/31	67.7 (48.6-83.3)*
Burkina Faso 1 [38,39]	6 months	95%, PC, 30-day	NR	83.3 (67.2-93.6)
	12 months	95%, PC, 30-day	NR	92.1 (78.6-98.3)
	36 months	95%, PC, 30-day	NR	100.0 (54.1-100.0)
Rwanda 1 [42]	NR	100%, SR, 3-day	49/57	86.0 (74.2-93.7)*
		100%, SR, all ART use	38/57	66.7 (52.9-78.6)
Dominican Republic 1 [53]	NR	100%, SR, 4-day	155/210	73.8 (67.3-79.6)*
Kenya 3 [60]	NR	95%, VAS, 30-day	8/10	80.0 (44.4-97.5)*
Subgroup (I^2 = 35.5%, p=0.2, N_p =4*)				**76.2 (67.8-83.0)**
High Income				
Canada 3 [23]	NR (PDI Start)	100%, SR, week	NR	87.2
	NR (PDI End)	100%, SR, week	NR	90.4
USA 1 [48]	NR	90%, SR, 3-day	6/9	66.7 (29.9-92.5)

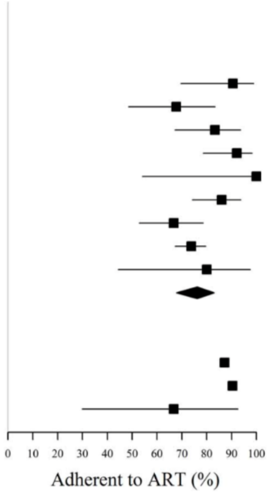

Figure 7. Forest plot of ART adherence among HIV-infected FSWs. Study estimates are grouped by country income and ordered by time on ART. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall or subgroup estimates. Only study estimates with a known sample size of at least 10 FSWs were used for pooling. For studies providing estimates over multiple time-periods, only one estimate was used for pooling (the most recent estimate from that study). I^2 and p-values are the measures of heterogeneity used. ART = antiretroviral, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations, m = median, PDI = peer driven intervention, PC = pill count, SR = self-report, VAS = visual analog scale.
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ART use among HIV-infected FSWs were higher in high-income countries compared to low- and middle-income countries. Conversely, pooled estimates of current ART use among HIV-infected FSWs were similar between high-income countries and low- and middle-income countries. However, there was substantial between-study heterogeneity for all pooled estimates of ART uptake. Varied study periods, different follow-up times and different ART eligibility criteria across studies could all contribute to the variability in study estimates. Nevertheless, pooled estimates of current ART use among HIV-infected FSWs are similar to estimates of current ART use among HIV-infected women in Burkina Faso (27%) and among HIV-infected female IDUs in Canada (30%) [62,63]. Likewise, in the one study in Rwanda that reported ART initiation among ART-eligible FSWs, the propor-

Population	Time on ART	Definition of Viral Suppression	n/N	Estimate (%) and 95% CI
Low and Middle Income				
Kenya 1 [28]	3 months	<100 copies/ml	39/97	40.2 (30.4-50.7)
	6 months	<100 copies/ml	69/95	72.6 (62.5-81.3)*
Burkina Faso 1 [38,39]	6 months	<300 copies/ml	27/34	79.4 (62.1-91.3)
	12 months	<300 copies/ml	27/35	77.1 (59.8-89.6)
	18 months	<300 copies/ml	24/30	80.0 (61.4-92.3)
	24 months	<300 copies/ml	7/8	87.5 (47.4-99.7)
	30 months	<300 copies/ml	9/12	75.0 (42.8-94.5)
	32 months (m)	<300 copies/ml	36/47	76.7 (61.4-88.2)
	36 months	<300 copies/ml	18/22	81.8 (59.7-94.8)
Burkina Faso 1 [56]	3.4 years (m)	<300 copies/ml	84/174	48.3 (40.7-56.0)*
Vietnam 1 [43]	NR	<180 copies/ml	13/29	44.8 (26.5-64.3)*
Dominican Republic 1 [53]	NR	<50 copies/ml	115/193	59.6 (52.3-66.6)*
Overall (I^2 = 82%, p=0.0008, N_p =4*)				**57.4 (45.7-68.2)**

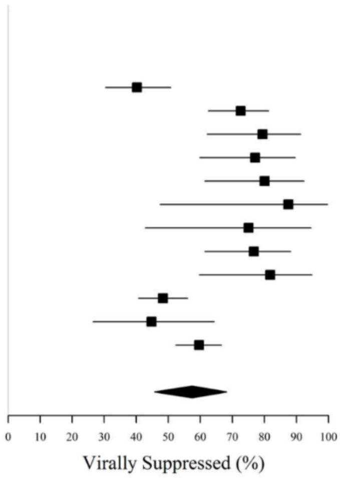

Figure 8. Forest plot of viral suppression among HIV-infected FSWs on ART. Study estimates are grouped by country income and ordered by time on ART. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall estimate. For studies providing estimates over multiple time-periods, only one estimate was used for pooling (the most recent estimate from that study). I^2 and p-values are the measures of heterogeneity used. ART = antiretroviral, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations, m = median.
doi:10.1371/journal.pone.0105645.g008

Population	Time on ART	ART Eligibility Criteria	N	Estimate (cells/mm^3) and IQR
A. Median at ART initiation				
Low and Middle Income				
Benin 1 [44]	ART initiation	CD4 count<200	53	134 (67-175)
Kenya 1 [29]	ART initiation	CD4 count<200	102	124
Kenya 1 [26]	ART initiation	NR	36	125 (76-168)
Kenya 1 [27]	ART initiation	NR	134	127 (79-165)
Kenya 1 [25]	ART initiation	NR	31	126 (68-159)
Kenya 1 [30]	ART initiation	CD4 count<200	21	121 (58-161)
Kenya 1 [51]	ART initiation	CD4 count<200	159	132 (80-180)
Kenya 2 [35]	ART initiation	NR	62	205
Kenya 2 [34]	ART initiation	NR	79	180
Burkina Faso 1 [38,39]	ART initiation	CD4 count<200	47	147 (79-183)
Burkina Faso 1 [56]	ART initiation	CD4 count<200 then <350	163	177 (122-228)
B. Median after ART initiation				
Low and Middle Income				
Kenya 1 [30]	28 days	CD4 count<200	19	204 (131-277)
Kenya 1 [29]	3 months	CD4 count<200	97	238
	6 months	CD4 count<200	95	236
	12 months	CD4 count<200	88	240
Kenya 1 [26]	5 months (m)	NR	36	241 (158-312)
Burkina Faso 1 [38,39]	6 months	CD4 count<200	43	234 (180-327)
	12 months	CD4 count<200	41	306 (249-381)
	36 months	CD4 count<200	22	343 (230-553)
Kenya 1 [25]	10 months (m)	NR	31	241 (161-292)
Benin 1 [44]	12 months	CD4 count<200	53	212
Kenya 1 [31]	15 months (m)	NR	30	308 (238-395)
Kenya 2 [34]	697 days (m)	NR	79	339
Rwanda 1 [42]	NR	CD4 count<350	57	441 (309-619)
			34	354 (213-456)[a]
C. Median gain				
Low and Middle Income				
Kenya 1 [28]	6 months	CD4 count<200	95	109 (66-176)
Benin 1 [44]	12 months	CD4 count<200	53	103 (25-178)
Burkina Faso 1 [38,39]	6 months	CD4 count<200	43	132 (41-196)
	12 months	CD4 count<200	41	177 (105-255)
	18 months	CD4 count<200	33	172 (121-309)
	24 months	CD4 count<200	29	221 (98-295)
	30 months	CD4 count<200	26	241 (87-319)
	36 months	CD4 count<200	22	230 (90-400)
Rwanda 1 [42]	NR	CD4 count<350	57	139 (34-261)

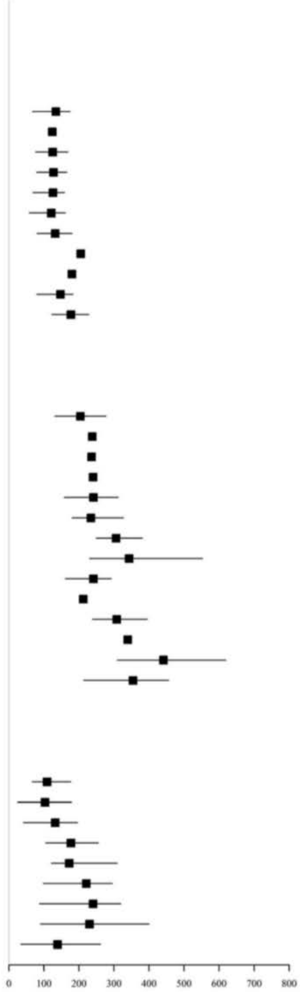

Figure 9. Forest plot of (A) median CD4 count and (B) median gains in CD4 count among HIV-infected FSWs on ART and starting ART. Study estimates are grouped by country income and ordered by time on ART. [a] N refers to a subset of FSWs who were eligible for ART upon HIV diagnosis and enrolled in HIV care following HIV diagnosis. ART = antiretroviral, FSW = female sex workers, CI = confidence interval, NR = not reported, N = sample size of FSWs available for each outcome, N_p = number of independent study populations, m = median, IQR = interquartile range.

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tion of ART-eligible FSWs in HIV care initiating ART was similar to the proportion of ART-eligible individuals in the Rwandan general population initiating ART (71%) [42].

Data from two African FSW research cohorts suggest that treatment discontinuation, loss to follow-up on ART, and mortality on ART among FSWs may be low, at least over the first few years of ART use [25,28,29,38,39]. However, these studies were conducted in research contexts where there is likely to be intensive follow-up of participants, and thus better retention on treatment. Even so, total treatment attrition after one year on ART in one of the African FSW cohorts was similar to that found in the sub-Saharan African general population after 12 months on ART (23%) [64]. In addition estimates of loss to follow-up and death on ART among FSWs are similar to if not better than estimates of loss to follow-up and death among women on ART enrolled in cohort studies in South Africa and Tanzania, where 17.5% and 25.6% were loss to follow-up, respectively, and 4.1% and 12.8% died on ART, respectively [65,66]. Only three studies in Dominican Republic, Canada and the USA reported on the fraction of ART-experienced FSWs that were no longer on ART, and there was substantial between-study heterogeneity. Although the proportion of FSWs in the Dominican Republic that reported ever but not current ART use was similar to that reported by women from the general population in the USA (9%) [67], the two cross-sectional studies in North America found much higher proportions of FSWs self-reporting that they were previously but no longer on ART [24,48]. However, the sample size of FSWs in these two North American studies was very small.

Population	Time on ART	n/N	Estimate (%) and 95% CI
A. CD4 count<200			
Low and Middle Income			
Kenya 1 [32]	ART initiation [a]	115/118	89.8 (83.3-94.5)
	6 months	37/111	33.3 (24.7-42.9)
	12 months	26/92	28.3 (19.4-38.6)
	18 months	13/65	20.0 (11.1-31.8)
	24 months	6/56	10.7 (4.5-21.9)*
Burkina Faso 1 [37]	NR	10/25	40.0 (21.1-61.3)*
Overall (I^2 = 88.0%, p=0.004, N_p =2*)			**22.2 (5.0-66.4)**
B. CD4 count 200-499			
Low and Middle Income			
Kenya 1 [32]	ART initiation [a]	13/128	10.2 (5.5-16.7)
	6 months	72/111	64.9 (55.2-73.7)
	12 months	64/92	69.6 (59.1-78.7)
	18 months	43/65	66.2 (53.4-77.4)
	24 months	44/56	78.6 (65.6-88.4)*
Burkina Faso 1 [37]	NR	11/25	44.0 (24.4-65.1)*
Overall (I^2 = 88.7%, p=0.003, N_p =2*)			**63.4 (27.7-88.7)**
C. CD4 count >500			
Low and Middle Income			
Kenya 1 [32]	ART initiation [a]	0/128	0.0 (0.0-2.8)
	6 months	2/111	1.8 (0.2-6.4)
	12 months	2/92	2.2 (0.3-7.6)
	18 months	9/65	13.9 (6.5-24.6)
	24 months	6/56	10.7 (4.0-21.8)*
Burkina Faso 1 [37]	NR	4/25	16.0 (4.5-36.1)*
Overall (I^2 = 0%, p=0.507, N_p =2*)			**12.5 (6.9-21.8)**

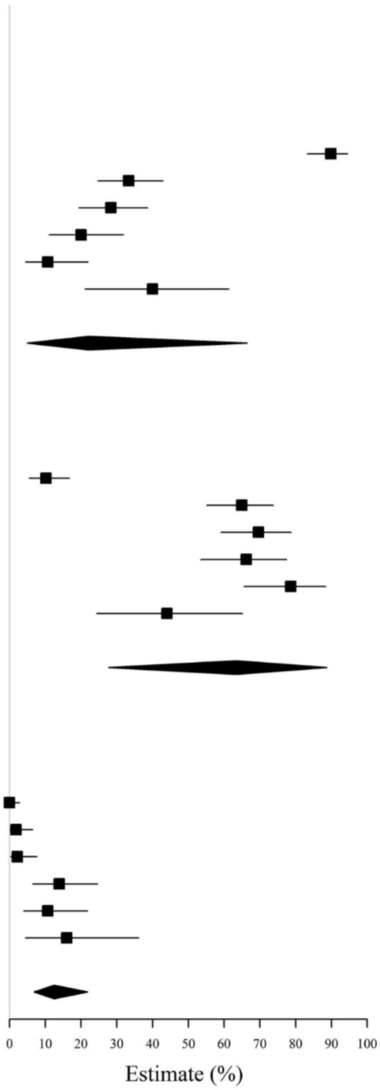

Figure 10. Forest plot of the fraction of HIV-infected FSWs on ART and starting ART with (A) CD4 counts <200 cells/mm^3 (B) CD4 counts 200–499 cells/mm^3 and (C) CD4 counts >500 cells/mm^3. Study estimates are grouped by country income and ordered by time on ART. The star symbol (*) highlights the study estimates (one per study population) included in the pooled overall estimates. For studies providing estimates over multiple time-periods, only one estimate was used for pooling (the most recent estimate from that study). I^2 and p-values are the measures of heterogeneity used. [a] ART initiation criteria is CD4 count <200 cells/mm^3. ART = antiretroviral, FSW = female sex workers, CI = confidence interval, NR = not reported, n = number of FSWs with each outcome, N = sample size of FSWs available for each outcome, N_p = number of independent study populations.
doi:10.1371/journal.pone.0105645.g010

Adherence among FSWs, in the few studies where it was measured, was found to be consistently high despite different methods of assessment, recall periods and adherence thresholds. The pooled estimate of adherence among FSWs is similar to that reported for the general population in sub-Saharan Africa, where 77% were estimated to be ≥80% adherent [68], and is also similar to if not better than that reported for women in the general population, where 62% were estimated to be ≥90% adherent [69]. Adherence counselling in 4 studies [23,38,39,44], monthly support groups in one study [60], and directly administered therapy in another study [30], could have contributed to the high adherence seen in these FSW study populations.

Limited data also indicate that overall just over half of FSWs initiating ART are achieving viral suppression, which is much lower than the pooled estimate of ART adherence seen among FSWs. However, there was considerable between-study heterogeneity in the pooled estimate of viral suppression, and the varied limits of viral load detection used to define viral suppression, which ranged from <50 copies/ml to <300 copies/ml, may have influenced the results. The cohort of FSWs in Burkina Faso which used the highest limit of viral load detection to define viral suppression (<300 copies/ml), had the highest estimates of viral suppression, and these were comparable to estimates of viral suppression (defined as viral load <400 copies/ml) seen among women from the general population in South Africa, where 87%–93% of women were virally suppressed after 12 to 36 months on ART [70]. The FSWs in Burkina Faso, who had the highest levels of viral suppression, also had high levels of adherence [38,39]. Thus, the lower estimates of viral suppression could also reflect lower adherence rates among FSWs in those study settings.

For a number of FSWs, improvements in CD4 count were also achieved within 6 to 24 months of ART initiation, and these were comparable to the median gains in CD4 count achieved among women in the general population from South Africa and the UK after 6 to 12 months on ART [70,71].

To date, this is the first study to systematically review and quantify the ART cascade among FSWs globally, which builds on a limited review already undertaken by the authors [15]. Available data indicate that FSWs can achieve promising levels of ART uptake, adherence, retention, and treatment response, at least in the short-term and in these research settings, which in some cases may even be comparable to that seen in the general population over similar time-periods. However, there are a number of limitations to this systematic review. In particular, the review and meta-analysis were limited by the scarcity and heterogeneity of eligible studies. The included studies, the majority of which had small sample sizes of HIV-infected FSWs, reported data on only twenty-one different FSW study populations from only fourteen countries in Asia, Africa, North America, South America, and Central America and the Caribbean, which limits the generalizability of these findings to FSWs elsewhere (Figure 2). Most of the included studies were also research cohorts, thus these results are of limited generalizability to FSWs in other routine programme (non-research) settings. FSWs enrolling in research cohorts may be more motivated to adhere to and remain on treatment, and there are likely to be a number of other HIV prevention and support services available to FSWs in these cohorts, which coupled with intense follow-up and intensive adherence counselling, could help to improve ART uptake, retention, adherence and treatment outcomes among FSWs in these studies [72,73]. Our pooled analyses are also limited by the heterogeneity between studies, but still provide useful overall estimates of engagement in HIV treatment among FSWs. Study periods were particularly variable across studies, and this is likely to influence HIV treatment outcomes, in particular ART uptake. The time periods of data collection spanned 24 years across the different study settings, and in some studies collection of data on HIV-infected FSWs started in the pre-HAART era. To address this issue, whenever possible we conducted sub-group analyses for ART uptake outcomes by time-period of data collection (i.e. data collected in the pre-HAART to HAART era versus HAART era alone). We found that this had an effect on pooled estimates of ART initiation, and although substantial between-study heterogeneity remained, this could indicate that it might not be appropriate to aggregate all data on ART uptake regardless of study period. In the majority of cohort studies, follow-up time on ART was also relatively short, so long term attrition and treatment outcomes in FSWs remain unknown. Lack of reporting on local ART eligibility criteria also made it more difficult to interpret estimates of ART uptake. In addition, adherence to medication was most frequently measured by either self-reports or pill counts, both of which are prone to biases, such as social desirability and recall bias (Table S6). Different types of recruitment settings and sampling methods may have also introduced selection bias into the included studies. However, it was difficult to fully assess risk of selection bias as very few studies reported sampling methodology (Table S6). Some studies reported using random samples, whilst a few others reported the use of non-probability sampling methods, such as snowball sampling and convenience sampling. Snowball sampling and convenience sampling are commonly used when studying hard-to-reach populations, but are likely to have introduced bias into the selection of participants [74]. A couple of studies also reported the use of respondent-driven sampling, which is a type of snowball sampling that aims to reduce bias by taking into account the non-random patterns of participant recruitment [74]. The different recruitment settings and strategies also highlight the diversity of FSW samples across studies (Table S6). Pooled estimates may mask the potential differences in HIV treatment and care across the varied contexts and settings of sex work. It is also possible that women who do not self-identify as FSWs may have been missed at study recruitment, so in some cases outcome data is likely to be restricted to self-identifying FSWs. Thus, results may not be generalizable to indirect FSWs, who may not have been captured in these samples. Publication bias may have also affected our summary estimates, but due to the small numbers of studies that reported each outcome we could not explore this in a meaningful way. In addition, as we did not search for available data in the grey literature (our review focussed on peer-reviewed published literature), we have likely excluded some ART data that may have been available, for example, from reports of integrated biological and behavioural assessment (IBBA) surveys among FSWs.

Despite the limitations, the results from this review are encouraging, and show that even though FSWs are considered a hard population to reach for HIV prevention and care, research cohorts in particular have achieved success at enrolling and retaining FSWs on ART with good adherence and treatment response. Importantly, this review also has important public health implications since it highlights large gaps in the spatial distribution of ART cascade estimates among FSWs (Figure 2) and the paucity of data on the ART cascade among FSWs in routine (non-research) programme settings. These data gaps are concerning, and impede our understanding of 'real-life' HIV treatment and care among FSWs and potential feasibility and effectiveness of targeting FSWs for expanded ART prevention strategies. It is crucial that routine programme data on HIV care and treatment among FSWs is collected and disseminated, in order to better characterise ART cascade outcomes among FSWs (see Box S1 for a summary of our recommendations for future data collection). In particular, information on the percentage of all HIV-infected FSWs receiving ART, and how this evolves over time is needed. Estimates of ART use are likely to be affected by ART initiation criteria, HIV testing policies and testing uptake, as well as rates of linkage to and retention in HIV care prior to ART initiation. So in order to interpret data on ART uptake among FSWs, information on the evolution of ART eligibility criteria over time, the CD4 count at which FSWs are diagnosed and started treatment, as well as the percentage of HIV-infected FSWs who receive HIV testing and are linked to HIV care is required. Furthermore, gathering additional short and long-term data on treatment retention, adherence and viral suppression among FSWs, using standardised indicators is crucial. In 2010, the WHO recommended a number of different early warning indicators to use for monitoring of HIV drug resistance in national ART programmes, which included the following ART care indicators: % of patients receiving ART lost to follow-up at 12 month, % of patients retained on first-line ART at

12 months, % of patients with 100% on-time drug pickups during the first 12 months of ART or during a specified time period, % patient adherence to antiretroviral therapy by pill count or other standardized measure, and % of patients with viral load <1000 copies/mm^3 at 12 months [75]. Gathering and reporting data on these types of ART care indicators for sex workers in routine surveys of sex workers, existing sex worker programmes, and new research studies of HIV care and treatment among FSWs, could help to better characterise the ART cascade among FSWs in different settings and contexts.

When scaling up ART programmes for FSWs, it will also be important to elucidate and overcome the barriers that FSWs face to initiating ART, remaining on treatment and adhering to ART. Many individual-level and structural-level barriers, such as stigma, discrimination, violence, and drug-use, often prevent FSWs from accessing HIV services and practicing HIV prevention and harm reduction, and these barriers may also influence the ability of FSWs to traverse through the HIV care cascade [76–79]. In two of the studies included in this systematic review, FSWs reported that inability to attend regular medical appointments, potential loss of wages from visiting ART centres, prior negative experiences with the health care system, the stigmatizing attitude of medical staff, and fear of adverse consequences as a result of others knowing their HIV status and occupation, were some of the factors that prevented them from initiating ART [24,46]. In three of the studies included in this systematic review, FSWs also reported that running out of pills, not being at home to take pills, feelings of sickness when taking pills, and potential loss of clients if seen taking ART during work hours, were factors that prevented them from adhering to treatment [42,44,46]. Another qualitative study among FSWs in Zimbabwe also found that discrimination from medical staff, shame, and anxiety about being known to be a sex worker, reduced the ability of FSWs to attend HIV treatment services [80]. Travelling times to health clinics and additional financial costs were also reported as barriers to treatment [80]. It is essential that new or ongoing HIV intervention and ART programmes among FSWs try to address the structural and social barriers to HIV treatment that FSWs' face. For example, *Abriendo Puertas*, is an ongoing integrated HIV care and prevention intervention for FSWs in Dominican Republic, that aims to promote HIV care and preventative behaviours among FSWs [53]. This intervention has four key components, including individual counselling and education, peer HIV service navigation and support, clinical care health provider sensitisation training, and community solidarity and mobilisation, which together aim to provide a multi-level response to the social and structural factors that prevent FSWs engaging and remaining in care and adhering to treatment [53]. In Zimbabwe, the Sisters with a Voice (SWV) programme, which provides free STI/HIV services and assisted referrals to ART centers for FSWs, has also initiated numerous measures to try and reduce the stigma, discrimination and barriers that FSWs face at public health clinics, including training and sensitisation for nurses at public ART centers and community mobilisation among FSWs [80].

In conclusion, existing studies in a limited number of research settings indicate that it is it is feasible to enrol and retain FSWs on ART with good adherence, at least in the short-term and in these research contexts. However, there is an evident gap in global data on ART cascade outcomes among FSWs. More data, particularly long-term data, from a larger number of FSW study populations and non-research settings, needs to be collected and disseminated. When scaling-up ART programmes for FSWs, the barriers to HIV care and treatment that they face also need to be addressed.

Supporting Information

Table S1 ART uptake outcomes.
(DOCX)

Table S2 Treatment attrition outcomes.
(DOCX)

Table S3 Adherence to ART.
(DOCX)

Table S4 Viral Suppression.
(DOCX)

Table S5 CD4 Counts at and/or after ART Initiation.
(DOCX)

Table S6 Risk of Bias Assessment.
(DOCX)

Box S1 Recommendations for Future Data Collection.
(DOCX)

Checklist S1 PRISMA Checklist.
(DOCX)

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Author Contributions

Conceived and designed the experiments: EM MCB PV SM MP. Analyzed the data: EM SM MCB. Conducted the literature search, data extraction and meta-analysis: EM. Drafted the article: EM. Provided input into article draft: SM MCB. Critically reviewed and edited the article: SM MCB MP PV CG.

References

1. Quinn TC, Wawer MJ, Sewankambo N, Serwadda D, Li C, et al. (2000) Viral load and heterosexual transmission of human immunodeficiency virus type 1. Rakai Project Study Group. New England Journal of Medicine 342: 921–929.
2. Castilla J, Del Romero J, Hernando V, Marincovich B, Garcia S, et al. (2005) Effectiveness of highly active antiretroviral therapy in reducing heterosexual transmission of HIV. Journal of Acquired Immune Deficiency Syndromes: JAIDS 40: 96–101.
3. Donnell D, Baeten JM, Kiarie J, Thomas KK, Stevens W, et al. (2010) Heterosexual HIV-1 transmission after initiation of antiretroviral therapy: a prospective cohort analysis. Lancet 375: 2092–2098.
4. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, et al. (2011) Prevention of HIV-1 infection with early antiretroviral therapy. N Engl J Med 365: 493–505.
5. Baggaley RF, White RG, Hollingsworth TD, Boily MC (2013) Heterosexual HIV-1 infectiousness and antiretroviral use: systematic review of prospective studies of discordant couples. Epidemiology 24: 110–121.
6. Wilson DP (2012) HIV treatment as prevention: natural experiments highlight limits of antiretroviral treatment as HIV prevention. PLoS Medicine/Public Library of Science 9: e1001231.
7. Hull MW, Wu Z, Montaner JSG (2012) Optimizing the engagement of care cascade: a critical step to maximize the impact of HIV treatment as prevention. Current Opinion in HIV & AIDS 7: 579–586.
8. Kranzer K, Govindasamy D, Ford N, Johnston V, Lawn SD (2012) Quantifying and addressing losses along the continuum of care for people living with HIV infection in sub-Saharan Africa: a systematic review. Journal of the International AIDS Society 15: 17383.
9. Hallett TB, Eaton JW (2013) A Side Door Into Care Cascade for HIV-Infected Patients? Journal of Acquired Immune Deficiency Syndromes: JAIDS 63 Suppl 2: S228–232.
10. Rosen S, Fox MP (2011) Retention in HIV care between testing and treatment in sub-Saharan Africa: a systematic review. PLoS Medicine/Public Library of Science 8: e1001056.
11. Mugglin C, Estill J, Wandeler G, Bender N, Egger M, et al. (2012) Loss to programme between HIV diagnosis and initiation of antiretroviral therapy in sub-Saharan Africa: systematic review and meta-analysis. Trop Med Int Health.
12. Boily MC, Lowndes C, Alary M (2002) The impact of HIV epidemic phases on the effectiveness of core group interventions: insights from mathematical models. Sexually Transmitted Infections 78 Suppl 1: i78–90.
13. Baral S, Beyrer C, Muessig K, Poteat T, Wirtz AL, et al. (2012) Burden of HIV among female sex workers in low-income and middle-income countries: a systematic review and meta-analysis. Lancet Infect Dis 12: 538–549.
14. Vickerman P, Foss AM, Pickles M, Deering K, Verma S, et al. (2010) To what extent is the HIV epidemic in southern India driven by commercial sex? A modelling analysis. AIDS 24: 2563–2572.
15. Delva W, Eaton JW, Meng F, Fraser C, White RG, et al. (2012) HIV treatment as prevention: optimising the impact of expanded HIV treatment programmes. PLoS Medicine/Public Library of Science 9: e1001258.
16. Alary M, Lowndes CM, Van de Perre P, Behanzin L, Batona G, et al. (2013) Scale-up of combination prevention and antiretroviral therapy for female sex workers in West Africa: time for action. AIDS 27: 1369–1374.
17. Kato M, Granich R, Duc Bui D, Tran HV, Nadol P, et al. (2013) The potential impact of expanding antiretroviral therapy and combination prevention in Vietnam: Towards elimination of HIV transmission. J Acquir Immune Defic Syndr.
18. Moher D, Liberati A, Tetzlaff J, Altman DG (2010) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg 8: 336–341.
19. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, et al. (2000) Meta-analysis of observational studies in epidemiology - A proposal for reporting. Jama-Journal of the American Medical Association 283: 2008–2012.
20. Pereira TPN, Salantic G, Ioannidisc J (2010) Critical interpretation of Cochran's Q test depends on power and prior assumptions about heterogeneity. Research Synthesis Methods 1: 149–161.
21. Engels EA, Schmid CH, Terrin N, Olkin I, Lau J (2000) Heterogeneity and statistical significance in meta-analysis: an empirical study of 125 meta-analyses. Statistics in Medicine 19: 1707–1728.
22. Kilmarx PH, Limpakarnjanarat K, Kaewkungwal J, Srismith R, Saisorn S, et al. (2000) Disease progression and survival with human immunodeficiency virus type 1 subtype E infection among female sex workers in Thailand. Journal of Infectious Diseases 181: 1598–1606.
23. Deering KN, Shannon K, Sinclair H, Parsad D, Gilbert E, et al. (2009) Piloting a peer-driven intervention model to increase access and adherence to antiretroviral therapy and HIV care among street-entrenched HIV-positive women in Vancouver. AIDS Patient Care & Stds 23: 603–609.
24. Shannon K, Bright V, Duddy J, Tyndall MW (2005) Access and utilization of HIV treatment and services among women sex workers in Vancouver's Downtown Eastside. Journal of Urban Health 82: 488–497.
25. Masese LN, Graham SM, Gitau R, Peshu N, Jaoko W, et al. (2011) A prospective study of vaginal trichomoniasis and HIV-1 shedding in women on antiretroviral therapy. BMC Infectious Diseases 11: 307.
26. Graham SM, Masese L, Gitau R, Richardson BA, Mandaliya K, et al. (2011) Genital ulceration does not increase HIV-1 shedding in cervical or vaginal secretions of women taking antiretroviral therapy. Sex Transm Infect 87: 114–117.
27. Graham SM, Masese L, Gitau R, Mwakangalu D, Jaoko W, et al. (2009) Increased risk of genital ulcer disease in women during the first month after initiating antiretroviral therapy. Journal of Acquired Immune Deficiency Syndromes: JAIDS 52: 600–603.
28. Graham SM, Masese L, Gitau R, Jalalian-Lechak Z, Richardson BA, et al. (2010) Antiretroviral adherence and development of drug resistance are the strongest predictors of genital HIV-1 shedding among women initiating treatment. Journal of Infectious Diseases 202: 1538–1542.
29. Graham SM, Jalalian-Lechak Z, Shafi J, Chohan V, Deya RW, et al. (2012) Antiretroviral treatment interruptions predict female genital shedding of genotypically resistant HIV-1 RNA. Journal of Acquired Immune Deficiency Syndromes: JAIDS 60: 511–518.
30. Graham SM, Holte SE, Peshu NM, Richardson BA, Panteleeff DD, et al. (2007) Initiation of antiretroviral therapy leads to a rapid decline in cervical and vaginal HIV-1 shedding. AIDS 21: 501–507.
31. Gitau RW, Graham SM, Masese LN, Overbaugh J, Chohan V, et al. (2010) Effect of acquisition and treatment of cervical infections on HIV-1 shedding in women on antiretroviral therapy. AIDS 24: 2733–2737.
32. McClelland RS, Graham SM, Richardson BA, Peshu N, Masese LN, et al. (2010) Treatment with antiretroviral therapy is not associated with increased sexual risk behavior in Kenyan female sex workers. AIDS 24: 891–897.
33. McClelland L, Wanje G, Kashonga F, Kibe L, McClelland RS, et al. (2011) Understanding the context of HIV risk behavior among HIV-positive and HIV-negative female sex workers and male bar clients following antiretroviral therapy rollout in Mombasa, Kenya. AIDS Educ Prev 23: 299–312.
34. McKinnon LR, Kimani M, Wachihi C, Nagelkerke NJ, Muriuki FK, et al. (2010) Effect of baseline HIV disease parameters on CD4+ T cell recovery after antiretroviral therapy initiation in Kenyan women. PLoS ONE [Electronic Resource] 5: e11434.
35. Mawji E, McKinnon L, Wachihi C, Chege D, Thottingal P, et al. (2012) Does antiretroviral therapy initiation increase sexual risk taking in Kenyan female sex workers? A retrospective case-control study. BMJ Open 2: e000565.
36. Lester RT, Yao XD, Ball TB, McKinnon LR, Omange WR, et al. (2009) HIV-1 RNA dysregulates the natural TLR response to subclinical endotoxemia in Kenyan female sex-workers. PLoS ONE [Electronic Resource] 4: e5644.
37. Low AJ, Clayton T, Konate I, Nagot N, Ouedraogo A, et al. (2011) Genital warts and infection with human immunodeficiency virus in high-risk women in Burkina Faso: a longitudinal study. BMC Infectious Diseases 11: 20.
38. Konate I, Traore L, Ouedraogo A, Sanon A, Diallo R, et al. (2011) Linking HIV prevention and care for community interventions among high-risk women in Burkina Faso–the ARNS 1222 "Yerelon" cohort. Journal of Acquired Immune Deficiency Syndromes: JAIDS 57 Suppl 1: S50–54.
39. Huet C, Ouedraogo A, Konate I, Traore I, Rouet F, et al. (2011) Long-term virological, immunological and mortality outcomes in a cohort of HIV-infected female sex workers treated with highly active antiretroviral therapy in Africa. BMC Public Health 11: 700.
40. Becker ML, Mishra S, Satyanarayana, Gurav K, Doshi M, et al. (2012) Rates and determinants of HIV-attributable mortality among rural female sex workers in Northern Karnataka, India. Int J STD AIDS 23: 36–40.
41. Kalokhe AS, Paranjape A, Bell CE, Cardenas GA, Kuper T, et al. (2012) Intimate partner violence among HIV-infected crack cocaine users. AIDS Patient Care & Stds 26: 234–240.
42. Braunstein SL, Umulisa MM, Veldhuijzen NJ, Kestelyn E, Ingabire CM, et al. (2011) HIV diagnosis, linkage to HIV care, and HIV risk behaviors among newly diagnosed HIV-positive female sex workers in Kigali, Rwanda. Journal of Acquired Immune Deficiency Syndromes: JAIDS 57: e70–76.
43. Dean J, Ta Thi TH, Dunford L, Carr MJ, Nguyen LT, et al. (2011) Prevalence of HIV type 1 antiretroviral drug resistance mutations in Vietnam: a multicenter study. AIDS Research & Human Retroviruses 27: 797–801.
44. Diabaté S, Zannou DM, Geraldo N, Chamberland A, Akakpo J, et al. (2011) Antiretroviral Therapy among HIV-1 Infected Female Sex Workers in Benin: A Comparative Study with Patients from the General Population. World Journal of AIDS 1: 94–99.
45. Reddon H, Wood E, Tyndall M, Lai C, Hogg R, et al. (2011) Use of North America's first medically supervised safer injecting facility among HIV-positive injection drug users. AIDS Educ Prev 23: 412–422.
46. Chakrapani V, Newman PA, Shunmugam M, Kurian AK, Dubrow R (2009) Barriers to free antiretroviral treatment access for female sex workers in Chennai, India. AIDS Patient Care & Stds 23: 973–980.
47. Schuelter-Trevisol F, da Silva MV, Oliveira CM, Rodrigues R (2007) HIV genotyping among female sex workers in the State of Santa Catarina. Revista Da Sociedade Brasileira de Medicina Tropical 40: 259–263.
48. Comulada WS, Swendeman DT, Rotheram-Borus MJ, Mattes KM, Weiss RE (2003) Use of HAART among young people living with HIV. Am J Health Behav 27: 389–400.
49. Balkus JE, Richardson BA, Mochache V, Chohan V, Chan JD, et al. (2013) A prospective cohort study comparing the effect of single-dose 2 G metronidazole

on trichomonas vaginalis infection in HIV-seropositive versus HIV-seronegative women. Sexually Transmitted Diseases 40: 499–505.
50. Cowan FM, Mtetwa S, Davey C, Fearon E, Dirawo J, et al. (2013) Engagement with HIV Prevention Treatment and Care among Female Sex Workers in Zimbabwe: A Respondent Driven Sampling Survey. PLoS ONE 8.
51. Day S, Odem-Davis K, Mandaliya K, Jerome K, Jaoko W, et al. (2012) Hepatitis b virus co-infection in human immunodeficiency virus positive female sex workers in mombasa, Kenya: A prospective cohort study. Journal of Investigative Medicine 60 (1): 195–196.
52. Dennis AM, Murillo W, De Maria Hernandez F, Guardado ME, Nieto AI, et al. (2013) Social network-based recruitment successfully reveals HIV-1 transmission networks among high-risk individuals in El Salvador. Journal of Acquired Immune Deficiency Syndromes 63: 135–141.
53. Donastorg Y, Barrington C, Perez M, Kerrigan D (2014) Abriendo Puertas: Baseline Findings from an Integrated Intervention to Promote Prevention, Treatment and Care among FSW Living with HIV in the Dominican Republic. PLoS One 9: e88157.
54. Graham SM, Rajwans N, Jaoko W, Estambale BB, McClelland RS, et al. (2013) Endothelial activation biomarkers increase after HIV-1 acquisition: plasma vascular cell adhesion molecule-1 predicts disease progression. AIDS 27: 1803–1813.
55. Jadhav A, Bhattacharjee P, Raghavendra T, Blanchard J, Moses S, et al. (2013) Risky Behaviors among HIV-Positive Female Sex Workers in Northern Karnataka, India. AIDS Res Treat 2013: 878151.
56. Low AJ, Konate I, Nagot N, Weiss HA, Kania D, et al. (2014) Cervicovaginal HIV-1 shedding in women taking antiretroviral therapy in burkina faso: A longitudinal study. Journal of Acquired Immune Deficiency Syndromes 65: 237–245.
57. Low AJ, Konate I, Nagot N, Weiss HA, Mabey D, et al. (2014) Neisseria gonorrhoeae and Chlamydia trachomatis infection in HIV-1-infected women taking antiretroviral therapy: a prospective cohort study from Burkina Faso. Sex Transm Infect 90: 100–103.
58. Cox J, Maurais E, Hu L, Moodie EEM, Law S, et al. (2014) Correlates of drug use cessation among participants in the Canadian HIV-HCV Co-infection Cohort. Drug and Alcohol Dependence 137: 121–128.
59. Tyurina A, Krupitsky E, Cheng DM, Coleman SM, Walley AY, et al. (2013) Is cannabis use associated with HIV drug and sex risk behaviors among Russian HIV-infected risky drinkers? Drug and Alcohol Dependence 132: 74–80.
60. Graham SM, Mugo P, Gichuru E, Thiong'o A, Macharia M, et al. (2013) Adherence to antiretroviral therapy and clinical outcomes among young adults reporting high-risk sexual behavior, including men who have sex with men, in coastal Kenya. AIDS and behavior 17: 1255–1265.
61. Mehta M, Semitala F, Lynen L, Colebunders R (2012) Antiretroviral treatment in low-resource settings: what has changed in the last 10 years and what needs to change in the coming years? Expert Rev Anti Infect Ther 10: 1287–1296.
62. Bila B, Egrot M (2009) Gender asymmetry in healthcare-facility attendance of people living with HIV/AIDS in Burkina Faso. Social Science & Medicine 69: 854–861.
63. Tapp C, Milloy MJ, Kerr T, Zhang R, Guillemi S, et al. (2011) Female gender predicts lower access and adherence to antiretroviral therapy in a setting of free healthcare. Bmc Infectious Diseases 11.
64. Fox MP, Rosen S (2010) Patient retention in antiretroviral therapy programs up to three years on treatment in sub-Saharan Africa, 2007–2009: systematic review. Tropical Medicine & International Health 15 Suppl 1: 1–15.
65. Maskew M, Brennan AT, Westreich D, McNamara L, MacPhail AP, et al. (2013) Gender Differences in Mortality and CD4 Count Response Among Virally Suppressed HIV-Positive Patients. Journal of Womens Health 22: 113–120.
66. Mosha F, Muchunguzi V, Matee M, Sangeda RZ, Vercauteren J, et al. (2013) Gender differences in HIV disease progression and treatment outcomes among HIV patients one year after starting antiretroviral treatment (ART) in Dar es Salaam, Tanzania. Bmc Public Health 13.
67. Hughes AJ, Mattson CL, Scheer S, Beer L, Skarbinski J (2014) Discontinuation of antiretroviral therapy among adults receiving HIV care in the United States. Journal of acquired immune deficiency syndromes (1999) 66: 80–89.
68. Mills EJ, Nachega JB, Buchan I, Orbinski J, Attaran A, et al. (2006) Adherence to antiretroviral therapy in sub-Saharan Africa and North America: a meta-analysis. JAMA 296: 679–690.
69. Ortego C, Huedo-Medina TB, Santos P, Rodriguez E, Sevilla L, et al. (2012) Sex differences in adherence to highly active antiretroviral therapy: A meta-analysis. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv 24: 1519–1534.
70. Cornell M, Schomaker M, Garone DB, Giddy J, Hoffmann CJ, et al. (2012) Gender Differences in Survival among Adult Patients Starting Antiretroviral Therapy in South Africa: A Multicentre Cohort Study. Plos Medicine 9.
71. Barber TJ, Geretti AM, Anderson J, Schwenk A, Phillips AN, et al. (2011) Outcomes in the first year after initiation of first-line HAART among heterosexual men and women in the UK CHIC Study. Antiviral Therapy 16: 805–814.
72. Jean K, Anglaret X, Moh R, Lert F, Dray-Spira R (2012) Barriers to HIV testing in Cote d'Ivoire: the role of individual characteristics and testing modalities. PLoS One 7: e41353.
73. McMahon JH, Elliott JH, Hong SY, Bertagnolio S, Jordan MR (2013) Effects of physical tracing on estimates of loss to follow-up, mortality and retention in low and middle income country antiretroviral therapy programs: a systematic review. PLoS ONE [Electronic Resource] 8: e56047.
74. Heckathorn DD (2002) Respondent-driven sampling II: Deriving valid population estimates from chain-referral samples of hidden populations. Social Problems 49: 11–34.
75. WHO (2011) Global HIV/AIDS response: epidemic update and health sector progress towards universal access: progress report 2011. WHO, Geneva, Switzerland.
76. Ghimire L, Smith WCS, van Teijlingen ER (2011) Utilisation of sexual health services by female sex workers in Nepal. Bmc Health Services Research 11.
77. Lazarus L, Deering KN, Nabess R, Gibson K, Tyndall MW, et al. (2012) Occupational stigma as a primary barrier to health care for street-based sex workers in Canada. Culture Health & Sexuality 14: 139–150.
78. Phrasisombath K, Thomsen S, Sychareun V, Faxelid E (2012) Care seeking behaviour and barriers to accessing services for sexually transmitted infections among female sex workers in Laos: a cross-sectional study. Bmc Health Services Research 12.
79. Shannon K, Kerr T, Allinott S, Chettiar J, Shoveller J, et al. (2008) Social and structural violence and power relations in mitigating HIV risk of drug-using women in survival sex work. Social Science & Medicine 66: 911–921.
80. Mtetwa S, Busza J, Chidiya S, Mungofa S, Cowan F (2013) ''You are wasting our drugs'': health service barriers to HIV treatment for sex workers in Zimbabwe. Bmc Public Health 13.

Appendix B: Supplementary information for Chapter 2

Text B1. Model equations

The workplace violence model is defined by a set of deterministic ordinary differential equations, which are solved through numerical integration using the ode15s solver in Matlab. The model equations for the 27 compartments shown in Figure 2.1 in chapter 2 are as follows:

$$\frac{dX_{i=1,j=1,k=1,mn}}{dt} = \mu_{mn}N_{mn} - \left(\mu_{mn} + \alpha_{mn}^{PH} + \alpha_{mn}^{CPV} + \alpha_{mn}^{CSV}\right)X_{i=1,j=1,k=1,mn}$$

$$\frac{dX_{i=1,j=1,k=1,mn}}{dt} = \alpha_{mn}^{CSV}X_{i=1,j=1,k=1,mn} + \nu_{mn}^{CSV}X_{i=3,j=1,k=1,mn} - \left(\mu_{mn} + \alpha_{mn}^{PH} + \alpha_{mn}^{CPV} + \epsilon\right)X_{i=2,j=1,k=1,mn}$$

$$\frac{dX_{i=3,j=1,k=1,mn}}{dt} = \epsilon X_{i=2,j=1,k=1,mn} - \left(\mu_{mn} + \nu_{mn}^{CSV} + \alpha_{mn}^{PH} + \alpha_{mn}^{CPV}\right)X_{i=3,j=1,k=1,mn}$$

$$\frac{dX_{i=1,j=2,k=1,mn}}{dt} = \alpha_{mn}^{CPV}X_{i=1,j=1,k=1,mn} + \nu_{mn}^{CPV}X_{i=1,j=3,k=1,mn} - \left(\mu_{mn} + \epsilon + \alpha_{mn}^{CSV}RR^{CPVtoCSV} + \alpha_{mn}^{PH}\right)X_{i=1,j=2,k=1,mn}$$

$$\begin{aligned}\frac{dX_{i=2,j=2,k=1,mn}}{dt} &= \alpha_{mn}^{CPV}X_{i=2,j=1,k=1,mn} + \alpha_{mn}^{CSV}RR^{CPVtoCSV}X_{i=1,j=2,k=1,mn} + \nu_{mn}^{CPV}X_{i=2,j=3,k=1,mn} \\ &\quad + \nu_{mn}^{CSV}RR^{CPVtoCSV}X_{i=3,j=2,k=1,mn} - \left(\mu_{mn} + 2\epsilon + \alpha_{mn}^{PH}\right)X_{i=2,j=2,k=1,mn}\end{aligned}$$

$$\begin{aligned}\frac{dX_{i=3,j=2,k=1,mn}}{dt} &= \alpha_{mn}^{CPV}X_{i=3,j=1,k=1,mn} + \epsilon X_{i=2,j=2,k=1,mn} + \nu_{mn}^{CPV}X_{i=3,j=3,k=1,mn} \\ &\quad - \left(\mu_{mn} + \nu_{mn}^{CSV}RR^{CPVtoCSV} + \alpha_{mn}^{PH} + \epsilon\right)X_{i=3,j=2,k=1,mn}\end{aligned}$$

$$\frac{dX_{i=1,j=3,k=1,mn}}{dt} = \epsilon X_{i=1,j=2,k=1,mn} - \left(\mu_{mn} + \nu_{mn}^{CPV} + \alpha_{mn}^{CSV} + \alpha_{mn}^{PH}\right)X_{i=1,j=3,k=1,mn}$$

$$\begin{aligned}\frac{dX_{i=2,j=3,k=1,mn}}{dt} &= \epsilon X_{i=2,j=2,k=1,mn} + \alpha_{mn}^{CSV}X_{i=1,j=3,k=1,mn} + \nu_{mn}^{CSV}X_{i=3,j=3,k=1,mn} \\ &\quad - \left(\mu_{mn} + \alpha_{mn}^{PH} + \epsilon + \nu_{mn}^{CPV}\right)X_{i=2,j=3,k=1,mn}\end{aligned}$$

$$\frac{dX_{i=3,j=3,k=1,mn}}{dt} = \epsilon X_{i=2,j=3,k=1,mn} + \epsilon X_{i=3,j=2,k=1,mn} - \left(\mu_{mn} + \nu_{mn}^{CSV} + \nu_{mn}^{CPV} + \alpha_{mn}^{PH}\right)X_{i=3,j=3,k=1,mn}$$

$$
\begin{aligned}
\frac{dX_{i=1,j=1,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=1,j=1,k=1,mn} + \nu_{mn}^{PH} X_{i=1,j=1,k=3,mn} \\
&\quad -\left(\mu_{mn} + \varepsilon + \alpha_{mn}^{CSV} RR^{PHtoCSV} + \alpha_{mn}^{CPV} RR^{PHtoCPV}\right) X_{i=1,j=1,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=2,j=1,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=2,j=1,k=1,mn} + \alpha_{mn}^{CSV} RR^{PHtoCSV} X_{i=1,j=1,k=2,mn} + \nu_{mn}^{PH} X_{i=2,j=1,k=3,mn} \\
&\quad + \nu_{mn}^{CSV} RR^{PHtoCSV} X_{i=3,j=1,k=2,mn} - \left(\mu_{mn} + 2\varepsilon + \alpha_{mn}^{CPV} RR^{PHtoCPV}\right) X_{i=2,j=1,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=3,j=1,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=3,j=1,k=1,mn} + \varepsilon X_{i=2,j=1,k=2,mn} + \nu_{mn}^{PH} X_{i=3,j=1,k=3,mn} \\
&\quad -\left(\mu_{mn} + \nu_{mn}^{CSV} RR^{PHtoCSV} + \varepsilon + \alpha_{mn}^{CPV} RR^{PHtoCPV}\right) X_{i=3,j=1,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=1,j=2,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=1,j=2,k=1,mn} + \nu_{mn}^{PH} X_{i=1,j=2,k=3,mn} + \alpha^{CPV} RR^{PHtoCPV} X_{i=1,j=1,k=2,mn} \\
&\quad + \nu_{mn}^{CPV} RR^{PHtoCPV} X_{i=1,j=3,k=2,mn} - \left(\mu_{mn} + 2\varepsilon + \alpha_{mn}^{CSV} RR^{PHtoCSV} RR^{CPVtoCSV}\right) X_{i=1,j=2,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=2,j=2,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=2,j=2,k=1,mn} + \nu_{mn}^{PH} X_{i=2,j=2,k=3,mn} + \alpha_{mn}^{CPV} RR^{PHtoCPV} X_{i=2,j=1,k=2,mn} \\
&\quad + \nu_{mn}^{CPV} RR^{PHtoCPV} X_{i=2,j=3,k=2,mn} + \alpha_{mn}^{CSV} RR^{PHtoCSV} RR^{CPVtoCSV} X_{i=1,j=2,k=2,mn} \\
&\quad + \nu^{CSV} RR^{PHtoCSV} RR^{CPVtoCSV} X_{i=3,j=2,k=2,mn} - \left(\mu_{mn} + 3\varepsilon\right) X_{i=2,j=2,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=3,j=2,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=3,j=2,k=1,mn} + \nu_{mn}^{PH} X_{i=3,j=2,k=3,mn} + \alpha_{mn}^{CPV} RR^{PHtoCPV} X_{i=3,j=1,k=2,mn} \\
&\quad + \nu_{mn}^{CPV} RR^{PHtoCPV} X_{i=3,j=3,k=2,mn} + \varepsilon X_{i=2,j=2,k=2,mn} \\
&\quad -\left(\mu_{mn} + \nu_{mn}^{CSV} RR^{PHtoCSV} RR^{CPVtoCSV} + 2\varepsilon\right) X_{i=3,j=2,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=1,j=3,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=1,j=3,k=1,mn} + \nu_{mn}^{PH} X_{i=1,j=3,k=3,mn} + \varepsilon X_{i=1,j=2,k=2,mn} \\
&\quad -\left(\mu_{mn} + \varepsilon + \nu_{mn}^{CPV} RR^{PHtoCPV} + \alpha_{mn}^{CSV} RR^{PHtoCSV}\right) X_{i=1,j=3,k=2,mn}
\end{aligned}
$$

$$
\begin{aligned}
\frac{dX_{i=2,j=3,k=2,mn}}{dt} &= \alpha_{mn}^{PH} X_{i=2,j=3,k=1,mn} + \nu_{mn}^{PH} X_{i=2,j=3,k=3,mn} + \alpha_{mn}^{CSV} RR^{PHtoCSV} X_{i=1,j=3,k=2,mn} \\
&\quad + \nu_{mn}^{CSV} RR^{PHtoCSV} X_{i=3,j=3,k=2,mn} + \varepsilon X_{i=2,j=2,k=2,mn} \\
&\quad -\left(\mu_{mn} + 2\varepsilon + \nu_{mn}^{CPV} RR^{PHtoCPV}\right) X_{i=2,j=3,k=2,mn}
\end{aligned}
$$

$$\frac{dX_{i=3,j=3,k=2,mn}}{dt} = \alpha_{mn}^{PH} X_{i=3,j=3,k=1,mn} + \nu_{mn}^{PH} X_{i=3,j=3,k=3,mn} + \varepsilon X_{i=2,j=3,k=2,mn} + \varepsilon X_{i=3,j=3,k=2,mn}$$
$$-\left(\mu_{mn} + \varepsilon + \nu_{mn}^{CPV} RR^{PHtoCPV} + \nu_{mn}^{CSV} RR^{PHtoCSV}\right) X_{i=3,j=3,k=2,mn}$$

$$\frac{dX_{i=1,j=1,k=3,mn}}{dt} = \varepsilon X_{i=1,j=1,k=2,mn} - \left(\mu_{mn} + \alpha_{mn}^{CSV} + \nu_{mn}^{PH} + \alpha_{mn}^{CPV}\right) X_{i=1,j=1,k=3,mn}$$

$$\frac{dX_{i=2,j=1,k=3,mn}}{dt} = \varepsilon X_{i=2,j=1,k=2,mn} + \alpha_{mn}^{CSV} X_{i=1,j=1,k=3,mn} + \nu_{mn}^{CSV} X_{i=3,j=1,k=3,mn}$$
$$-\left(\mu_{mn} + \alpha_{mn}^{CPV} + \nu_{mn}^{PH} + \varepsilon\right) X_{i=2,j=1,k=3,mn}$$

$$\frac{dX_{i=3,j=1,k=3,mn}}{dt} = \varepsilon X_{i=3,j=1,k=2,mn} + \varepsilon X_{i=2,j=1,k=3,mn} - \left(\mu_{mn} + \nu_{mn}^{PH} + \alpha_{mn}^{CPV} + \nu_{mn}^{CSV}\right) X_{i=3,j=1,k=3,mn}$$

$$\frac{dX_{i=1,j=2,k=3,mn}}{dt} = \varepsilon X_{i=1,j=2,k=2,mn} + \alpha_{mn}^{CPV} X_{i=1,j=1,k=3,mn} + \nu_{mn}^{CPV} X_{i=1,j=3,k=3,mn}$$
$$-\left(\mu_{mn} + \nu_{mn}^{PH} + \alpha_{mn}^{CSV} RR^{CPVtoCSV} + \varepsilon\right) X_{i=1,j=2,k=3,mn}$$

$$\frac{dX_{i=2,j=2,k=3,mn}}{dt} = \varepsilon X_{i=2,j=2,k=2,mn} + \alpha_{mn}^{CPV} X_{i=2,j=1,k=3,mn} + \nu_{mn}^{CPV} X_{i=2,j=3,k=3,mn} + \alpha_{mn}^{CSV} RR^{CPVtoCSV} X_{i=1,j=2,k=3,mn}$$
$$+\nu_{mn}^{CSV} RR^{CPVtoCSV} X_{i=3,j=2,k=3,mn} - \left(\mu_{mn} + 2\varepsilon + \nu_{mn}^{PH}\right) X_{i=2,j=2,k=3,mn}$$

$$\frac{dX_{i=3,j=2,k=3,mn}}{dt} = \varepsilon X_{i=3,j=2,k=2,mn} + \alpha_{mn}^{CPV} X_{i=3,j=1,k=3,mn} + \nu_{mn}^{CPV} X_{i=3,j=3,k=3,mn} + \varepsilon X_{i=2,j=2,k=3,mn}$$
$$-\left(\mu_{mn} + \varepsilon + \nu_{mn}^{CSV} RR^{CPVtoCSV} + \nu_{mn}^{PH}\right) X_{i=3,j=2,k=3,mn}$$

$$\frac{dX_{i=1,j=3,k=3,mn}}{dt} = \varepsilon X_{i=1,j=3,k=2,mn} + \varepsilon X_{i=1,j=2,k=3,mn} - \left(\mu_{mn} + \nu_{mn}^{CPV} + \nu_{mn}^{PH} + \alpha_{mn}^{CSV}\right) X_{i=1,j=3,k=3,mn}$$

$$\frac{dX_{i=2,j=3,k=3,mn}}{dt} = \varepsilon X_{i=2,j=3,k=2,mn} + \varepsilon X_{i=2,j=2,k=3,mn} + \alpha_{mn}^{CSV} X_{i=1,j=3,k=3,mn} + \nu_{mn}^{CSV} X_{i=3,j=3,k=3,mn}$$
$$-\left(\mu_{mn} + \nu_{mn}^{PH} + \nu_{mn}^{CPV} + \varepsilon\right) X_{i=2,j=3,k=3,mn}$$

$$\frac{dX_{i=3,j=3,k=3,mn}}{dt} = \varepsilon X_{i=3,j=3,k=2,mn} + \varepsilon X_{i=3,j=2,k=3,mn} + \varepsilon X_{i=2,j=3,k=3,mn} - \left(\mu_{mn} + \nu_{mn}^{PH} + \nu_{mn}^{CPV} + \nu_{mn}^{CSV}\right) X_{i=3,j=3,k=3,mn}$$

The indices are:

- i – client sexual violence status (1: no experience of violence, 2: experienced violence recently in the last 6 months, 3: experienced violence in the past but not within the last 6 months)
- j – client physical violence status (1: no experience of violence, 2: experienced violence recently in the last 6 months, 3: experienced violence in the past but not within the last 6 months)
- k – police harassment status (1: no experience of violence, 2: experienced violence recently in the last 6 months, 3: experienced violence in the past but not within the last 6 months)
- m – work environment (1: outdoor/public, 2: informal indoor, 3: brothel/quasi-brothel)
- n – injecting drug use (1: non IDU, 2: ever IDU)

The state variables are:

- X_{ijkmn} is the number of sex workers in violence state *ijk* who are in work environment *m* with IDU status *n*
- N_{mn} is the total number of sex workers in work environment *m* with IDU status *n*

The parameters are:

- μ_{mn} is the rate of leaving sex work, which depends on work environment *m* and IDU status *n*
- α_{mn}^{CSV} is the rate of experiencing first client sexual violence, which depends on work environment *m* and IDU status *n*
- α_{mn}^{CPV} is the rate of experiencing first client physical violence, which depends on work environment *m* and IDU status *n*
- α_{mn}^{PH} is the rate of experiencing first police harassment, which depends on work environment *m* and IDU status *n*
- ν_{mn}^{CSV} is the rate of experiencing repeat client sexual violence after the first violent incident, which depends on work environment *m* and IDU status *n*
- ν_{mn}^{CPV} is the rate of experiencing repeat client physical violence after the first violent incident, which depends on work environment *m* and IDU status *n*
- ν_{mn}^{PH} is the rate of experiencing repeat police harassment after the first violent incident, which depends on work environment *m* and IDU status *n*
- ε is the rate of transition from recent to non-recent violence states, which is the same for all types of workplace violence

- $RR^{PHtoCPV}$ is the increased risk of experiencing client physical violence (first and recurrent incidents) after a recent experience of police harassment
- $RR^{PHtoCSV}$ is the increased risk of experiencing client sexual violence (first and recurrent incidents) after a recent experience of police harassment
- $RR^{CPVtoCSV}$ is the increased risk of experiencing client sexual violence (first and recurrent incidents) after a recent experience of client physical violence

Initial Model Conditions:

At the start of the model simulation, there are 1500 FSWs, and this total FSW population size was kept constant throughout the simulations. A fixed proportion of the FSW population start the simulation in each work environment and injecting drug use status, and the proportion in each of these sub-groups was kept constant throughout the model simulation. All FSWs have no prior experience of any workplace violence at the start of the model simulation.

Text B2. Estimating incidence rates of workplace violence from AESHA cohort data

Melissa Braschel, who is the AESHA statistician, carried out analyses to estimate incidence of workplace violence from AESHA cohort data.

Incidence of first-time violence was estimated from AESHA data by dividing the total number of reported first-time violence events by the total number of person-years at risk among FSWs with at least one follow-up interview who did not report violence at enrolment. A first-time violence event was defined as the first time a FSW reported violence in the last 6 months at a follow-up interview. Person-years at risk started at the baseline interview. For participants who did not report any violence during follow-up, person-years at risk was censored at the last follow-up visit, while for participants who did report violence during follow-up, person-years at risk was censored at the estimated date of the first report of violence (mid-interval between follow-up visits). Thus, subsequent reports of violence are excluded from the calculation.

Incidence of first-time and repeat violence was calculated from AESHA data by dividing the total number of violence events for all FSWs by the total number of person-years at risk for all FSWs. A violent event was defined as a report of violence in the last 6 months at a baseline or follow-up interview. For the purposes of this analysis, person-years at risk was considered to start 6 months prior to the baseline interview, in order to include occurrence of violence in the 6 months prior to enrolment. For participants who reported violence at the last follow-up visit, person-years at risk was censored at the estimated date of last violence (mid-interval between follow-up visits), and for participants who did not report violence at the last follow-up, person-years at risk was censored at the date of the last follow-up visit.

These incidence rates were based on data collected from baseline and follow-up interviews conducted between 2010 and 2014. Each incidence rate for each type of workplace violence was summarised for all FSWs and for FSWs in each work environment with 95% CIs using Poisson regression.

Text B3. Sensitivity analysis results

A summary of the sensitivity analysis results was provided in the main text. Here I provide further details on each of the four sensitivity analyses.

1) Influence of parameter uncertainty

To estimate the sensitivity of the model to uncertainty in the parameters and determine which calibrated parameters have the most influence over different model outcomes, PRCCs were calculated. Tables B8-B11 show the PRCCs with an absolute value of 0.2 or more for incidence rates of first-time workplace violence among all FSWs, incidence rates of first-time and repeat workplace violence among all FSWs, relative reduction in ICU prevalence among all FSWs due to each intervention, and relative reduction in client violence among all FSWs due to elimination of police harassment, respectively. The higher the absolute PRCC value of the parameter, the more important it is in influencing the model outcome.

As expected, the parameters that were most strongly associated with incidence rates of first-time workplace violence were the rates at which FSWs experience that type of workplace violence for the first-time (Table B8). The higher the rate at which FSWs experience workplace violence for the first-time the higher the incidence estimate. Likewise, the parameters that were most strongly associated with incidence rates of first-time and repeat workplace violence were the rates at which FSWs experience that type of workplace violence for the first-time or repeatedly (Table B9). Due to the high prevalence of police harassment, the multiplier for increased rate of first-time and repeat client physical violence if recently experienced police harassment ($RR^{PHtoCPV}$), also had a strong positive correlation with incidence of first-time and repeat client physical violence. The multiplier for increased rate of first-time and repeat client sexual violence if recently experienced police harassment ($RR^{PHtoCSV}$), was also one of the parameters most strongly associated with incidence of first-time and repeat client sexual violence. $RR^{PHtoCPV}$ and $RR^{PHtoCSV}$ were the parameters most strongly correlated with the relative reduction in prevalence of recent client physical violence and recent client sexual violence due to elimination of police harassment (Table B10). The larger the association between police harassment and client violence, the greater the impact a police intervention could have on reducing client violence. As a number of the model outcomes were sensitive to the degree of association between police harassment and client violence ($RR^{PHtoCPV}$ and $RR^{PHtoCSV}$), it is important that studies seek to measure and reduce the uncertainty in the degree to which different types of workplace violence interact and influence each other. None of the calibrated parameters were strongly correlated with the impact of interventions on relative reduction in inconsistent condom use (Table B11), indicating that uncertainty in the calibrated parameters of the workplace violence model does not have too much influence on the magnitude of the ICU outcomes estimates.

2) Univariate sensitivity of fixed parameters

Figures B2-B5 show tornado plots of the univariate sensitivity analyses. In these univariate sensitivity analyses, fixed parameters and important parameters from PRCC analysis (PRCC=>0.5) were varied one at a time between a lower and upper value (±10% of baseline value) while all other model parameters were held at their baseline values.

In univariate sensitivity analyses for incidence of first-time workplace violence (Figure B2), varying the proportion of FSWs that were brothel-based, which is a fixed parameter in the model, had the most influence on incidence rates of first-time police harassment and client physical violence. There was an inverse relationship, where if more FSWs were brothel-based, incidence estimates were lower. This is because brothel-based FSWs have the lowest first-time rates of police harassment and client physical violence (Table B3), thus increasing the proportion of brothel-based FSWs in the model results in a lower overall incidence rate. The most influential parameter for incidence rate of first-time client sexual violence was the proportion of FSWs who have ever injected drugs, another fixed parameter in the model (Figure B2). FSWs who have ever injected drugs have higher baseline rates of first-time violence compared to FSWs who have never injected drugs (Table B3), so as the proportion of ever IDUs increases, the incidence rate of first-time client sexual violence also increases.

In univariate sensitivity analyses for incidence of first-time and repeat workplace violence (Figure B3), varying the time spent recently experiencing workplace violence (θ), a fixed parameter, had the most influence on incidence rates of first-time and repeat police harassment. Varying θ from 0.45-0.55 years yielded incidence rates which ranged from 65.2-73.6 per 100 person-years. Higher values of θ resulted in lower incidence of police harassment due to fewer FSWs transitioning from recent to non-recent compartments, and thus fewer FSWs repeatedly experiencing violence. The most influential parameter for incidence rate of first-time and repeat client physical violence was the multiplier for increased rate of first-time and repeat client physical violence if recently experienced police harassment ($RR^{PHtoCPV}$). As $RR^{PHtoCPV}$ increases, the incidence rate of first-time and repeat client physical violence increases. The incidence rate of first-time and repeat client sexual violence was most sensitive to the proportion of FSWs who have ever injected drugs. As the proportion of ever-IDU FSWs increased the incidence rate of client sexual violence decreased. This inverse relationship is driven by the fact that among outdoor-based FSWs there is a higher baseline incidence rate of first-time and repeat client sexual violence among non-IDU FSWs than ever-IDU FSWs (due to the combination of parameter values in the best fit parameter set), so increasing the proportion of ever IDUs results in a lower incidence rate. However, it is likely unrealistic that rates of violence would be higher among those who have never injected drugs compared to those that have ever injected drugs. This highlights a limitation of my analysis which I discuss in the main text (Section 2.5.2).

Univariate sensitivity analyses also show that the most influential parameter for the impact of eliminating police harassment on the relative reduction in prevalence of recent client physical violence is the multiplier for increased rate of first-time and repeat client physical violence if recently experienced police harassment ($RR^{PHtoCPV}$) (Figure B4). When $RR^{PHtoCPV}$ was varied from 1.8-2.2 the relative reduction in prevalence of recent client sexual violence ranged from 20.6-26.8%. As $RR^{PHtoCPV}$ increased, the impact of the intervention increased. Similarly, the relative reduction in prevalence of recent client sexual violence due to eliminating police harassment was most sensitive to the multiplier for increased rate of first-time and repeat client sexual violence if recently experienced police harassment ($RR^{PHtoCSV}$), where an increase in $RR^{PHtoCSV}$ resulted in a greater intervention impact. Varying $RR^{PHtoCSV}$ from 2.7-3.3 yielded a relative reduction in prevalence of recent client sexual violence which ranged from 35.5-40.2%.

For each of the 5 interventions evaluated, univariate sensitivity analyses show that the relative reduction in prevalence of ICU due to each intervention was most sensitive to the proportion of FSWs who are ever IDU (Figure B5), indicating the importance of knowing the size of the IDU FSW population when modelling the potential impact of interventions.

3) Sensitivity of intervention impact to ICU assumptions

The 5-year impact on average ICU after applying each of the 5 interventions using the alternative ICU assumption is shown for all FSWs in Figure B6. Under this alternative assumption it is assumed that the increased risk in ICU for FSWs who have experienced multiple types of workplace violence is a product of the increased risk associated with each type of workplace violence. As expected this results in a larger relative reduction in ICU for each intervention compared to the original ICU assumption. This is because the average ICU at baseline is larger under this alternative assumption (Table B6). The increase in relative reduction in ICU under this alternative assumption is largest for Intervention 1, where elimination of police harassment resulted in a median relative reduction in ICU of 7.5% after 5 years compared to 3.2% under the baseline ICU assumption. Like the original ICU assumption, Intervention 5 results in the largest relative reduction in ICU, followed by Intervention 3, Intervention 4, Intervention 2 and lastly Intervention 1.

4) Importance of incorporating between-violence dynamics

In the final sensitivity analysis, the model was re-calibrated assuming that there was no relationship between the different types of workplace violence (i.e. $RR^{PHtoCPV}$=1, $RR^{PHtoCSV}$=1 and $RR^{CPVtoCSV}$=1). Figures B7-B13 show the fit of the re-calibrated model to the cross-validation prevalence outcomes. Figures B7-B12 show that the fit of the re-calibrated model to prevalence of each type of workplace violence by FSW sub-group was very similar to that of the original calibrated model. Figure B13 also shows the re-calibrated model was able to fit well to the majority of data on prevalence of experiencing multiple types of workplace violence. However, in contrast to the original calibrated model, the re-calibrated model no longer had any model runs that fit prevalence of experiencing both recent client sexual violence and recent client physical violence or that fit prevalence of experiencing all three types of workplace violence recently (Figure B13). Figures B14-B15 also show that the estimates of incidence of workplace violence are very similar between the two different model calibrations, with the original calibrated model tending to have slightly wider confidence intervals in comparison to the re-calibrated model. Figure B16 highlights that interventions had a similar impact across the two different model calibration, and was most different for intervention 1 (elimination of police harassment), which had a smaller impact on the ICU outcome under the alternative calibration.

Table B1. Prevalence data used in cross-validation

	% (95% CI) [2]
Prevalence of workplace violence stratified by work environment and injecting drug use	
Ever experienced police harassment	
Non-IDU, outdoor-based	63.4% (52.8-73.2%)
Non-IDU, informal indoor-based	46.8% (34.0-59.9%)
Non-IDU, brothel-based	15.2% (10.7-20.7%)
Ever-IDU outdoor-based	77.7% (71.7-83.0%)
Ever-IDU, informal indoor-based	76.1% (68.0-83.1%)
Ever-IDU, brothel-based	73.9% (51.6-89.8%)
Recently[1] experienced police harassment	
Non-IDU, outdoor-based	44.1% (33.8-54.8%)
Non-IDU, informal indoor-based	24.2% (14.2-36.7%)
Non-IDU, brothel-based	11.1% (7.2-16.0%)
Ever-IDU outdoor-based	48.7% (41.9-55.4%)
Ever-IDU, informal indoor-based	44.0% (35.5-52.9%)
Ever-IDU, brothel-based	52.2% (30.6-73.2%)
Ever experienced client physical violence	
Non-IDU, outdoor-based	52.7% (42.1-63.1%)
Non-IDU, informal indoor-based	48.4% (35.5-61.4%)
Non-IDU, brothel-based	11.1% (7.2-16.0%)
Ever-IDU outdoor-based	73.7% (67.4-79.3%)
Ever-IDU, informal indoor-based	70.1% (61.6-77.7%)
Ever-IDU, brothel-based	73.9% (51.6-89.8%)
Recently[1] experienced client physical violence	
Non-IDU, outdoor-based	17.2% (10.2-26.4%)
Non-IDU, informal indoor-based	12.9% (5.7-23.9%)
Non-IDU, brothel-based	6.5% (3.6-10.6%)
Ever-IDU outdoor-based	25.0% (19.5-31.2%)
Ever-IDU, informal indoor-based	20.9% (14.4-28.8%)
Ever-IDU, brothel-based	17.4% (5.0-38.8%)
Ever experienced client sexual violence	
Non-IDU, outdoor-based	44.1% (33.8-54.8%)
Non-IDU, informal indoor-based	46.8% (34.0-59.9%)
Non-IDU, brothel-based	9.2% (5.7-13.9%)
Ever-IDU outdoor-based	63.8% (57.2-70.1%)
Ever-IDU, informal indoor-based	64.9% (56.2-73.0%)
Ever-IDU, brothel-based	60.9% (38.5-80.3%)
Recently[1] experienced client sexual violence	
Non-IDU, outdoor-based	16.1% (9.3-25.2%)
Non-IDU, informal indoor-based	12.9% (5.7-23.9%)
Non-IDU, brothel-based	4.1% (1.9-7.7%)
Ever-IDU outdoor-based	22.3% (17.0-28.3%)
Ever-IDU, informal indoor-based	15.7% (10.0-23.0%)
Ever-IDU, brothel-based	17.4% (5.0-38.8%)
Prevalence of multiple types of workplace violence	
Experienced police harassment and client physical violence	
Ever	38.8% (35.3-42.4%)
Recently[1]	8.9% (7.0-11.2%)
Experienced police harassment and client sexual violence	
Ever	34.5% (31.1-38.0%)
Recently[1]	8.8% (6.8-11.0%)
Experienced client physical violence and client sexual violence	
Ever	37.6% (34.1-41.2%)
Recently[1]	8.2% (6.4-10.4%)
Experienced all three types of workplace violence	
Ever	30.7% (27.4-34.1%)
Recently[1]	4.6% (3.3-6.4%)

Abbreviations: FSWs, female sex workers; IDU, injecting drug use

[1] In the last 6 months

[2] Prevalence estimates are from baseline surveys of 753 participants enrolled in AESHA between 2010 and 2014

Table B2. Values for fixed parameters used in the univariate sensitivity analyses

Parameter	Symbol	Baseline value (i.e. fixed value)[1]	Lower value	Upper value
Fixed parameters				
% of FSWs who are ever-IDU	*FracIDU*	51.0%	45.9%	56.1%
% of FSWs who are outdoor-based	*FracOutdoor*	42.0%	37.8%	46.2%
% of FSWs who are informal indoor-based	*FracInformal*	26.0%	23.4%	28.6%
% of FSWs who are brothel-based	*FracBrothel*	32.0%	28.8%	35.2%
Time to non-recent police harassment or client physical violence or client sexual violence from recent police harassment, client physical violence or client sexual violence (years)	θ	0.5	0.45	0.55

Note: When the % of FSWs who are in one work environment increases, the % of FSWs in the other two work environments decreases proportionately. Similarly, when the % of FSWs who are in one work environment decreases, the % of FSWs in the other two work environments increases proportionately.
[1] Baseline values are from the best fitting parameter set (see Section 2.3.2.4 for further details)

Table B3. Baseline values for calibrated and ICU parameters in univariate sensitivity analyses

	Symbol	Baseline value [1]
Calibrated parameters		
Lifetime duration selling sex (years) in each sub-group (κ_{mn})		
Non-IDU, outdoor-based	κ_{11}	19.4
Non-IDU, informal indoor-based	κ_{12}	20.6
Non-IDU, brothel-based	κ_{13}	5.4
Ever-IDU outdoor-based	κ_{21}	30.0
Ever-IDU, informal indoor-based	κ_{22}	35.1
Ever-IDU, brothel-based	κ_{23}	33.9
Rate (per year) that FSWs experience police harassment for the first time by sub-group (α_{mn}^{PH})		
Non-IDU, outdoor-based	α_{11}^{PH}	0.0862
Non-IDU, informal indoor-based	α_{12}^{PH}	0.0499
Non-IDU, brothel-based	α_{13}^{PH}	0.0163
Ever-IDU outdoor-based	α_{21}^{PH}	0.1246
Ever-IDU, informal indoor-based	α_{22}^{PH}	0.1307
Ever-IDU, brothel-based	α_{23}^{PH}	0.1045
Rate (per year) that FSWs experience client physical violence for the first time by sub-group (α_{mn}^{CPV})		
Non-IDU, outdoor-based	α_{11}^{CPV}	0.0621
Non-IDU, informal indoor-based	α_{12}^{CPV}	0.0490
Non-IDU, brothel-based	α_{13}^{CPV}	0.0071
Ever-IDU outdoor-based	α_{21}^{CPV}	0.0754
Ever-IDU, informal indoor-based	α_{22}^{CPV}	0.0402
Ever-IDU, brothel-based	α_{23}^{CPV}	0.1336
Rate (per year) that FSWs experience client sexual violence for the first time by sub-group (α_{mn}^{CSV})		
Non-IDU, outdoor-based	α_{11}^{CSV}	0.0341
Non-IDU, informal indoor-based	α_{12}^{CSV}	0.0006
Non-IDU, brothel-based	α_{13}^{CSV}	0.0182
Ever-IDU outdoor-based	α_{21}^{CSV}	0.0284
Ever-IDU, informal indoor-based	α_{22}^{CSV}	0.0355
Ever-IDU, brothel-based	α_{23}^{CSV}	0.0266
Rate (per year) that FSWs re-experience police harassment if previously experienced police harassment by sub-group (ν_{mn}^{PH})		
Non-IDU, outdoor-based	ν_{11}^{PH}	5.0008
Non-IDU, informal indoor-based	ν_{12}^{PH}	3.1421

Non-IDU, brothel-based	ν_{13}^{PH}	7.3982
Ever-IDU outdoor-based	ν_{21}^{PH}	2.6661
Ever-IDU, informal indoor-based	ν_{22}^{PH}	2.7248
Ever-IDU, brothel-based	ν_{23}^{PH}	8.9422
Rate (per year) that FSWs re-experience client physical violence if previously experienced client physical violence by sub-group (ν_{mn}^{CPV})		
Non-IDU, outdoor-based	ν_{11}^{CPV}	0.6215
Non-IDU, informal indoor-based	ν_{12}^{CPV}	1.4375
Non-IDU, brothel-based	ν_{13}^{CPV}	3.8544
Ever-IDU outdoor-based	ν_{21}^{CPV}	0.8388
Ever-IDU, informal indoor-based	ν_{22}^{CPV}	0.1047
Ever-IDU, brothel-based	ν_{23}^{CPV}	1.4860
Rate (per year) that FSWs re-experience client sexual violence if previously experienced client sexual violence by sub-group (ν_{mn}^{CSV})		
Non-IDU, outdoor-based	ν_{11}^{CSV}	0.9129
Non-IDU, informal indoor-based	ν_{12}^{CSV}	1.1956
Non-IDU, brothel-based	ν_{13}^{CSV}	1.7168
Ever-IDU outdoor-based	ν_{21}^{CSV}	0.0368
Ever-IDU, informal indoor-based	ν_{22}^{CSV}	0.3442
Ever-IDU, brothel-based	ν_{23}^{CSV}	1.1610
Multiplier (relative risk ratio) for increased rate of first-time and repeat client physical violence if recently experienced police harassment	$RR^{PHtoCPV}$	4.40
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced police harassment	$RR^{PHtoCSV}$	2.00
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced client physical violence	$RR^{CPVtoCSV}$	3.01
ICU parameters		
ICU in 2013 if:		
Non-IDU, outdoor-based	ICU_{B1}	13.3%
Non-IDU, informal indoor-based	ICU_{B2}	13.4%
Non-IDU, brothel-based	ICU_{B2}	7.2%
Relative risk (RR) for ICU if ever IDU	RR_{IDU}	0.98
RR for ICU due to the following workplace violence experiences:		
Recent police harassment	$RR_{R\text{-}PH}$	1.6
Recent client physical violence	$RR_{R\text{-}CPV}$	1.6
Non-recent client physical violence	$RR_{NR\text{-}CPV}$	1.5
Ever client sexual violence	$RR_{E\text{-}CSV}$	4.6

Note: parameter symbol subscript m = injecting drug status (1= non-IDU, 2 = ever-IDU); parameter symbol subscript n = work environment (1= outdoor-based, 2 = informal indoor-based, 3 = brothel-based). Baseline values are the value from the best fitting parameter set if a calibrated parameter, or the value from the corresponding ICU parameter set if a condom use parameter.

[1] Baseline values are from the best fitting parameter set if a calibrated parameter (see Section 2.3.2.4 for further details), or from the corresponding ICU parameter set if a condom use parameter (see Section 2.3.3)

Table B4. Posterior range for calibrated parameters

Parameter	Symbol	Prior range	Posterior median (95% CrI)
Lifetime duration selling sex (years) in each sub-group (κ_{mn})			
Non-IDU, outdoor-based	κ_{11}	16.5-23.3	20.01 (16.87-23.15)
Non-IDU, informal indoor-based	κ_{12}	16.8-27.1	22.57 (17.48-26.86)
Non-IDU, brothel-based	κ_{13}	5.4-8.0	6.87 (5.46-7.93)
Ever-IDU outdoor-based	κ_{21}	28.1-32.2	30.00 (28.14-32.05)
Ever-IDU, informal indoor-based	κ_{22}	32.2-39.7	36.27 (32.39-39.55)
Ever-IDU, brothel-based	κ_{23}	23.7-39.4	30.66 (24.57-38.91)
Rate (per year) that FSWs experience police harassment for the first time by sub-group (α_{mn}^{PH})			
Non-IDU, outdoor-based	α_{11}^{PH}	0-0.134	0.094 (0.035-0.127)
Non-IDU, informal indoor-based	α_{12}^{PH}	0-0.066	0.043 (0.007-0.065)
Non-IDU, brothel-based	α_{13}^{PH}	0-0.038	0.025 (0.005-0.037)
Ever-IDU outdoor-based	α_{21}^{PH}	0-0.157	0.125 (0.063-0.156)
Ever-IDU, informal indoor-based	α_{22}^{PH}	0-0.132	0.105 (0.043-0.132)
Ever-IDU, brothel-based	α_{23}^{PH}	0-0.252	0.125 (0.028-0.237)
Rate (per year) that FSWs experience client physical violence for the first time by sub-group (α_{mn}^{CPV})			
Non-IDU, outdoor-based	α_{11}^{CPV}	0-0.084	0.057 (0.009-0.082)
Non-IDU, informal indoor-based	α_{12}^{CPV}	0-0.069	0.042 (0.009-0.068)
Non-IDU, brothel-based	α_{13}^{CPV}	0-0.027	0.015 (0.001-0.027)
Ever-IDU outdoor-based	α_{21}^{CPV}	0-0.122	0.083 (0.028-0.118)
Ever-IDU, informal indoor-based	α_{22}^{CPV}	0-0.096	0.062 (0.017-0.095)
Ever-IDU, brothel-based	α_{23}^{CPV}	0-0.256	0.141 (0.008-0.248)
Rate (per year) that FSWs experience client sexual violence for the first time by sub-group (α_{mn}^{CSV})			
Non-IDU, outdoor-based	α_{11}^{CSV}	0-0.060	0.030 (0.002-0.058)
Non-IDU, informal indoor-based	α_{12}^{CSV}	0-0.066	0.024 (0.001-0.064)
Non-IDU, brothel-based	α_{13}^{CSV}	0-0.024	0.011 (0.001-0.023)
Ever-IDU outdoor-based	α_{21}^{CSV}	0-0.076	0.029 (0.006-0.073)
Ever-IDU, informal indoor-based	α_{22}^{CSV}	0-0.073	0.034 (0.003-0.068)
Ever-IDU, brothel-based	α_{23}^{CSV}	0-0.119	0.064 (0.006-0.115)
Rate (per year) that FSWs re-experience police harassment if previously experienced police harassment by sub-group (ν_{mn}^{PH})			
Non-IDU, outdoor-based	ν_{11}^{PH}	0-7.950	5.016 (0.229-7.840)
Non-IDU, informal indoor-based	ν_{12}^{PH}	0-4.493	2.693 (0.355-4.368)
Non-IDU, brothel-based	ν_{13}^{PH}	0-12.497	6.916 (1.032-12.101)
Ever-IDU outdoor-based	ν_{21}^{PH}	0-4.438	3.549 (1.951-4.380)
Ever-IDU, informal indoor-based	ν_{22}^{PH}	0-3.963	2.780 (0.682-3.892)
Ever-IDU, brothel-based	ν_{23}^{PH}	0-14.758	6.968 (0.438-14.158)
Rate (per year) that FSWs re-experience client physical violence if previously experienced client physical violence by sub-group (ν_{mn}^{CPV})			
Non-IDU, outdoor-based	ν_{11}^{CPV}	0-1.856	0.893 (0.040-1.813)
Non-IDU, informal indoor-based	ν_{12}^{CPV}	0-1.614	0.882 (0.048-1.561)
Non-IDU, brothel-based	ν_{13}^{CPV}	0-8.168	4.693 (0.194-7.800)
Ever-IDU outdoor-based	ν_{21}^{CPV}	0-1.349	0.692 (0.062-1.274)
Ever-IDU, informal indoor-based	ν_{22}^{CPV}	0-1.260	0.544 (0.074-1.217)
Ever-IDU, brothel-based	ν_{23}^{CPV}	0-1.858	0.956 (0.091-1.800)
Rate (per year) that FSWs re-experience client sexual violence if previously experienced client sexual violence by sub-group (ν_{mn}^{CSV})			
Non-IDU, outdoor-based	ν_{11}^{CSV}	0-2.185	0.868 (0.024-1.936)
Non-IDU, informal indoor-based	ν_{12}^{CSV}	0-1.755	0.782 (0.059-1.640)
Non-IDU, brothel-based	ν_{13}^{CSV}	0-3.913	1.685 (0.144-3.653)
Ever-IDU outdoor-based	ν_{21}^{CSV}	0-1.446	0.141 (0.009-0.892)
Ever-IDU, informal indoor-based	ν_{22}^{CSV}	0-0.994	0.361 (0.013-0.952)
Ever-IDU, brothel-based	ν_{23}^{CSV}	0-2.629	1.401 (0.120-2.455)

Parameter	Symbol	Prior range	Posterior median (95% CrI)
Multiplier (relative risk ratio) for increased rate of first-time and repeat client physical violence if recently experienced police harassment	$RR^{PHtoCPV}$	1.2-2.3	1.76 (1.26-2.26)
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced police harassment	$RR^{PHtoCSV}$	1.6-3.4	2.29 (1.62-3.30)
Multiplier (relative risk ratio) for increased rate of first-time and repeat client sexual violence if recently experienced client physical violence	$RR^{CPVtoCSV}$	4.1-8.1	5.56 (4.15-7.93)

Note: parameter symbol subscript m = injecting drug status (1= non-IDU, 2 = ever-IDU); parameter symbol subscript n = work environment (1= outdoor-based, 2 = informal indoor-based, 3 = brothel-based)
Abbreviations: IDU, injecting drug use; CrI, credible interval.

Table B5. Model estimates of annual incidence rates of violence

	Mean incidence rate per 100 pyrs (95% CrI)		
Type of workplace violence	**Police harassment**	**Client physical violence**	**Client sexual violence**
Incidence of first-time workplace violence among:			
All FSWs	5.2 (4.1-6.2)	4.1 (3.3-4.9)	3.3 (2.6-4.3)
Non-IDU, outdoor-based FSWs	9.4 (3.5-12.7)	6.7 (1.1-9.9)	5.5 (0.4-9.9)
Non-IDU, informal indoor-based FSWs	4.3 (0.7-6.5)	4.5 (0.9-7.5)	3.9 (0.2-9.4)
Non-IDU, brothel-based FSWs	2.5 (0.5-3.7)	1.6 (0.1-2.9)	1.5 (0.1-3.0)
Ever-IDU outdoor-based FSWs	12.5 (6.3-15.6)	10.0 (4.2-14.0)	6.1 (1.8-13.7)
Ever-IDU, informal indoor-based FSWs	10.5 (4.3-13.2)	7.5 (2.2-11.0)	6.4 (1.0-11.7)
Ever-IDU, brothel-based FSWs	12.5 (2.8-23.7)	16.5 (1.1-28.7)	12.0 (1.7-23.7)
Outdoor-based FSWs	10.6 (7.0-13.8)	7.6 (4.7-11.5)	5.1 (2.7-10.0)
Informal-indoor based FSWS	6.3 (3.6-9.3)	5.4 (2.6-8.5)	4.8 (1.6-9.7)
Brothel-based FSWs	2.7 (0.8-3.9)	1.9 (0.4-3.2)	1.7 (0.3-3.3)
Non-IDU FSWs	3.4 (2.0-4.6)	2.5 (1.4-3.8)	2.1 (0.8-3.9)
Ever-IDU FSWs	10.7 (7.2-13.9)	7.9 (5.4-12.5)	5.6 (3.2-9.7)
Incidence of first-time and repeat workplace violence among:			
All FSWs	67.8 (63.7-76.5)	33.4 (29.3-39.7)	30.3 (24.9-34.4)
Non-IDU, outdoor-based FSWs	87.1 (13.8-117.0)	37.1 (4.4-69.6)	42.0 (5.8-90.8)
Non-IDU, informal indoor-based FSWs	47.5 (7.4-78.7)	31.2 (2.3-60.3)	40.4 (3.5-80.1)
Non-IDU, brothel-based FSWs	23.3 (5.4-36.9)	13.6 (0.9-28.6)	10.0 (1.0-24.4)
Ever-IDU outdoor-based FSWs	99.4 (74.9-114.2)	50.3 (8.7-70.0)	26.3 (3.2-62.2)
Ever-IDU, informal indoor-based FSWs	91.0 (38.9-108.8)	39.2 (7.9-67.3)	40.6 (3.6-92.7)
Ever-IDU, brothel-based FSWs	112.3 (24.0-149.9)	59.0 (11.4-106.4)	99.1 (24.4-136.1)
Outdoor-based FSWs	94.2 (74.2-108.2)	46.3 (20.9-64.5)	31.4 (12.3-54.3)
Informal indoor-based FSWS	77.1 (40.5-97.3)	38.4 (10.3-54.0)	40.4 (15.2-72.6)
Brothel-based FSWs	30.3 (13.1-46.3)	17.8 (4.1-33.3)	17.7 (7.6-30.8)
Non-IDU FSWs	41.2 (28.3-54.1)	22.9 (10.3-33.3)	23.5 (9.5-45.4)
Ever-IDU FSWs	95.7 (81.1-106.1)	45.0 (27.6-60.5)	36.1 (18.5-52.8)

Abbreviations: FSWs, female sex workers; IDU, injecting drug use; pyrs, person years; CrI, credible interval

Table B6. Average prevalence of inconsistent condom use at baseline under the original and alternative ICU assumptions

	Median ICU prevalence (95% CrI)	
	Original ICU assumption	**Alternative ICU assumption**
All FSWs	43.1% (24.0%-57.0%)	51.1% (33.1%-60.0%)
Non-IDU, outdoor-based FSWs	40.2% (18.5%-66.2%)	57.0% (25.5%-72.9%)
Non-IDU, informal indoor-based FSWs	47.0% (19.4%-77.2%)	56.0% (23.6%-80.3%)
Non-IDU, brothel-based FSWs	5.9% (2.5%-10.1%)	6.5% (2.7%-11.2%)
Ever-IDU outdoor-based FSWs	63.1% (25.8%-88.5%)	76.3% (45.3%-90.4%)
Ever-IDU, informal indoor-based FSWs	70.7% (27.8%-93.4%)	80.2% (45.6%-93.4%)
Ever-IDU, brothel-based FSWs	17.4% (5.6%-36.3%)	33.6% (11.4%-72.7%)
Outdoor-based FSWs	56.1% (24.5%-80.8%)	70.7% (43.9%-82.1%)
Informal-indoor based FSWs	64.2% (25.3%-85.3%)	72.0% (39.7%-86.8%)
Brothel-based FSWs	7.2% (3.0%-12.2%)	9.3% (3.5%-16.0%)
Non-IDU FSWs	21.1% (12.9%-30.5%)	26.9% (14.8%-34.4%)
Ever-IDU FSWs	63.6% (32.5%-86.0%)	74.7% (44.8%-87.3%)

Abbreviations: FSWs, female sex workers; IDU, injecting drug use; ICU, inconsistent condom use; CrI, credible interval

Table B7. Relative reduction in prevalence of inconsistent condom use by FSW sub-group

	Median Relative Reduction in ICU prevalence after 5 years of intervention (95% CrI)				
	Intervention 1	**Intervention 2**	**Intervention 3**	**Intervention 4**	**Intervention 5**
FSW sub-group:					
Non-IDU, outdoor-based	4.4% (0.8%-14.7%)	12.8% (3.4%-23.1%)	48.1% (17.5%-67.4%)	16.2% (6.0%-27.9%)	56.4% (24.1%-71.6%)
Non-IDU, informal indoor-based	2.1% (0.3%-7.3%)	12.2% (3.1%-17.7%)	47.5% (15.5%-67.0%)	13.8% (5.8%-19.6%)	52.9% (26.7%-70.1%)
Non-IDU, brothel-based	3.4% (0.6%-8.8%)	11.7% (1.5%-20.5%)	19.5% (3.8%-40.0%)	15.1% (2.7%-24.3%)	23.3% (5.9%-41.3%)
Ever-IDU outdoor-based	3.0% (1.1%-7.9%)	9.8% (3.0%-22.8%)	48.7% (22.0%-70.6%)	11.6% (5.0%-24.3%)	57.9% (38.3%-73.1%)
Ever-IDU, informal indoor-based	2.6% (0.8%-6.8%)	7.4% (2.2%-16.7%)	46.0% (18.3%-64.8%)	9.2% (5.0%-17.3%)	54.4% (34.1%-72.1%)
Ever-IDU, brothel-based	2.1% (0.2%-7.2%)	9.9% (4.1%-24.0%)	54.4% (23.2%-74.8%)	11.6% (6.5%-25.3%)	64.1% (41.1%-76.5%)

Abbreviations: FSWs, female sex workers; IDU, injecting drug use; ICU, inconsistent condom use; CrI, credible interval
Intervention key: Intervention 1 - Eliminate police harassment; Intervention 2 – Eliminate client physical violence; Intervention 3 - Eliminate client violence and eliminate ICU associated with previous exposure to client violence; Intervention 4 - Eliminate workplace violence; Intervention 5 - Eliminate workplace violence and eliminate ICU associated with previous exposure to workplace

Table B8. PRCCs for incidence rate of first-time workplace violence

Incidence rate of first-time police harassment per 100 pyrs		Incidence rate of first-time client physical violence per 100 pyrs		Incidence rate of first-time client sexual violence per 100 pyrs	
Parameter	**PRCC**	**Parameter**	**PRCC**	**Parameter**	**PRCC**
α_{13}^{PH}	0.93	α_{13}^{CPV}	0.81	α_{13}^{CSV}	0.83
α_{21}^{PH}	0.70	α_{11}^{CPV}	0.59	α_{21}^{CSV}	0.64
α_{12}^{PH}	0.64	α_{22}^{CPV}	0.53	α_{22}^{CSV}	0.48
α_{22}^{PH}	0.62	α_{21}^{CPV}	0.42	α_{11}^{CSV}	0.45
α_{11}^{PH}	0.61	ν_{21}^{CPV}	-0.41	α_{12}^{CPV}	0.38
κ_{11}	-0.37	α_{12}^{CPV}	0.40	$RR^{PHtoCSV}$	0.33
ν_{12}^{PH}	-0.29	ν_{22}^{CPV}	-0.32	ν_{23}^{CSV}	-0.23
κ_{21}	-0.28	ν_{11}^{CPV}	-0.32		
α_{21}^{CSV}	-0.25	$RR^{PHtoCSV}$	-0.22		
α_{23}^{CSV}	-0.23				
κ_{12}	-0.23				
α_{11}^{CPV}	0.22				

Note: PRCC values are presented in descending order of strength. Only PRCCs with an absolute value of 0.2 or more are shown. The 'α' parameters relate to rates of first-time workplace violence, 'ν' parameters relate to repeat rates of workplace violence, and 'κ' parameters relates to lifetime duration selling sex.

Table B9. PRCCs for incidence rate of first-time and repeat workplace violence

Incidence rate of first-time and repeat police harassment per 100 pyrs		Incidence rate of first-time and repeat client physical violence per 100 pyrs		Incidence rate of first-time and repeat client sexual violence per 100 pyrs	
Parameter	**PRCC**	**Parameter**	**PRCC**	**Parameter**	**PRCC**
ν_{22}^{PH}	0.74	ν_{21}^{CPV}	0.86	ν_{21}^{CSV}	0.73
α_{13}^{PH}	0.58	ν_{22}^{CPV}	0.73	ν_{22}^{CSV}	0.62
ν_{21}^{PH}	0.57	ν_{11}^{CPV}	0.59	$RR^{PHtoCSV}$	0.49
ν_{11}^{PH}	0.53	$RR^{PHtoCPV}$	0.56	ν_{11}^{CSV}	0.48
α_{22}^{PH}	0.53	α_{13}^{CPV}	0.44	α_{11}^{CSV}	0.33
ν_{23}^{PH}	0.28	ν_{13}^{CPV}	0.38	ν_{13}^{CSV}	0.27
α_{21}^{CSV}	-0.27	ν_{23}^{CPV}	0.36	ν_{23}^{CPV}	0.26
α_{11}^{PH}	0.27	$RR^{PHtoCSV}$	0.34	ν_{12}^{CSV}	0.23
ν_{12}^{CSV}	-0.27	ν_{12}^{CPV}	0.33	$RR^{CPVtoCSV}$	0.23
ν_{21}^{CSV}	-0.26	ν_{22}^{PH}	0.33	α_{21}^{PH}	0.22
α_{21}^{PH}	0.23	κ_{11}	0.21	ν_{23}^{CSV}	0.21
ν_{22}^{CSV}	-0.23			α_{22}^{CSV}	0.21
ν_{13}^{PH}	0.22			α_{13}^{CSV}	0.21
α_{13}^{CPV}	0.20				
α_{23}^{PH}	0.20				

Note: PRCC values are presented in descending order of strength. Only PRCCs with an absolute value of 0.2 or more are shown. The 'α' parameters relate to rates of first-time workplace violence, the 'ν' parameters relate to repeat rates of workplace violence, and 'κ' parameters relates to lifetime duration selling sex.

Table B10. PRCCs for relative reduction in prevalence of client violence due to elimination of police harassment

Client physical violence		Client sexual violence	
Parameter	**PRCC**	**Parameter**	**PRCC**
$RR^{PHtoCPV}$	0.96	$RR^{PHtoCSV}$	0.89
ν_{22}^{PH}	0.46	$RR^{PHtoCPV}$	0.56
ν_{13}^{CPV}	-0.34	ν_{22}^{PH}	0.43
ν_{21}^{PH}	0.33	ν_{21}^{CSV}	0.34
α_{13}^{CPV}	-0.32	α_{22}^{PH}	0.33
ν_{11}^{CPV}	-0.23	ν_{11}^{CSV}	-0.32
κ_{12}	-0.21	ν_{21}^{PH}	0.30
		ν_{12}^{CSV}	-0.28
		κ_{13}	-0.26
		α_{11}^{CSV}	-0.25
		ν_{12}^{CPV}	-0.22
		ν_{11}^{PH}	0.22
		α_{22}^{CSV}	-0.21

Note: PRCC values are presented in descending order of strength. Only PRCCs with an absolute value of 0.2 or more are shown. The 'α' parameters relate to rates of first-time workplace violence, the 'ν' parameters relate to repeat rates of workplace violence, and 'κ' parameters relates to lifetime duration selling sex.

Table B11. PRCCs for relative reduction in prevalence of ICU by intervention

Intervention 1 – Relative reduction in prevalence of ICU		Intervention 2 – Relative reduction in prevalence of ICU		Intervention 3 – Relative reduction in prevalence of ICU		Intervention 4 – Relative reduction in prevalence of ICU		Intervention 5 – Relative reduction in prevalence of ICU	
Parameter	**PRCC**	**Parameter**	**PRCC**	**Parameter**	**PRCC**	**Parameter**	**PRCC**	**Parameter**	**PRCC**
κ_{11}	-0.40	α_{21}^{CPV}	0.40	α_{21}^{CPV}	0.31	α_{21}^{CPV}	0.36	α_{21}^{CPV}	0.29
ν_{21}^{PH}	0.35	α_{23}^{CPV}	0.29	α_{13}^{PH}	-0.29	κ_{11}	-0.32	ν_{13}^{CPV}	-0.28
α_{11}^{CSV}	-0.34	$RR^{PHtoCPV}$	0.25	ν_{13}^{CPV}	-0.28	ν_{11}^{CPV}	-0.26	κ_{21}	-0.27
α_{12}^{CPV}	-0.34	ν_{11}^{CPV}	-0.23	α_{22}^{CPV}	0.26	$RR^{PHtoCPV}$	0.26	ν_{13}^{CSV}	0.27
ν_{11}^{CPV}	-0.33	κ_{13}	0.22	α_{23}^{CPV}	0.26	ν_{12}^{CSV}	0.25	α_{11}^{PH}	-0.26
ν_{12}^{PH}	0.29	α_{22}^{CPV}	0.21	ν_{13}^{CSV}	0.26	α_{23}^{CPV}	0.25	$RR^{PHtoCPV}$	0.25
ν_{21}^{CPV}	-0.27	ν_{13}^{CSV}	0.20	α_{11}^{PH}	-0.25	ν_{22}^{PH}	0.24	κ_{11}	-0.25
α_{21}^{CSV}	-0.26			$RR^{PHtoCPV}$	0.22	ν_{12}^{PH}	0.23	$RR^{CPVtoCSV}$	0.24
$RR^{PHtoCPV}$	0.24					$RR^{PHtoCSV}$	-0.22	α_{13}^{PH}	-0.21
ν_{11}^{CSV}	-0.23					α_{12}^{CSV}	0.22	α_{23}^{CPV}	0.20
ν_{22}^{PH}	0.23					ν_{11}^{CSV}	-0.21		
K_{21}	-0.23								
ν_{22}^{CPV}	-0.21								
ν_{22}^{CSV}	0.21								
α_{13}^{CPV}	-0.21								
ν_{13}^{PH}	-0.20								
ν_{12}^{CSV}	0.20								

Note: PRCC values are presented in descending order of strength. Only PRCCs with an absolute value of 0.2 or more are shown. The ‘α’ parameters relate to rates of first-time workplace violence, the ‘ν’ parameters relate to repeat rates of workplace violence, and ‘κ’ parameters relates to lifetime duration selling sex.

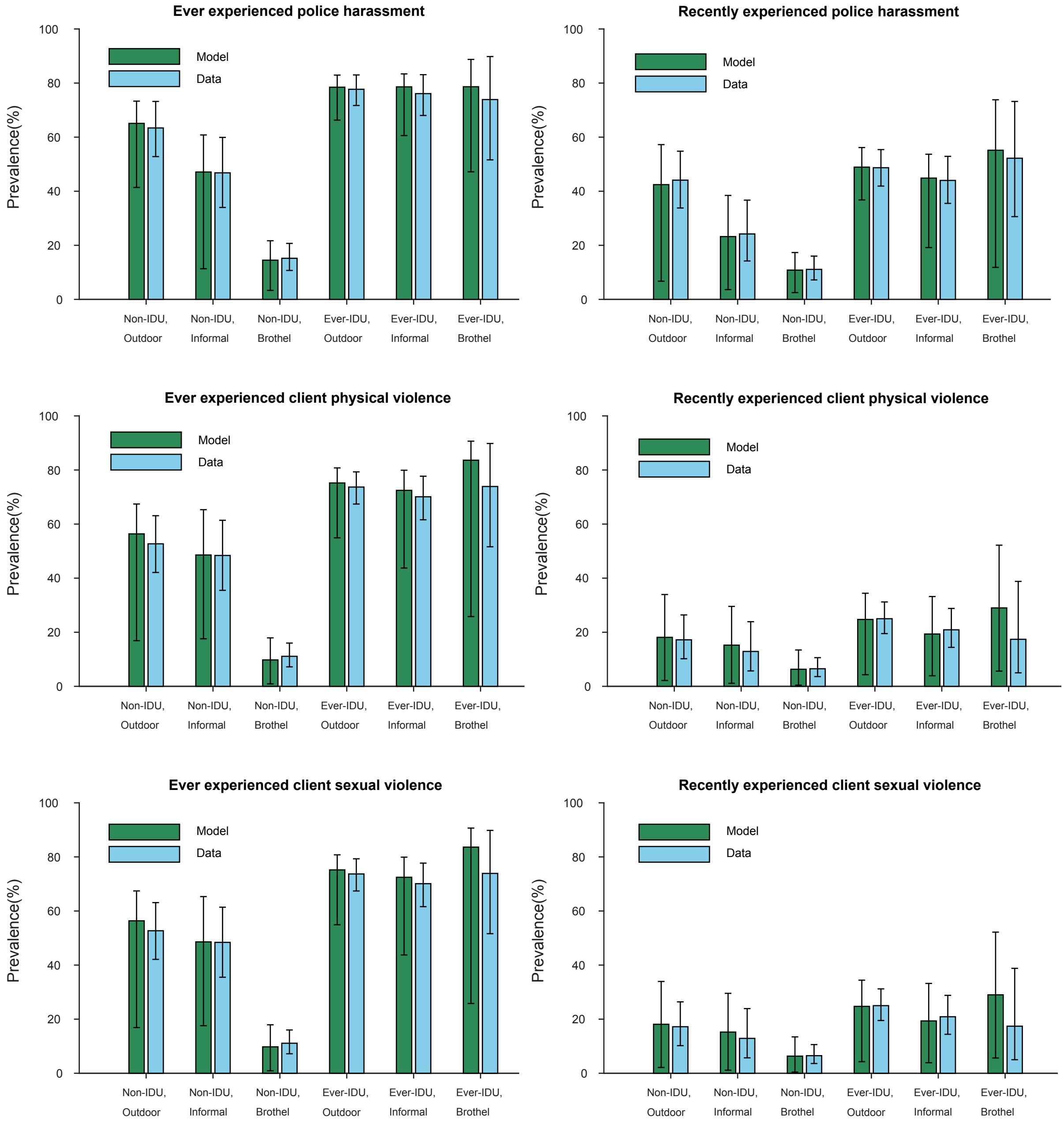


Figure B1. Prevalence of workplace violence by FSW sub-group: Model projections compared to cross-validation AESHA data. PH, police harassment; CPV, client physical violence; CSV, client sexual violence; IDU, injecting drug user. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

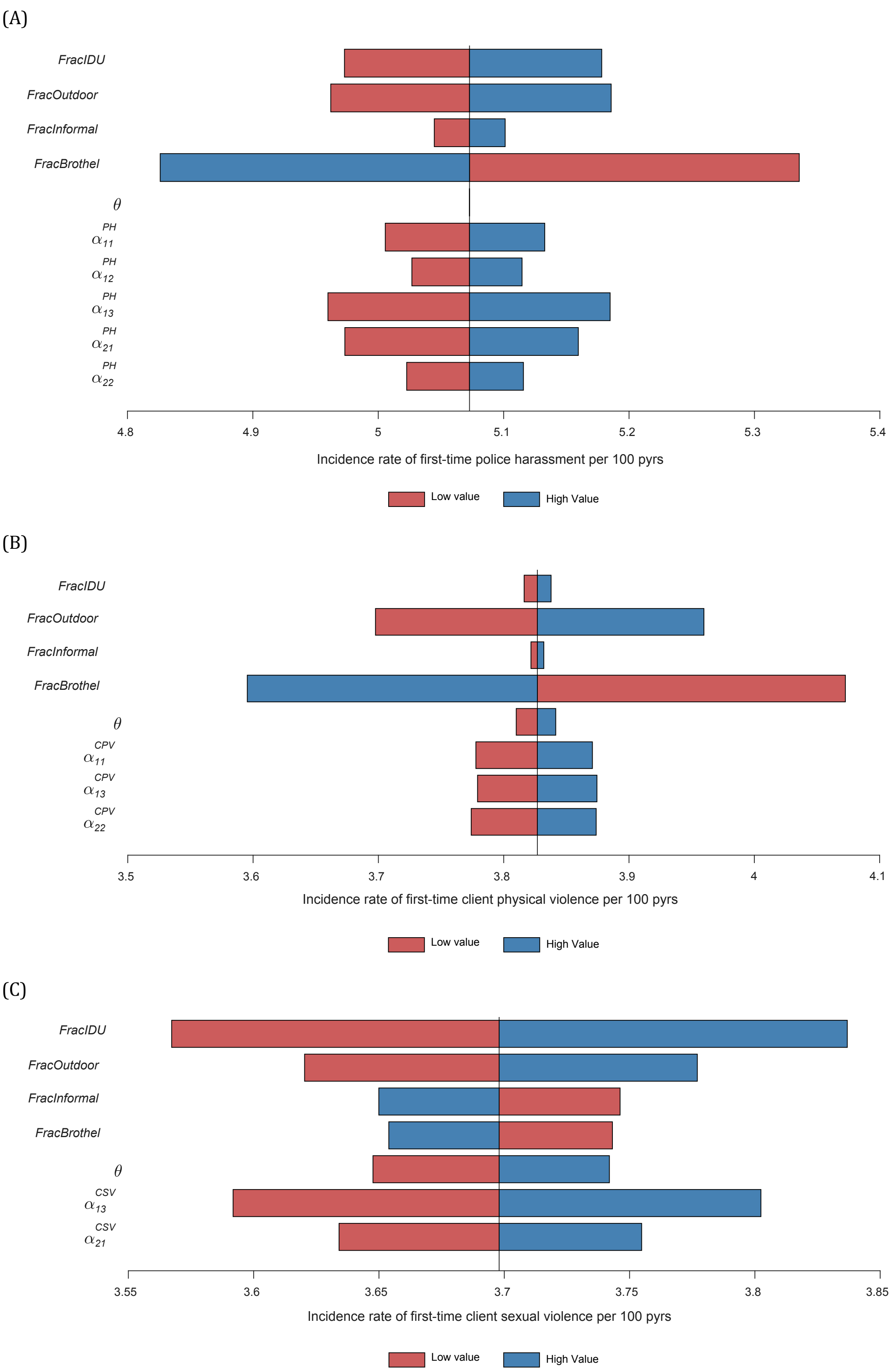


Figure B2. Tornado plot of univariate sensitivity analyses showing the impact of fixed parameters and important parameters from PRCC analysis on A) incidence of first-time police harassment, B) incidence of first-time client physical violence and C) incidence of first-time client sexual violence. The black vertical lines show the outcome estimate at baseline.

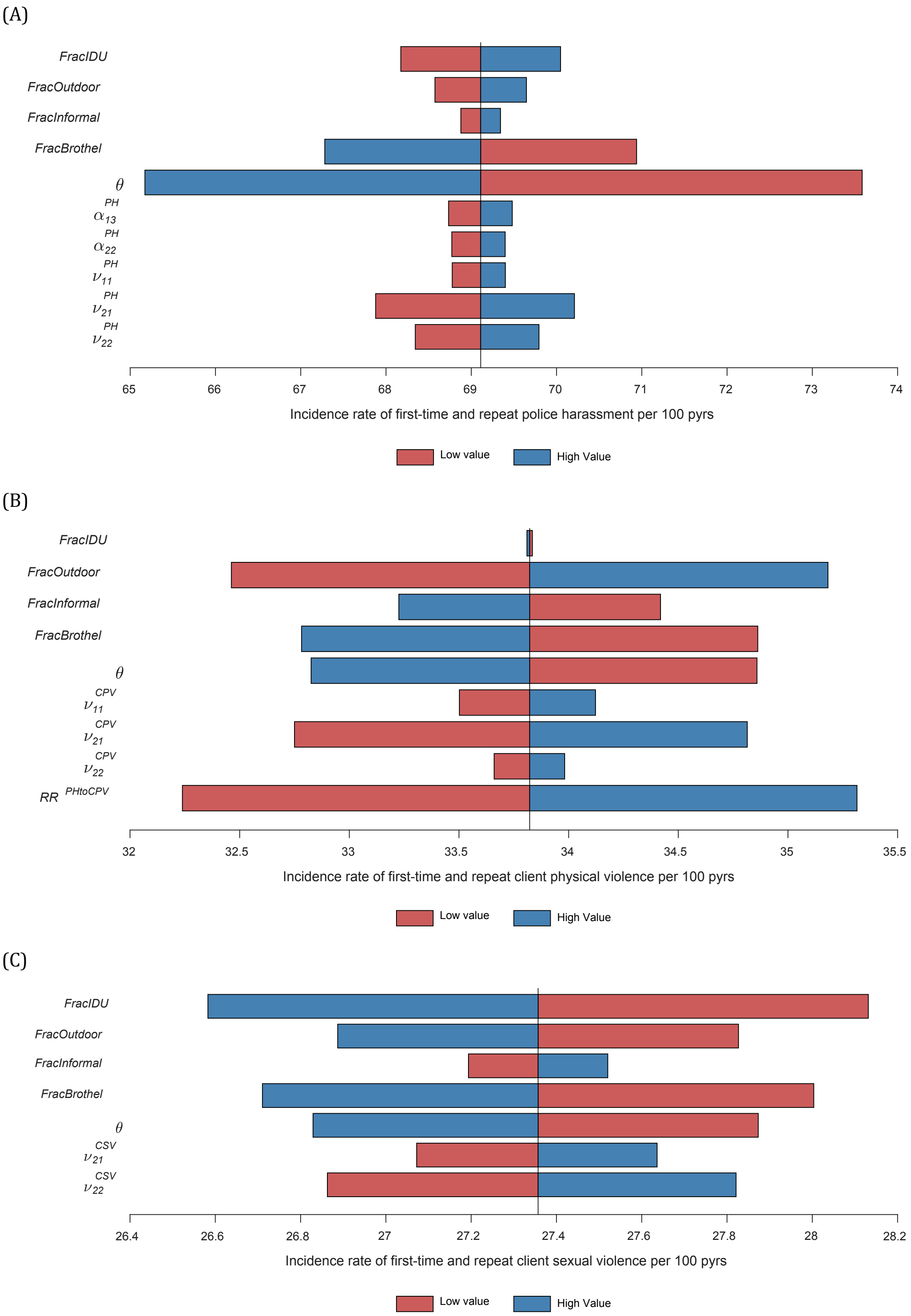


Figure B3. Tornado plot of univariate sensitivity analyses showing the impact of fixed parameters and important parameters from PRCC analysis on A) incidence of first-time and repeat police harassment, B) incidence of first-time and repeat client physical violence and C) incidence of first-time and repeat client sexual violence. The black vertical lines show the outcome estimate at baseline.

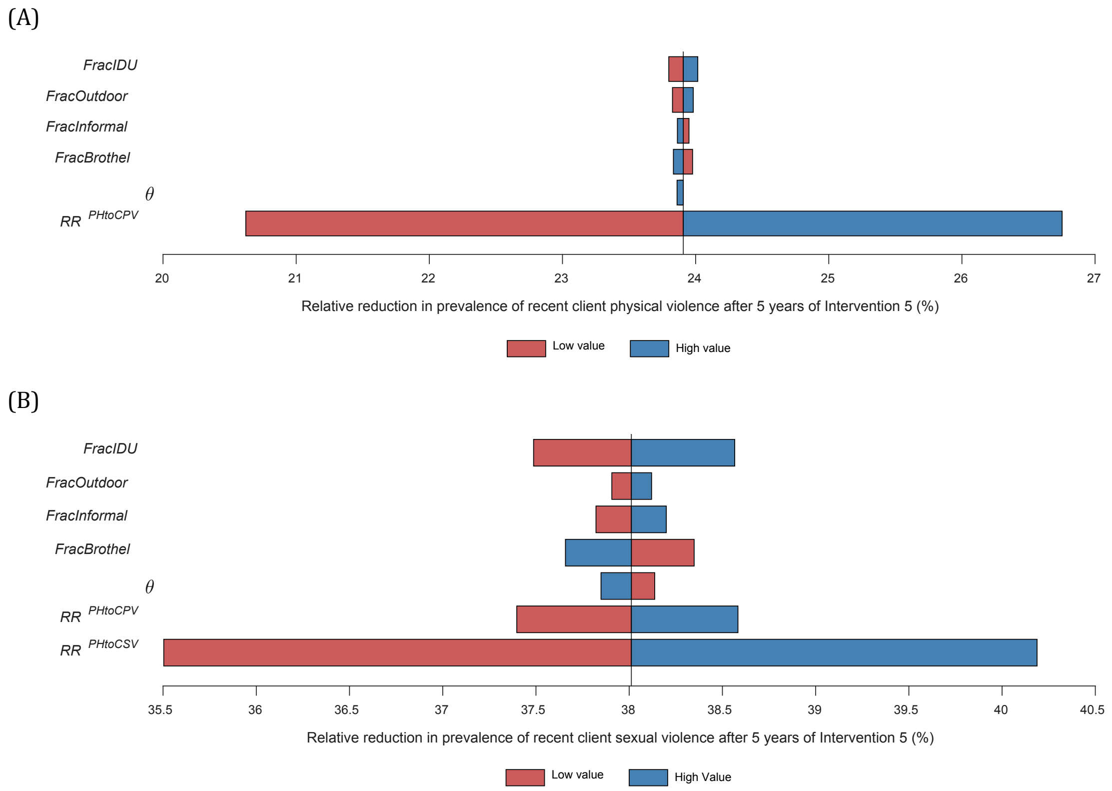


Figure B4. Tornado plot of univariate sensitivity analyses showing the impact of fixed parameters and important parameters from PRCC analysis on relative reduction in prevalence of A) client physical violence and (B) client sexual violence due to elimination of police harassment (Intervention 1). The black vertical lines show the outcome estimate at baseline.

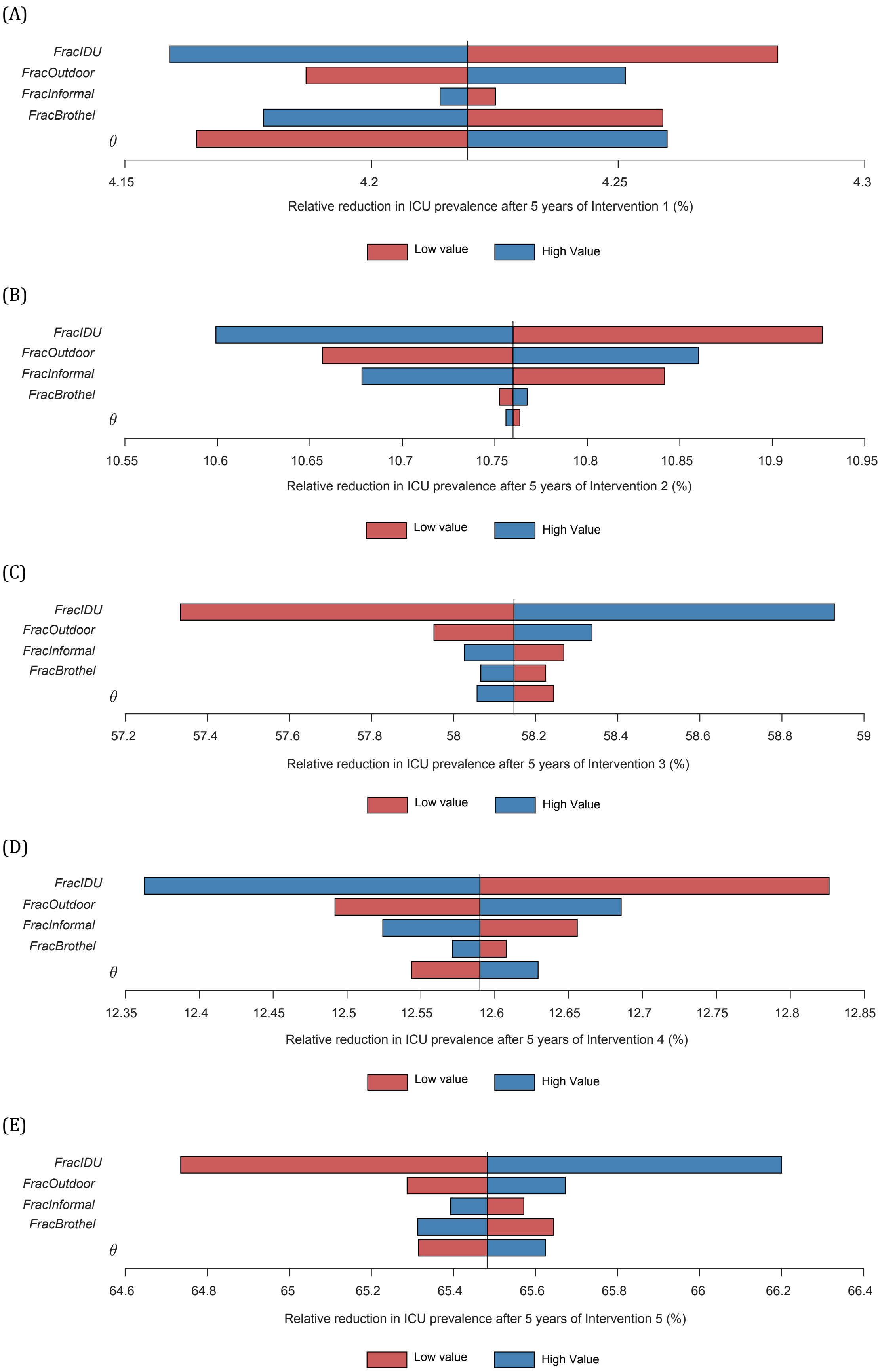


Figure B5. Tornado plot of univariate sensitivity analyses showing the impact of fixed parameters and important parameters from PRCC analysis on relative reduction in prevalence of inconsistent condom use due to Interventions 1- 5 (A-E). The black vertical lines show the outcome estimate at baseline.

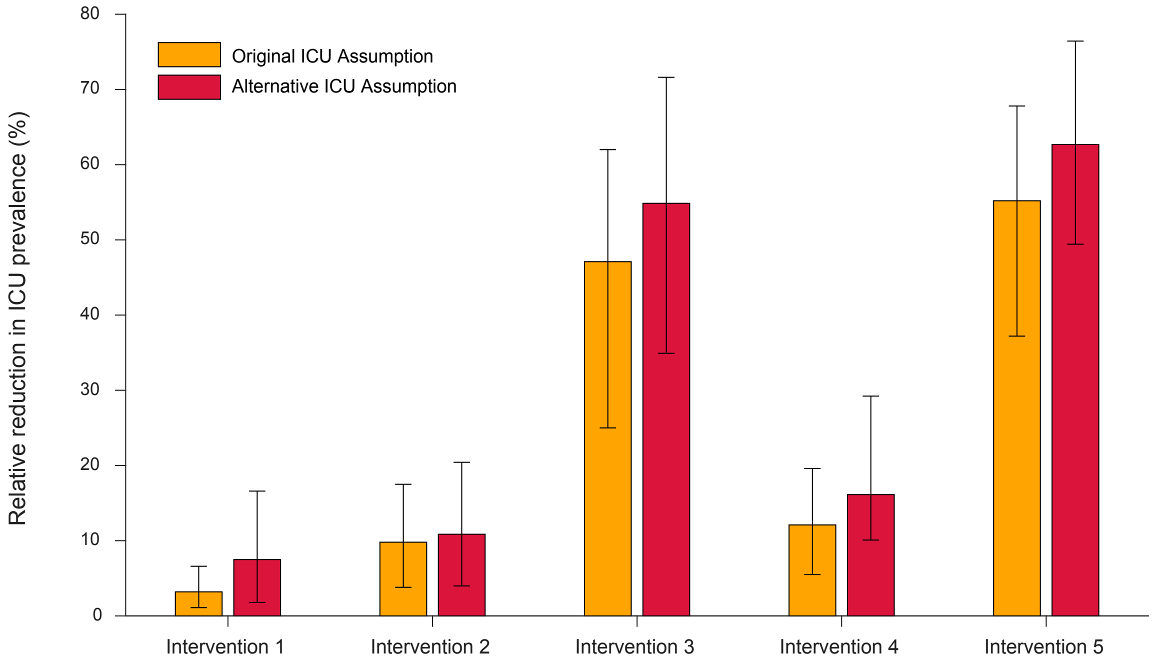


Figure B6. Relative reduction in prevalence of inconsistent condom use among all FSWs after 5 years of each intervention: original ICU assumption versus alternative ICU assumption. Coloured bars represent the median value of the model fits and error bars represent the 95% credible interval of the model fits. Intervention key: Intervention 1 - Eliminate police harassment; Intervention 2 – Eliminate client physical violence; Intervention 3 - Eliminate client violence and eliminate ICU associated with previous exposure to client violence; Intervention 4 - Eliminate workplace violence; Intervention 5 - Eliminate workplace violence and eliminate ICU associated with previous exposure to workplace.

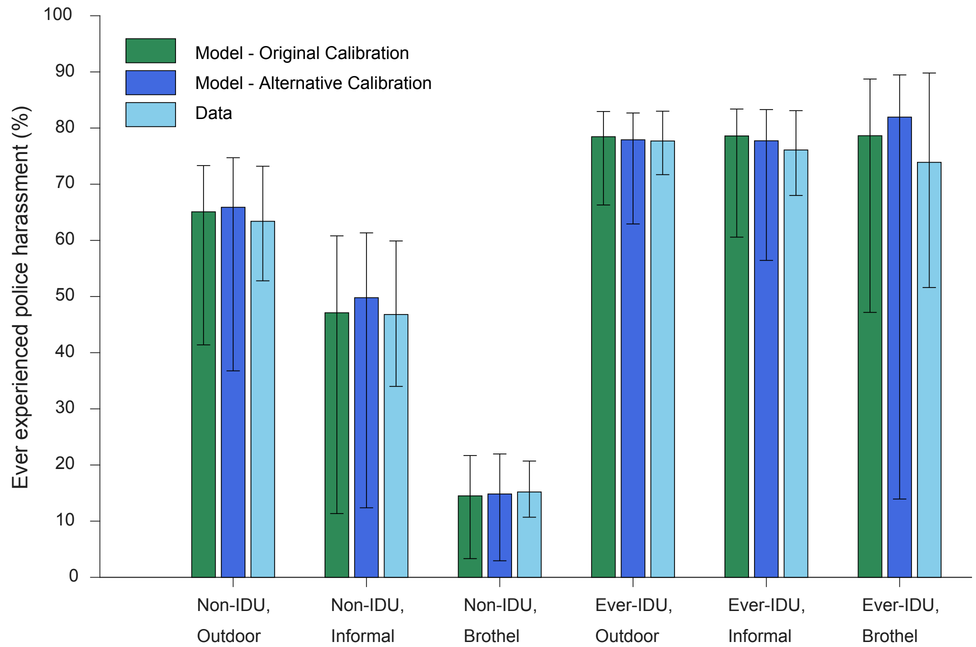


Figure B7. Prevalence of ever experiencing police harassment by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

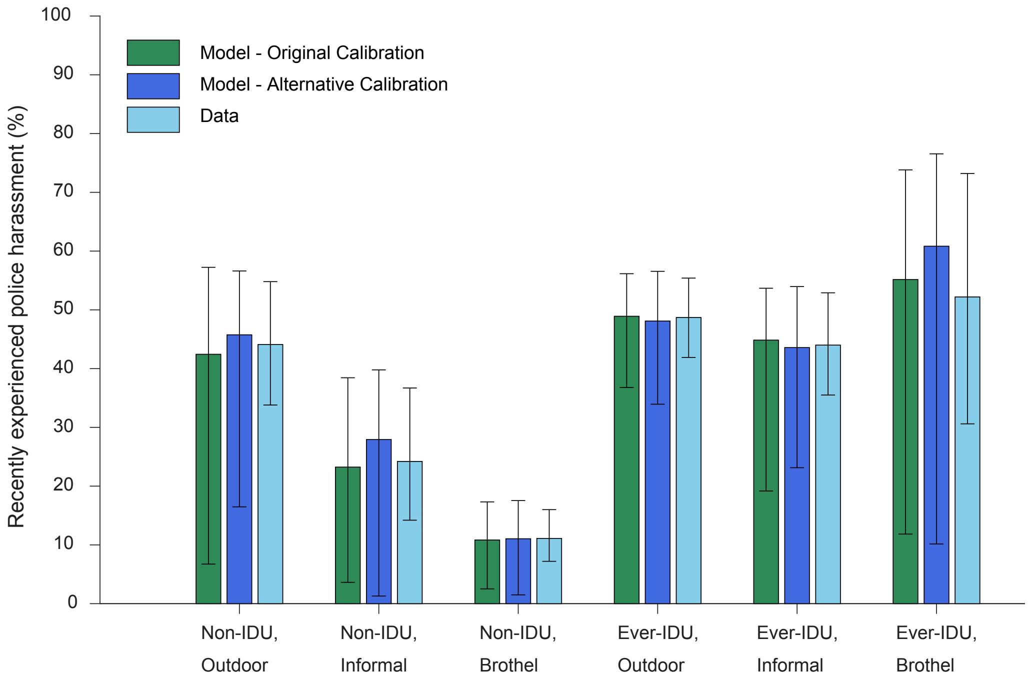


Figure B8. Prevalence of recently experiencing police harassment by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

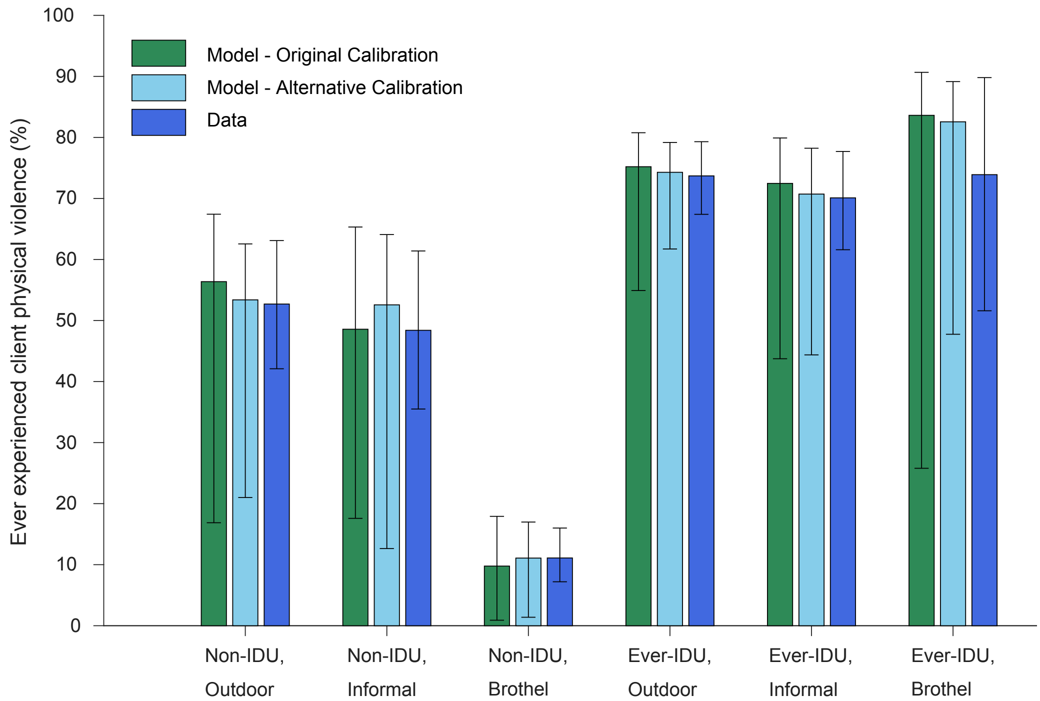


Figure B9. Prevalence of ever experiencing client physical violence by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

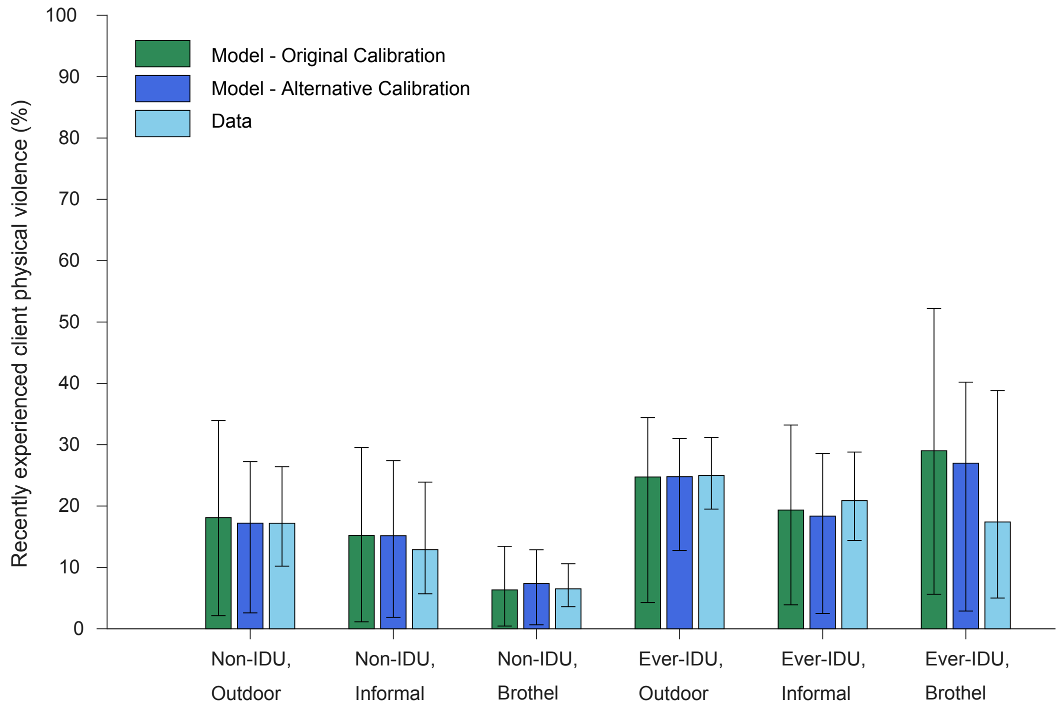


Figure B10. Prevalence of recently experiencing client physical violence by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

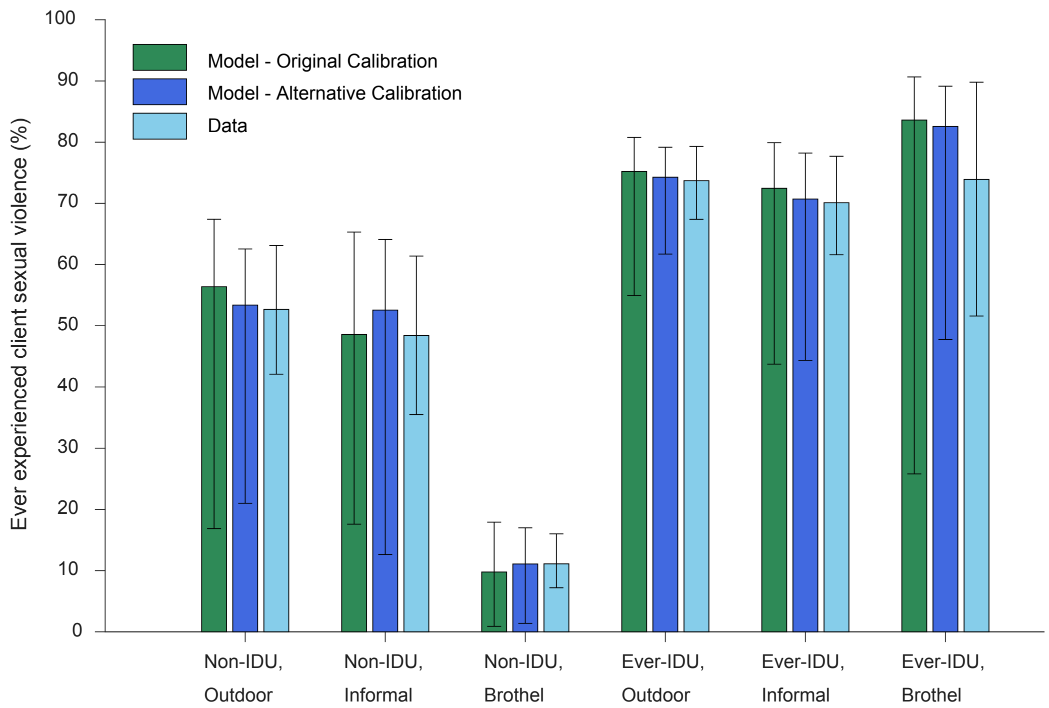


Figure B11. Prevalence of ever experiencing client sexual violence by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

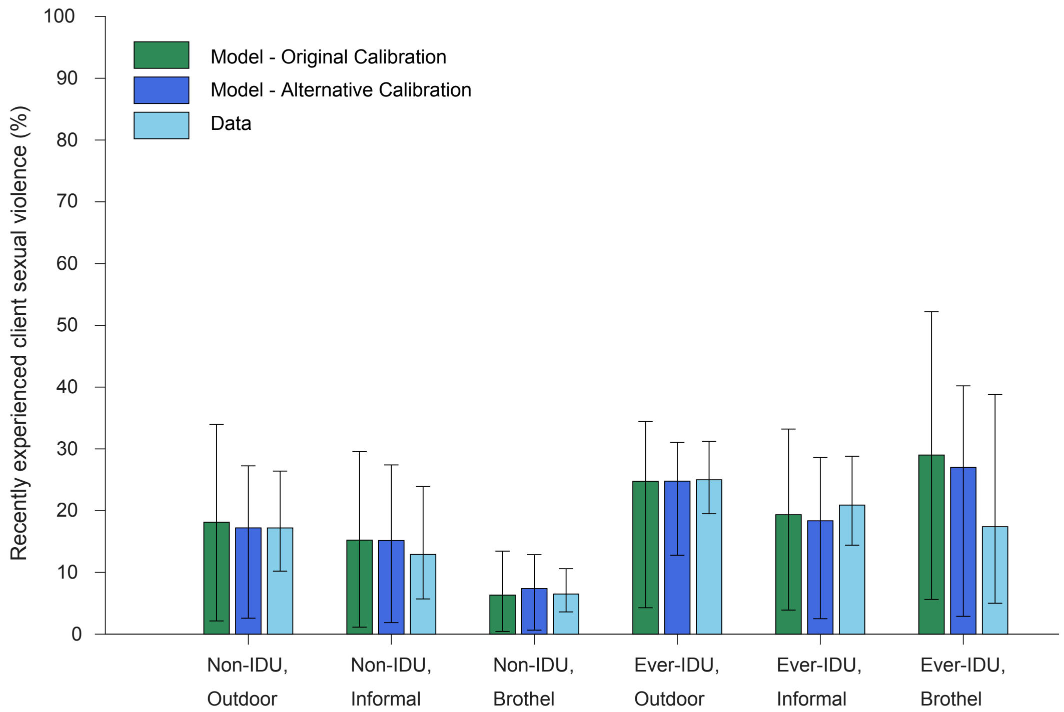


Figure B12. Prevalence of recently experiencing client sexual violence by FSW sub-group: Alternative model calibration vs original model calibration and data. IDU, injecting drug use. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

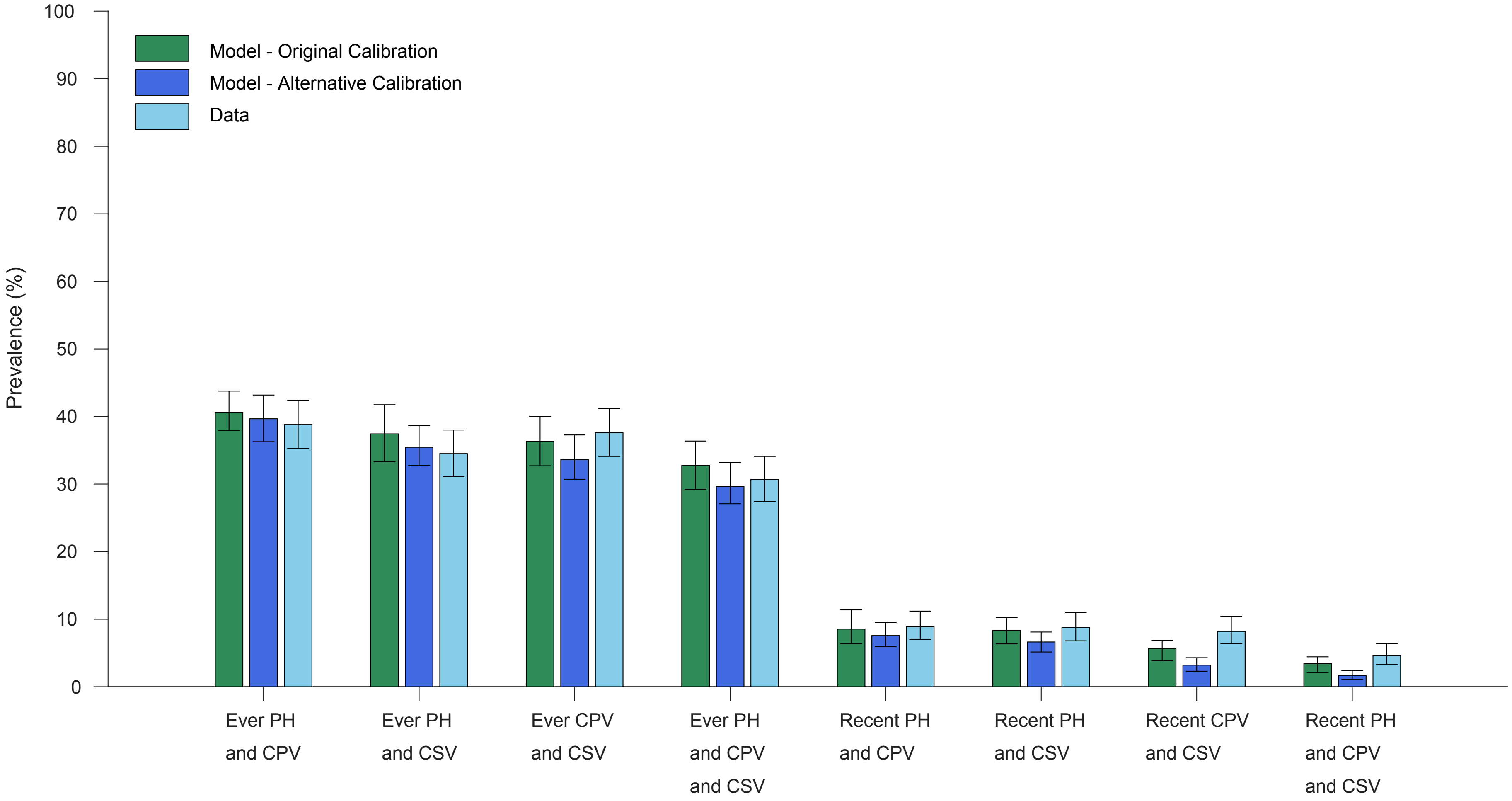
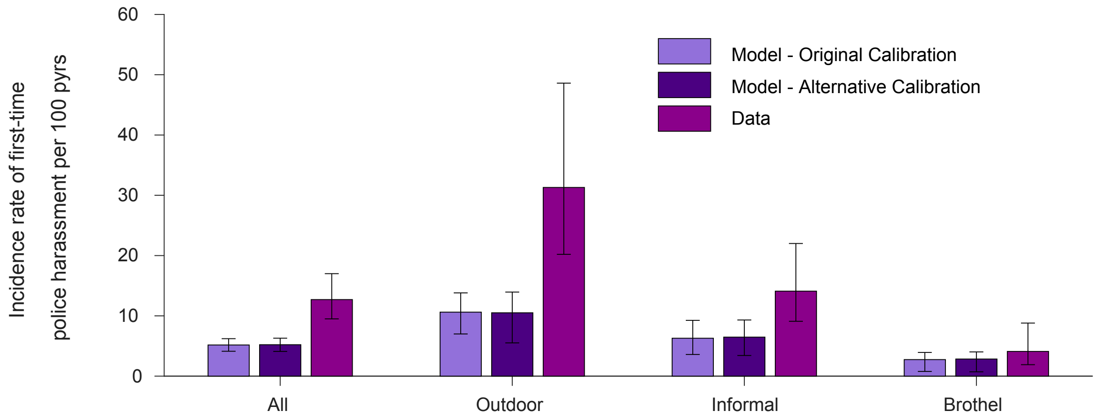
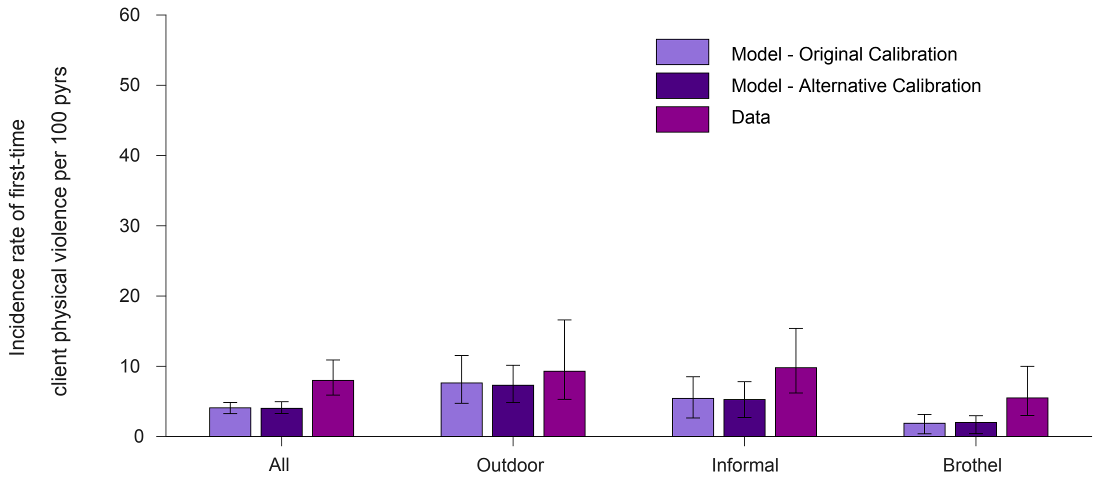


Figure B13. Prevalence of experiencing multiple types of workplace violence among all FSWs: Alternative model calibration vs original model calibration and data. PH, police harassment; CPV, client physical violence; CSV, client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

(A)



(B)



(C)

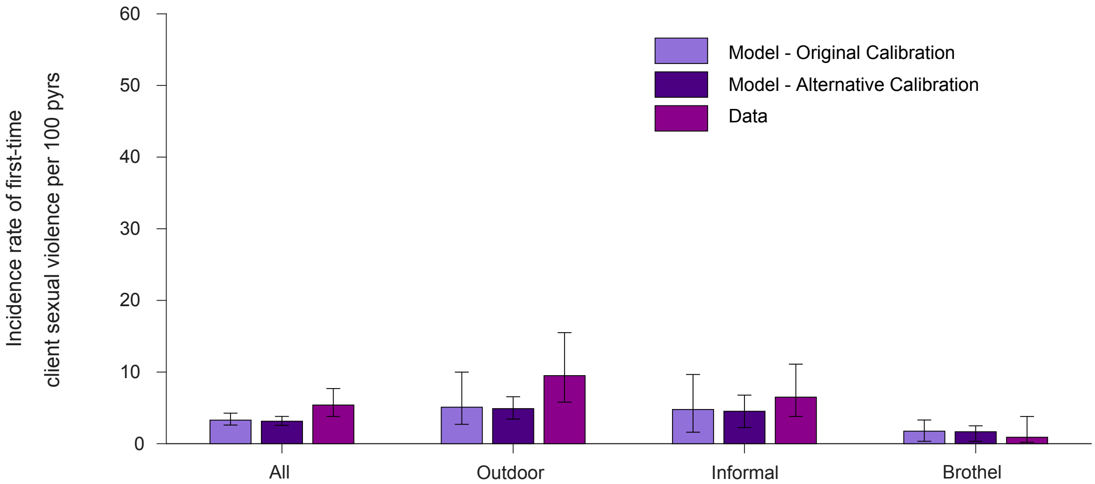
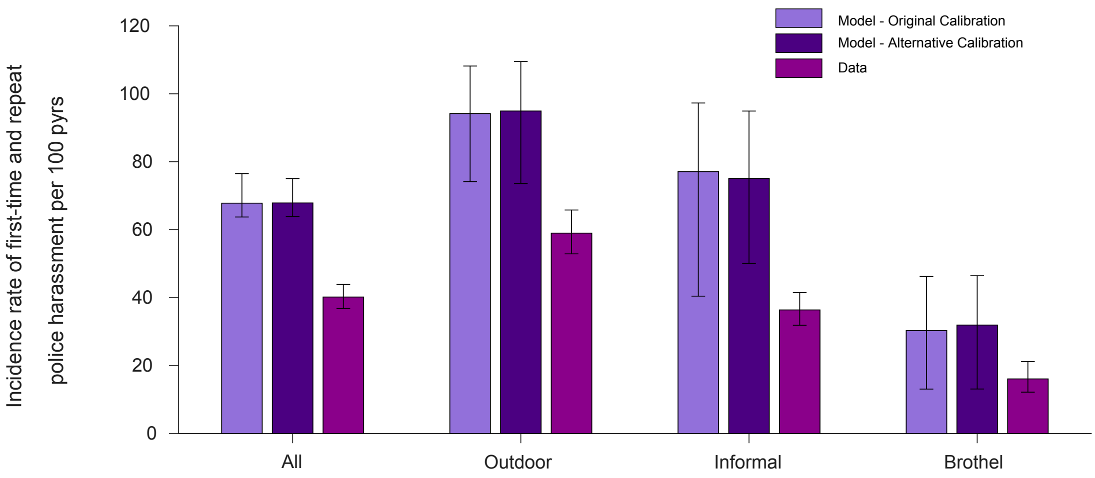
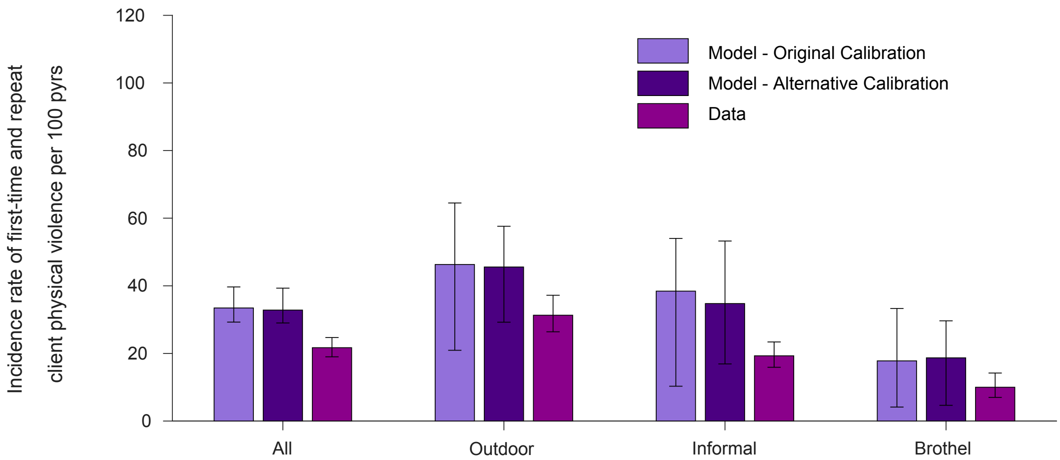


Figure B14. Incidence rates of first-time workplace violence among all FSWs and by FSWs work environment: Alternative model calibration vs original model calibration and data. (A) Police harassment (B) Client physical violence. (C) Client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

(A)



(B)



(C)

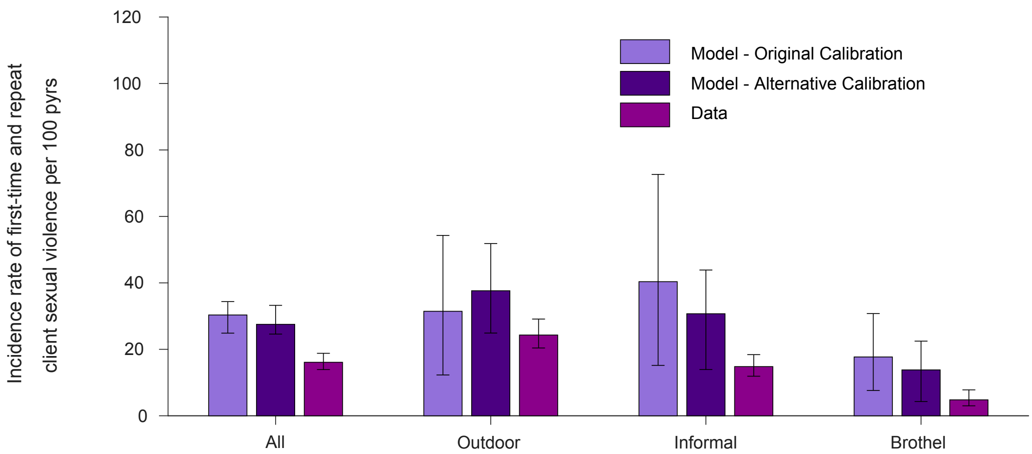


Figure B15. Incidence rates of first-time and repeat workplace violence among all FSWs and by FSWs work environment: Alternative model calibration vs original model calibration and data. (A) Police harassment (B) Client physical violence. (C) Client sexual violence. Coloured bars represent the median value of the model fits or the point estimate from AESHA data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from AESHA data.

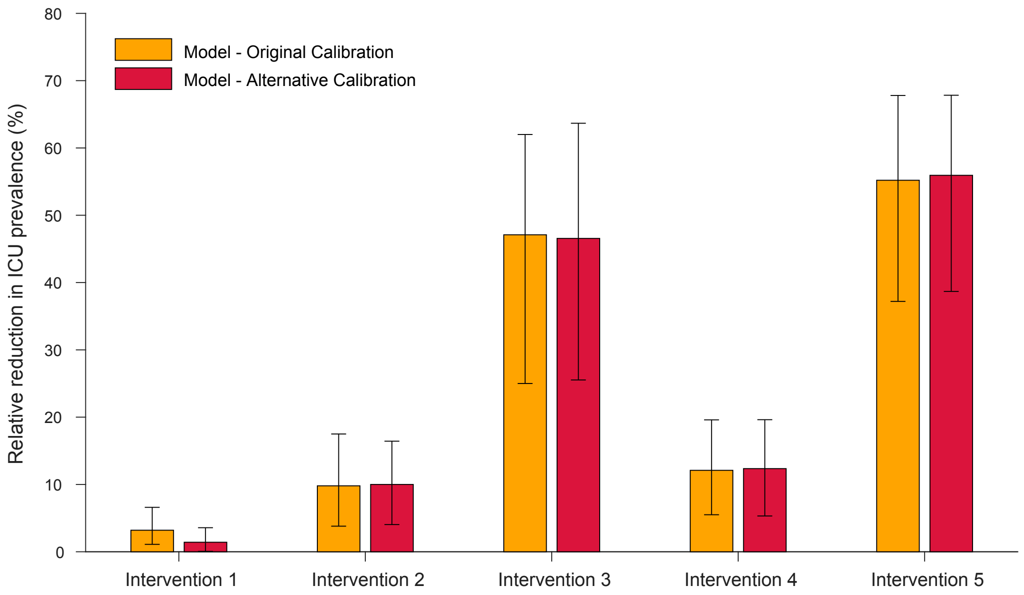


Figure B16. Relative reduction in prevalence of inconsistent condom use among all FSWs after 5 years of each intervention: Original model calibration vs alternative model calibration. Coloured bars represent the median value of the model fits and error bars represent the 95% credible interval of the model fits. Intervention key: Intervention 1 - Eliminate police harassment; Intervention 2 – Eliminate client physical violence; Intervention 3 - Eliminate client violence and eliminate ICU associated with previous exposure to client violence; Intervention 4 - Eliminate workplace violence; Intervention 5 - Eliminate workplace violence and eliminate ICU associated with previous exposure to workplace.

Appendix C: Supplementary information for Chapter 3

Table C1. Factors associated with violence against FSWs[1]

Study	Study dates, design, sample	Factor/s	Violence outcome measure/s	AOR (95% CI)	Abbreviations, definitions and other details
Alemayehu *et al* 2015 [1] (Ethiopia) **	2013; Cross-sectional; 250 FSWs	Basic literacy vs completion of university-level education Completion of elementary school vs completion of university-level education Completion of secondary school vs completion of university-level education Married vs unmarried Household monthly income of 51.2-101.9 vs <51.1 USD Household monthly income of 102-153.1 vs <51.1 USD Drug use Duration in sex work of 1-4 years vs 10 or more years	SV, ever SV, ever SV, ever SV, ever SV, ever SV, ever SV, ever SV, ever	5.38 (1.15-25.2) 6.96 (1.55-31.25) 7.93 (1.65-38.16) 3.85 (1.34-11.09) 2.44 (1.12-5.37) 7.94 (2.46-25.58) 5.37 (1.78-16.21) 11.57 (1.56-85.6)	SV (sexual violence) defined as experiencing one or more of the following: verbal sexual assault, unwanted genitalia touch, forceful sexual intercourse, physical harm, and pressure to have sex without a condom
Argento *et al* 2014 [2] (Canada) **	2010-2012 Longitudinal 387 FSWs	Age (per year increase) Physically and/or sexually abused before age 18 Less than daily prescription opioid use (past 6 months) Inconsistent condom use for vaginal and/or anal sex with intimate partner (past 6 months) Financial support provided to intimate partner (past 6 months) Sources drugs from intimate partner (past 6 months)	IPV, past 6 months IPV, past 6 months IPV, past 6 months IPV, past 6 months IPV, past 6 months IPV, past 6 months	0.96 (0.93-0.98) 2.05 (1.14-3.69) 1.72 (1.02-2.89) 1.84 (1.07-3.16) 1.65 (1.05-2.59) 1.62 (1.02-2.56)	IPV (intimate partner violence) defined as moderate or severe sexual and/or physical violence by any male intimate (non-commercial) partner
Beattie *et al* 2010 [3] (India)	2005-2009 Cross-sectional 3852 FSWs (1882 at baseline and 1970 at follow-up)	Participant in follow-up vs baseline	Beaten or raped, past year	0.70 (0.53-0.93)	Structural intervention implemented and expanded over time since 2004 in study setting; raped defined as being physically forced to have sexual intercourse with someone when you did not want to
Beletsky *et al* 2012 [4] (Mexico) **	2008-2009 Cross-sectional 624 FSW-IDUs	Sexual abuse by a police officer (past 6 months) Groin injection (past month) Normally inject in public (past month) Obtained syringes from pharmacy (past month) HIV positive Years of education completed (per year increase) Often/always injected drugs with a client around (past month)	SC by police, past 6 months SC by police, past 6 months SC by police, past 6 months SC by police, past 6 months SC by police, past 6 months SC by police, past 6 months SC by police, past 6 months	12.76 (6.58-24.72) 1.84 (1.15-2.93) 1.64 (1.14-2.36) 1.54 (1.06-2.23) 2.54 (1.11-5.80) 0.92 (0.87-0.98) 0.64 (0.44-0.94)	SC (syringe confiscation)
Berger *et al* 2016 [5] (Swaziland) **	2011 Cross-sectional 325 FSWs	Ever been blackmailed as a result of selling sex Ever felt afraid to seek health services because of selling sex Non-injection illicit drug use (past year)	PSV, ever PSV, ever PSV, ever	1.93 (1.07-3.52) 1.74 (1.01-2.99) 1.84 (1.02-3.33)	PSV (physical and sexual violence) defined as ever being beaten up as a result of selling sex or ever being forced to have sex since the age of 18 or both
Bhattacharjee *et al* 2013 [6] (India)	2005-2010 Cross-sectional 1750 FSWs	Membership in peer group or collective	PV, past 6 months Did not give bribe to police to avoid trouble	0.70 (0.53-0.92) 1.46 (1.04-2.06)	Structural intervention implemented and expanded over time since 2004 in study setting; PV (physical violence) defined as being hurt, slapped, pushed, kicked, punched, choked, or burned

Bhattacharjee *et al* 2016 [7] (India) **	2008-2009 (round 2); 2010-2011 (round 3); Cross-sectional; 4110 FSWs	Round 3 survey vs round 2 survey Illiterate vs literate Income solely from sex work Practise sex work outside of home district Solicit on the street/public place vs home Solicit in brothels vs home No. of clients (per average week) ≥ 10 vs <10 Age at start of sex work 25-29 years vs ≤ 19 years	Arrest, ever Arrest, past year Arrest during a routine raid Arrest, ever Arrest, past year Arrest, ever Arrest, past year Arrest, ever Arrest, past year Arrest, ever Arrest, past year Arrest, ever Arrest, ever Arrest, past year Arrest, ever	0.63 (0.48-0.83) 0.59 (0.41-0.86) 0.21 (0.11-0.42) 1.44 (1.09-1.90) 1.49 (1.03-2.16) 2.00 (1.56-2.56) 1.74 (1.24-2.44) 1.61 (1.19-2.19) 1.78 (1.20-2.62) 2.27 (1.61-3.20) 2.22 (1.40-3.53) 3.01 (1.90-4.77) 2.27 (1.72-3.00) 2.27 (1.55-3.32) 0.59 (0.38-0.91)	Structural intervention implemented and expanded over time since 2004 in study setting
Blanchard *et al* 2005 [8] (India)	2002 Cross-sectional 1588 FSWs	Participant was Devadasi (traditional sex work) vs non-Devadasi Rural residence vs urban residence Illiterate vs can read and write Work at home vs brothel, lodge or public place	CSV, past year Police harassment, ever Police harassment, ever CSV, past year CSV, past year Police harassment, ever	0.41 (0.28-0.61) 0.40 (0.27-0.60) 2.27 (1.56-3.33) 1.44 (1.03-2.00) 0.44 (0.30-0.63) 0.36 (0.25-0.52)	CSV (client sexual violence) defined as a client using violence to force sex
Blanchard *et al* 2013 [9] (India)	2010 Cross-sectional 1750 FSWs	Power with others i.e. collective identity and solidarity (per one unit increase in empowerment level)	Violence or abuse by more powerful groups	1.34 (p<0.05)	
Carlson *et al* 2012 [10] (Mongolia)	2007-2009 RCT (baseline, and 3 and 6 months post intervention) 222 FSWs	Participated in wellness intervention Participated in risk-reduction intervention Participated in risk-reduction and motivational interview intervention	PV, past 90 days, any partner SV, past 90 days, any partner PV or SV, past 90 days, any partner PV, past 90 days, any partner SV, past 90 days, any partner PV or SV, past 90 days, any partner PV, past 90 days, any partner SV, past 90 days, any partner PV or SV, past 90 days, any partner	0.15 (0.07-0.35) 0.05 (0.02-0.14) 0.20 (0.10-0.43) 0.11 (0.04-0.34) 0.06 (0.02-0.19) 0.14 (0.03-0.61) 0.29 (0.13-0.65) 0.15 (0.08-0.33) 0.46 (0.24-0.88)	PV (physical violence); SV (sexual violence); violence measured using Revised Conflict Tactics Scale
Chersich *et al* 2007 [11] (Kenya)	2005-2006 Cross-sectional 719 FSWs	Binge vs non-binge drinker Never married vs separated or divorced Widowed vs separated or divorced No. of sexual partners (increase per 1 partner)	CSV, past year CSV, past year CSV, past year CSV, past year	1.85 (1.27-2.71) 1.65 (1.10-2.48) 2.26 (1.17-4.35) 1.14 (1.09-1.19)	CSV (client sexual violence) defined as any client physically forcing them to have sex without payment
Chersich *et al* 2014 [12] (Kenya) **	2006 Longitudinal 400 HIV-ve FSWs	Harmful or dependent drinking vs no drinking Hazardous drinking vs no drinking	SV, past year PV, past year PV, past year	4.14 (1.93-8.89) 8.40 (3.92-17.96) 3.07 (1.69-5.58)	SV (sexual violence) defined as being physically forced to have sex when they did not want to; PV (physical violence) defined as being pushed, slapped, hit or kicked by a partner
Choi *et al* 2011 [13] (China)	2007-2008 Cross-sectional 491 FSWs	Sexual health knowledge (per one unit increase) Thai vs mainland Chinese Vietnamese vs mainland Chinese Junior secondary vs primary or lower education Economic pressure (per one unit increase)	Client violence Client violence Client violence Client violence Client violence	b=0.19 (p<0.05) b=-0.80 (p<0.05) b=-1.05 (p<0.05) b=-0.72 (p<0.05) b=0.22 (p<0.001)	Client violence is a score based on seven questionnaire items relating to client verbal violence (including verbal insults and threats); client physical

					violence (including incidents where the client threw something at the respondent; pushed, grabbed, shoved, slapped, spanked, kicked, bit, or hit the respondent with a fist; hit or tried to hit the respondent with a hard object; beat up, threatened the respondent with a gun or knife; actually used a gun or knife on the sex worker); and clients sexual violence (including the use of threats or force to make her have oral or anal sex or to have vaginal sex when she wanted to terminate the transaction)
Conners *et al* 2015 [14] (Mexico) **	2013-2014 Cross-sectional 603 FSWs	Seeing violence toward sex workers from clients More than half of clients use drugs More than half of clients are foreign Street worker occupation	Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months	5.61 (1.83-17.21) 3.96 (1.51-10.38) 3.47 (1.43-8.44) 2.98 (1.16-7.65)	Client violence defined as any sexual violence (forced or coerced into having sex or engaging in a sexual activity against your will) or physical violence (physically abused) by a client
Decker *et al* 2010 [15] (Thailand)	2007 Cross-sectional 815 FSWs	Participant was trafficked	Sexual violence at sex work initiation Workplace violence or mistreatment, past 7 days	2.29 (1.11-4.72) 1.38 (1.13-1.67)	Workplace violence defined as being yelled at, hit, forced to perform sex acts you did not want to perform, not paid, paid less than agreed, or made to do other things you didn't want to within the work setting
Decker *et al* 2016 [16] (Cameroon) **	Cross-sectional 1817 FSWs	Lifetime physical and/or sexual violence	Arrest, ever Jailed or imprisoned, ever Refused police protection due to being a sex worker, ever	2.02 (1.64-2.49) 1.87 (1.11-3.15) 1.41 (1.12-1.78)	Physical violence defined been beaten up or physically hurt by someone because you are a sex work; Sexual violence defined as been forced to have sex when you did not want to
Deering *et al* 2012 [17] (Canada) **	2010 Cross-sectional 207 FSWs	Olympics period vs post-Olympics period	Police harassment (stopping or following SWs) without arrest, last month	3.95 (1.92-8.14)	All SWs are brothel-based

Deering *et al* 2013 [18] (India)	2007-2008 Cross-sectional 1219 FSWs	Arrested in the last year	Client violence, past year	1.84 (1.02-3.31)	Client violence defined as any physical violence (hurt, hit, slapped, pushed, kicked, punched, choked, burned) or sexual violence (beaten or otherwise physically forced to have sexual intercourse with someone even though you didn't want to)
El-Bassel *et al* 2001 [19] (USA)	1996-1997 Cross-sectional 105 FSWs	Intravenous heroin use Traded sex for money or drugs at a crack house	Client violence, past year Client violence, past year	9.81 (2.67-36.00 8.70 (2.11-35.78)	All street-based SWs; client violence defined as any physical violence (physical abuse) or sexual violence (forced to have sex when you did not want to, or sexually abused or raped)
Erausquin *et al* 2011 [20] (India)	2009-2010 Cross-sectional 835 FSWs	Police had sex with respondent so she could avoid trouble (past 6 months) Police accepted bribe or gift from respondent so she could avoid trouble (past 6 months) Police took condoms away (past 6 months) Police raided workplace (past 6 months) Police arrested respondent (past 6 months)	Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months	3.06 (1.89-4.93) 3.16 (2.00-4.98) 5.62 (3.22-9.82) 4.64 (3.16-6.81) 7.14 (4.45-11.44)	Client violence defined as any physical violence (beating) or sexual violence (forced sexual intercourse)
Fawole *et al* 2014 [21] (Nigeria) **	2009 Cross-sectional 305 FSWs	Age ≥ 30 years vs ≤ 25 years Permanent vs temporary brothel resident Duration in sex work >5 years vs <1 year Good knowledge on violence types	SV SV SV PV PV	2.23 (1.15-4.36) 2.08 (1.22-3.55) 2.01 (0.98-4.10) 4.40 (1.84-10.51) 0.45 (0.26-0.77)	All FSWs are brothel-based; SV (sexual violence); PV (physical violence
Fonner *et al* 2014 [22] (Swaziland) **	2011 Cross-sectional 325 FSWs	High vs low social cohesion High vs low social participation	Refused police protection, ever Verbal/physical harassment, ever	0.53 (0.31-0.90) 0.55 (0.33-0.91)	
George *et al* 2011 [23] (India)	2010 Cross-sectional 1138 FSWs	Contract work , past 6 months	PV, past 6 months SV, past 6 months	3.16 (2.01-4.95) 2.14 (1.16-3.95)	PV (physical violence) assessed with 5 items; SV (sexual violence) assessed using 10 items
George *et al* 2013 [24] (India)	2010 Cross-sectional 1137 FSWs	Trafficked into sex work	SV, past 6 months PV or SV, past 6 months	2.09 (1.42-3.06) 1.93 (1.34-3.01)	PV (physical violence) assessed with 6 items; SV (sexual violence) assessed using 8 items
Go *et al* 2011 [25] (India)	2002 Cross-sectional 522 FSWs	Had unprotected sex with a non-spousal partner in past 3 months and ≥20 days of alcohol consumption in past 30 days vs no unprotected sex with a non-spousal partner in past 3 months and 0-9 days of alcohol consumption in past 30 days Spoke with 1-5 people about family violence in last 3 months vs spoke to no one	Sexual violence, any partner, past 3 months	2.66 (1..13-6.29) 0.61 (0.44-0.86)	All FSWs from near wine shops; SV (sexual violence) defined as being forced (threatened, pressured or physically forced) to have sex by a partner when you did not want to because you were afraid to refuse

Goldenburg *et al* 2014 [26] (Canada) **	2010-2011 Cross-sectional 508 FSWs	Early sex work entry (<18 years) Early sex work entry (<16 years)	Arrested on sex work charges, ever Arrested on sex work charges, ever	2.07 (1.32-3.25) 2.75 (1.73-4.36)	
Gupta *et al* 2011 [27] (India)	2006 Cross-sectional 812 FSWs	Entered sex work via trafficking	Any violence, past 6 months PV or SV violence, past 6 months	1.93 (1.32-2.81) 1.99 (1.36-2.90)	PV (physical violence) defined as being beaten (e.g. hit, slapped, pushed, kicked, punched, choked or burned) ; SV (sexual violence) defined as being forced to have vaginal, anal or oral sex against your will; any violence defined as any physical, sexual or severe violence; severe violence defined as being threatened with a knife or gun or had a weapon used against you
Hail-Jares *et al* 2015 [28] (China) **	2011-2012 Cross-sectional 218 FSWs	Financial support from ≤1 source vs 3+ sources Lack of financial support from sisters/peer SWs Lack of psychosocial support from sisters/peer SWs Lack of psychosocial support from family	IPV IPV IPV Client violence, past 6 months	2.5 (1.1-5.9) 3.2 (1.6-6.6) 5.1 (2.2-11.8) 2.2 (1.0-4.6)	All FSWs are street-based; IPV (intimate partner violence) defined as any experience of a partner throwing something or hitting her, or withholding money, or forcing her to have sex with someone against her will, or threatening to no longer help in terms of finances or housing, or threatening to hurt her family or friends, or intentionally destroying personal property or threatening to tell others that she is a sex worker; client violence defined as any experience of a client throwing something or hitting her, or withholding money, or forcing her to have sex with someone against her will, or verbally insulting or yelling at her
Hong *et al* 2013 [29] (China)	Cross-sectional 937 FSWs	Non-Han ethnicity Had ≥ middle school education Living with stable partners Level 2 venue (night club, KTV, bar or dancing hall) vs Level 1 venue (sauna)	Client violence Stable partner violence Stable partner violence Stable partner violence Client violence	1.91 (1.10-2.98) 1.54 (1.04-2.26) 0.55 (0.39-0.77) 1.55 (1.11-2.16) 0.64 (0.43-0.96)	Violence from clients or stable partners includes any physical violence (e.g., slapped you or threw something at you that could hurt you; pushed you or shoved you or pulled your hair; kicked you; dragged

					you or beat you up), sexual violence (e.g., forced you into intercourse; inserted something into your genitals), and psychological abuse (e.g., belittled or humiliated you in front of others; threatened to hurt you or someone you care about). Violence from stable partners also includes any of the following: ignoring you for a long time, threat of separating you from your children or terminating your pregnancy, and restriction of your freedom.
Katsulis *et al* 2015 [30] (Mexico) **	1999-2001 Cross-sectional 140 FSWs	Insecure housing Outdoor sex work	Any violence, ever Sexual violence, ever	3.74 (1.38-10.07)	Any violence defined as experiencing either verbal violence (e.g. threats), economic violence (e.g. robbery), physical violence (e.g. slaps, kicks, punches, use of a weapon), or sexual violence (e.g. rape or attempted rape)
Micheni *et al* 2015 [31] (Kenya) **	2005-2014 Longitudinal 367 FSWs	Alcohol use (past month)	Rape Physical assault	4.4 (1.41-14.0) 12.3 (1.8-85.6)	
Muldoon *et al* 2015 [32] (Uganda) **	2011-2012 Cross-sectional 400 SWs	Service clients in a bar/club (past 6 months) Inconsistent condom use with any client (past 6 months) Manager or pimp (past 6 months) Rushed client negotiations because of police presence	Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months	2.07 (1.19-3.59) 2.87 (1.54-5.35) 2.05 (1.24-3.39) 1.61 (1.03-2.52)	Client violence defined as experiencing any of the following from a client: physical assault, attempted sexual assault, rape, gang rape, locked in a car, abducted/kidnapped, thrown out of a moving car, strangled, assaulted with a weapon, or genital mutilation
Muldoon *et al* 2015 [33] (Canada) **	2010-2012 Cross-sectional 257 SWs	Low vs high sexual relationship power	IPV, past 6 months Moderate physical violence, past 6 months Severe physical violence, past 6 months Sexual violence, past 6 months	8.36 (3.01-23.20) 7.56 (2.06-27.74) 10.47 (2.26-48.57) 10.87 (1.32-89.23)	All SWs have a non-commercial partner; IPV (intimate partner violence) defined as any physical, sexual, and emotional violence; moderate physical violence defined as slapped or pushed/shoved; severe

					physical violence defined as hit, kicked or beaten up, chocked or burnt, or threatened or used a gun or other weapon; sexual violence defined as forced to have sex against their will, having sex when frightened of consequences, or forced to perform something sexually degrading
Odinokova *et al* 2014 [34] (Russia)	2007-2008 Cross-sectional 896 FSWs	College/university education vs secondary/vocational school (both study sites combined = St Petersburg and Orenburg) Binge alcohol use (past year) (Orenburg only) Injection drug use the day prior to study enrolment (both study sites combined) Street sex work (both study sites combined) Street sex work (St Petersburg only) Street sex work (Orenburg only) Ever raped during sex work (both study sites combined) Ever raped during sex work (St Petersburg only)	Police sexual coercion	0.66 (0.45-0.98) 2.98 (1.20-7.4) 1.94 (1.15-3.3), 8.03 (4.58-14.07) 20.70 (8.07-53.08) 4.44 (2.18-9.06) 2.09 (1.46-2.99) 2.19(1.44-3.33)	
Pack *et al* 2014 [35] (Kenya) **	2011-2012; Cross-sectional; 619 FSWs	Visited Likoni drop-in centre vs Chaani drop-in centre Provide financial support to one or two others vs no one Physical or sexual child abuse Witnessed mother abuse Condom use at last sex with a non-paying partner Hazardous alcohol use vs harmful alcohol use (last month)	Partner violence, past month Partner violence, past month Partner violence, past month Partner violence, past month Partner violence, past month Partner violence, past month	0.18 (0.09-0.36) 2.14 (1.07-4.27) 2.47 (1.54-3.95) 1.64 (1.05-2.57) 0.50 (0.31-0.81) 2.60 (1.56-4.32)	All FSWs are moderate risk drinkers; partner violence is defined as either being beaten or physically abused by a client, threatened or verbally abused by a client, robbed or not paid as agreed by a client, forced to have sex with a client when you did not want to, forced to do other sexual things that you did not agree to, forced to have sex without a condom, beaten or physically abused by a non-paying partner, or forced to have sex with a non-paying partner when you did not want to.
Platt *et al* 2011 [36] (UK)	2008-2009 Cross-sectional 268 FSWs	Currently has a non-paying partner Alcohol AUDIT score ≥ 3 vs <3 Ever arrested or imprisoned	CPV, past 12 months CPV, past 12 months CPV, past 12 months	2.0 (1.03-3.96) 0.4 (0.21-0.82) 2.6 (1.14-5.71)	All indoor FSWs; CPV (client physical violence) defined as reporting one or more of the following incidences: being robbed, hit, beaten, threatened, attacked with a weapon, kidnapped
Reed *et al* 2010 [37] (India)	2007 Cross-sectional 673 FSWs	Currently in debt	PV, past 6 months	2.4 (1.5-3.9)	PV (physical violence) defined as being beaten (e.g. hit, slapped, pushed, kicked,

					punched, chocked or burned) or threatened with a knife, gun, or other weapon, or having had a weapon used against them
Reed *et al* 2011 [38] (India)	2007 Cross-sectional 673 FSWs	High residential instability (>5 evictions in past 5 years)	SV, past 6 months PV, past 6 months	3.5 (2.1-5.8) 3.1 (2.1-4.7)	PV (physical violence) defined as being beaten (e.g. hit, slapped, pushed, kicked, punched, chocked or burned) or threatened with a knife, gun, or other weapon, or having had a weapon used against them; SV (sexual violence) defined as being forced to have vaginal, anal or oral sex against their will by anyone
Reed *et al* 2012 [39] (India)	2007 Cross-sectional 673 FSWs	High mobility (having worked in ≥3 villages/towns in the past year)	SV, past 6 months PV, past 6 months	5.2 (3.0-8.9) 1.7 (1.1-2.7)	PV (physical violence) defined as being beaten (e.g. hit, slapped, pushed, kicked, punched, chocked or burned) or threatened with a knife, gun, or other weapon, or having had a weapon used against them; SV (sexual violence) defined as being forced to have vaginal, anal or oral sex against their will by anyone
Richter *et al* 2012 [40] (South Africa) **	2010 Cross-sectional 1653 FSWs	Outdoor sex work vs indoor sex work Duration in sex work 1-5 years vs <1 year Duration in sex work >5 years vs <1 year From Sandton (Johannesburg) vs Cape Town From Rustenburg vs Cape Town	Negative police interaction, past year Negative police interaction, past year Negative police interaction, past year Negative police interaction, past year Negative police interaction, past year	1.64 (1.15-2.36) 2.15 (1.36-3.39) 2.83 (1.78-4.53) 1.82 (1.15-2.88) 0.06 (0.03-0.13)	Negative police interaction defined as any police violence, arrest, harassment, theft, bribery, or fines
Saggurti *et al* 2012 [41] (India)	Cross-sectional 5498 FSWs	≥4 moves in past 2 years vs 2-3 moves Stayed for ≤1 month in previous 2 places vs more than 1 month Visited *Jatra* (special religious festival) places Visited a place frequented by seasonal male migrant workers	PV or SV, past 6 months PV or SV, past 6 months PV or SV, past 6 months PV or SV, past 6 months	1.4 (1.2-1.6) 1.4 (1.2-1.6) 2.1 (1.8-2.4) 1.3 (1.0-1.6)	PV (physical violence); SV (sexual violence)
Schwitters *et al* 2014 [42] (Uganda) **	2012 Cross-sectional 1467 FSWs	Years as a sex worker Sex with client at home vs in open space Sex with client at client's/other home vs in open space Sex with client at hotel vs in open space 5+ alcoholic drinks when drinking vs 0 drinks Client demands no condom use frequently vs never Client demands no condom use sometimes vs never	CSV, past 6 months CPV, past 6 months CPV, past 6 months CPV, past 6 months CPV, past 6 months CSV, past 6 months CPV, past 6 months CSV, past 6 months	1.02 (1.01-1.10) 0.12 (0.03-0.49) 0.17 (0.04-0.74) 0.12 (0.02-0.68) 2.60 (1.54-4.43) 5.27 (3.02-9.19) 6.01 (2.98-12.14) 3.79 (2.24-6.46)	CSV (client sexual violence) defined as a customer forcing you to do sex acts you did not want to do; CPV (client physical violence) defined as a customer hitting or hurting you
Semple *et al* 2015 [43] (Mexico) **	2011-2013 Cross-sectional 1089 FSWs	Financial situation bad or extremely bad Street sex worker vs other	CSV, past month CPV, past month CSV, past 6 month CPV, past 6 months	2.00 (1.31-3.05) 1.74 (1.14-2.67) 1.88 (1.14-3.12) 2.14 (1.27-3.60)	CSV (client sexual violence) defined as a client forcing you to have sex against your will, forcing you to suck or

		Used alcohol before or during sex with client (past month) Used drugs before or during sex with client (past month) Injected drugs (past month) Emotional support (per unit increase in score) Population of research site municipality ≥ 500,000 inhabitants vs < 500,000 inhabitants	CSV, past 6 month CPV, past 6 months CSV, past 6 month CSV, past 6 month CSV, past 6 month CPV, past 6 months CSV, past 6 month	2.30 (1.33-3.98) 2.05 (1.18-3.56) 2.19 (1.07-4.49) 2.92 (1.48-5.75) 0.68 (0.48-0.96) 0.63 (0.44-0.89) 1.87 (1.19-2.94)	lick someone else, raping you with a physical object, raping you using a weapon, forcing you to watch a sex act, forcing you to have sex with someone else, forcing you to masturbate someone else, masturbating you against your will, forcing you to kiss or touch someone else, or kissing or touching you against your will; CPV (client physical violence) defined as being stabbed by a client, tortured by a client, threatened with murder by a client, choked or strangled by a client, or kidnapped by a client
Shannon *et al* 2009 [44] (Canada)	2006-2008 Prospective observational 251 FSWs	Pressured into sex without a condom Unprotected sex Primary partner procured drugs for FSW Homeless Unable to access drug treatment Police confiscated drug use paraphernalia (without arrest) Prior assault by police Serviced clients in cars and public spaces Moved working areas away from the main streets owing to policing	PV CPV SV SV PV SV PV CPV PV SV CPV CPV CPV	2.23 (1.40-3.61) 1.85 (1.10-3.10) 1.82 (1.01-3.25) 1.63 (1.03-2.81) 2.14 (1.34-3.43) 1.73 (1.09-3.12) 1.96 (1.03-3.43) 2.13 (1.26-3.62) 1.50 (1.02-2.41) 2.61 (1.32-5.16) 3.45 (1.98-6.02) 1.50 (1.08-2.57) 2.13 (1.26-3.62)	All street-based FSWs; PV (physical violence) defined as being physically abused by someone (e.g. partner, pimp, dealer, police, security guard, stranger or other, but excluding clients) in last 6 months; SV (sexual violence) defined as being forced to have sex (penetrative) against your will by someone (excludes clients) in last 6 months; CPV (client perpetrated violence) defined as having a "bad date" (verbal harassment, abduction or kidnap, sexual assault, rape, strangling, physical assault or beating, assault with a weapon, being thrown out of a moving car, or other) with a client in last 6 months.
Shaw *et al* 2012 [45] (India)	2008 Cross-sectional 175 MSM and transgender SWs	Anal sex with 5+ non-regular male sex partners, past week	SV, past year	4.08 (1.17-14.26)	SV (sexual violence) defined as being physically forced to have sexual intercourse
Sherwood *et al* 2015 [46] (The Gambia)	2011 Cross-sectional 251 FSWs	Client sexual violence (ever)	Beaten up a result of selling sex, ever Tortured as a result of selling sex, ever	2.44 (1.22-4.85) 1.85 (1.01-3.42)	Client sexual violence defined as ever having a client use force or violence

**					to make the participant have sex or certain kinds of sex
Silverman *et al* 2011 [47] (India)	Cross-sectional 211 FSWs	Trafficked into sex work	CSV, first month of sex work	3.1 (1.6-6.1)	All FSWs HIV-infected; CSV (client sexual violence) defined as anyone using violence or force to make you have sex or certain types of sex with male clients
Socias *et al* 2015 [48] (Canada) **	2010-2013 Longitudinal 720 SWS	Age (per year younger) Minority sexual/gender status Heavy drinking (≥ 4 drinks per day) Canadian born vs immigrant/migrant Unstable housing Servicing clients in public spaces vs formal indoor establishments Police harassment without arrest	Incarceration, last 6 months Incarceration, last 6 months Incarceration, last 6 months Incarceration, last 6 months Incarceration, last 6 months Incarceration, last 6 months Incarceration, last 6 months	1.04 (1.02-1.06) 1.62 (1.13-2.34) 1.99 (1.20-3.29) 3.28 (1.26-8.53) 4.32 (2.17-8.62) 4.32 (2.17-8.62) 1.82 (1.35-2.45)	Incarceration defined as been in detention, prison or jail overnight or longer
Stulhofer *et al* 2015 [49] (Croatia) **	2007-2008/2014 Cross-sectional 154/237 FSWs	2nd study wave (2014) vs 1st study wave (2007-2008) (Zagreb study site only) Secondary or higher education vs primary or less Condom used at most recent non-commercial vaginal or anal intercourse	Client violence, last 12 months Client violence, last 12 months Client violence, last 12 months	0.48 (0.25-0.95) 0.55 (0.34-0.91) 0.37 (0.20-0.67)	Client violence defined as experience of a violent client
Suryawanshi *et al* 2016 [50] (India) **	2007-2008 Cross-sectional 5498 FSWs	Planning to move from current place of sex work vs not planning to move Not decided if moving from current place of sex work vs not planning to move	Sexual violence by occasional clients Sexual violence by regular clients Sexual violence by any sex partner Sexual violence by non-paying partner	1.98 (1.51-2.60) 2.00 (1.47-2.72) 1.75 (1.37-2.24) 0.59 (0.42-0.82)	All SWs defined as mobile; Sexual violence with clients or partners defined as being beaten/physically forced to have sex by that partner
Ulibarri *et al* 2010 [51] (Mexico)	2004-2006 Cross-sectional 300 FSWs	Childhood abuse Spouse or steady partner had sex with another partner Increased mean relationship power scale score	IPV, past 6 months IPV, past 6 months IPV, past 6 months	2.23 (1.21-4.09) 2.40 (1.32-4.37) 0.35 (0.18-0.66)	All FSWs have a current spouse or steady partner; IPV (intimate partner violence) is any emotional, physical or sexual abuse by a current spouse or steady partner
Ulibarri *et al* 2014 [52](Mexico) **	2004-2006 Cross-sectional 924 FSWs	Has clients who currently use drugs Intimate partner violence (past 6 months) Higher level of psychological distress symptoms	Client violence, past 6 months Client violence, past 6 months Client violence, past 6 months	3.70 (1.46-9.34) 2.63 (1.50-4.62) 1.92 (1.00-3.67)	Intimate partner violence defined as any emotional, physical or sexual abuse by a current spouse or steady partner; Client violence defined as any emotional, physical or sexual abuse by a client
Wilson *et al* 2015 [53] (Kenya) **	2012-2013 Cross-sectional 357 HIV+ve FSWs	Severe alcohol use vs non-drinker Controlling behaviours by emotional partner	IPV, last year IPV, last year	4.39 (1.16-16.63) 4.98 (2.31-10.74)	IPV (intimate partner violence) is any physical violence (slapped, pushed, hit, kicked, choked or threatened with a weapon), emotional violence (insulted, belittled, intimidated, threatened to hurt someone you care

					about) or sexual violence (forced sex, coerced sex or degrading sexual behaviour) by an emotional partner (boyfriend or husband)
Wirtz *et al* 2015 [54] (Russia) **	2011 Cross-sectional 754 FSWs	Active drug injecting compared to non-injecting	Police extortion (money), last 6 months Police extortion (sex), last 6 months Police extortion (money, sex, or information), last 6 months CPV, last 6 months CSV, last 6 months	2.2 (1.1-4.7) 3.2 (1.2-8.7) 3.0 (1.5-5.9) 7.3 (2.1-24.7) 3.3 (1.5-7.1)	CPV (client physical violence); CSV (client sexual violence) defined as experiencing a client coerce or physically forced you to have vaginal sex
		Active drug injecting compared to former injector	Police extortion (money, sex, or information), last 6 months CPV, last 6 months CSV, last 6 months	2.2 (1.1-4.3) 7.7 (2.2-27.1) 2.9 (1.3-6.5)	
Zhang *et al* 2013 [55] (China)	Cross-sectional 983 FSWs	Risky drinking vs low risk drinking	Sexual advantages taken by clients	2.19 (1.49-3.23)	
		Heavy drinking vs low risk drinking	Sexual advantages taken by clients Client demand for extra sexual services Raped or sexually assaulted by client Clothes stripped off by clients Clients purposely injured genital	2.49 (1.47-4.21) 2.11 (1.28-3.46) 2.58 (1.10-6.05) 3.44 (1.10-10.76) 4.71 (1.31-16.99)	
		Hazardous drinking vs low risk drinking	Sexual advantages taken by clients Client demand for extra sexual services Raped or sexually assaulted by client Clothes stripped off by clients	5.31 (2.56-11.01) 3.54 (1.93-6.50) 3.57 (1.46-8.72) 3.79 (1.15-12.52)	
Zhang *et al* 2015 [56] (China) **	2008-2009 Cross-sectional 743 FSWs	Intention of inconsistent condom use with stable partner in future	Physical violence from stable partners	2.01 (1.05-3.83)	IPV (intimate partner violence) defined as any physical (e.g. slapped you or thrown something at you that could hurt you; pushed you or shoved you or pulled your high, kicked you), sexual (e.g. had sexual intercourse when you did not want to; put something into your genitals) or emotional violence (e.g. belittled or humiliated you in front of other, threatened to hurt you or someone you cared about) from stable partners
		STD infection history	IPV Physical violence from stable partners Sexual violence from stable partners	4.04 (1.7-9.61) 1.94 (1.01-3.72) 2.09 (1.06-4.11)	
		Never HIV tested	Sexual violence from stable partner	1.70 (1.03-2.81)	
		FSWs ever used alcohol vs never	IPV	1.85 (1.23-2.77)	
		Education of stable partner	IPV Physical violence from stable partners	0.64 (0.43-0.94) 0.50 (0.32-0.78)	
		Type of stable partner is boyfriend	Sexual violence from stable partners	3.46 (1.12-10.68)	
		Type of stable partner is spouse	IPV Physical violence from stable partners	4.41 (1.37-14.17) 3.43 (1.09-10.84)	
		Type of stable partner is lover	IPV Sexual violence from stable partners	3.26 (1.12-9.51) 3.64 (1.27-10.40)	
		Friction with stable partner	Any IPV Physical violence from stable partners Sexual violence from stable partners	1.74 (1.46-2.07) 1.57 (1.30-1.90) 1.36 (1.11-1.66)	
		Concurrent partnership by stable partner	Any IPV Physical violence from stable partners Sexual violence from stable partners	2.17 (1.32-3.56) 1.83 (1.09-3.09) 2.39 (1.39-4.09)	

[1] Adapted from Deering et al [57]. Table includes details on factors which were found to be significantly associated with violence against FSWs in the adjusted analyses of peer-reviewed studies published up to September 2016 (see Box 3.1 in Chapter 3 for further details on the literature review search strategy).
** Highlights the studies identified in my supplementary literature review searches. Other studies were identified in the existing published systematic review by Deering et al [57].
Abbreviations: FSW – female sex worker; AOR – adjusted odds ratios, CI – confidence interval

Table C2. Perpetrators of physical and sexual violence during the first and most recent month of sex work

	Sexual violence		Physical violence	
	%	N	%	N
Perpetrator/s during the first month of sex work [1]				
Regular client	47.1	17	42.1	19
New client	58.8	17	57.9	19
Regular transactional sex partner	5.9	17	5.3	19
New transactional sex partner	5.9	17	0.0	19
Intimate partner	11.8	17	5.3	19
Perpetrator/s during the most recent month of sex work [1]				
Regular client	63.3	30	46.0	37
New client	33.3	30	40.5	37
Regular transactional sex partner	10.0	30	10.8	37
New transactional sex partner	3.3	30	2.7	37
Intimate partner	13.3	30	13.5	37

[1] Proportions will not sum to 100% because participants who experienced violence can select all that apply

Table C3. Factors associated with lifetime sexual violence in bivariate analysis

	Lifetime sexual violence				
	Yes		No		
Individual	**%**	**N**	**%**	**N**	**p-value**
Current age, years					
14-20	57.1	119	58.3	283	0.809
21-24	42.9	119	41.7	283	
Highest level of education completed					
None	32.8	119	29.1	282	0.507
Primary school	52.1	119	51.4	282	
High school or higher	15.1	119	19.5	282	
Ever married	7.6	119	6.4	283	0.647
Age at entry into sex work, years					
<=18	55.2	116	60.8	263	0.311
19+	44.8	116	39.2	263	
Duration in sex work, years					
0-2	62.1	116	65.4	263	0.593
3+	37.9	116	34.6	263	
Frequency of alcohol consumption, in last month					
Less than once a month	15.1	119	25.8	283	0.050
1-3 times a month	16.0	119	14.5	283	
1 to 3 times a week	30.3	119	33.6	283	
Almost every day	16.0	119	12.0	283	
Every day	22.7	119	14.1	283	
Binge-drank, in last month	33.6	119	27.6	283	0.240
No. of times inebriated, in last month					
0 times	56.3	119	65.0	283	0.103
1-3 times	23.5	119	24.0	283	
4-6 times	10.1	119	6.0	283	
7+times	10.1	119	5.0	283	
Ever used drugs	31.9	119	30.4	283	0.762
Has a regular source of income	11.9	118	18.4	283	0.033
Interpersonal					
No. of clients in a typical week, in first month of sex work					
0-3	63.5	115	73.8	271	0.074
4+	36.5	115	26.2	271	
No. of clients, in last week					
0-4	51.0	104	63.0	254	0.019
5+	49.0	104	37.0	254	
No. of transactional sex partners, in first month of sex work					
0-1	55.9	118	67.0	273	0.033
2+	44.1	118	33.0	273	
No. of transactional sex partners, in last week					
0	68.1	116	68.7	275	0.906
1+	31.9	116	31.3	275	
Had sex with an intimate partner, in last month	50.4	115	42.7	281	0.144
Ever been inebriated when had sex, in last month	32.2	118	25.6	281	0.208
Ever had sex with an inebriated partner, in last month	69.8	119	69.2	282	0.901
Ever been high when had sex, in last month	16.1	118	14.7	279	0.727
Structural					
Main place/way met paying clients, in first month of sex work					
Entertainment venue	54.6	119	53.2	280	0.818
Street/bus stop	26.9	119	25.4	280	
Other (e.g. hotel, home)	18.5	119	21.4	280	
Main place/way met paying clients, in most recent month of sex work					
Entertainment venue	55.9	118	60.2	279	0.551
Street/bus stop	16.1	118	17.2	279	
Other (e.g. hotel, home)	28.0	118	22.6	279	
Had a manager or pimp, in first month of sex work	11.8	119	10.3	283	0.730
Coerced or deceived into having sex with first 10 clients after self-identifying as a sex worker	37.0	119	22.7	282	0.002

Lifetime physical violence	60.5	119	17.0	283	<0.001
Lifetime police assault or arrest	53.4	118	41.8	282	0.035
No. of sex workers that you know personally					
0-5	30.3	119	32.3	282	0.205
6-15	34.4	119	42.6	282	
16-30	21.9	119	14.5	282	
31+	13.4	119	10.6	282	

Table C4. Factors associated with lifetime physical violence in bivariate analysis

	Lifetime physical violence				
	Yes		No		
Individual	**%**	**N**	**%**	**N**	**p-value**
Current age, years					
14-20	56.1	123	58.7	283	0.595
21-24	43.9	123	41.3	283	
Highest level of education completed					
None	34.1	123	28.4	282	0.499
Primary school	48.8	123	52.8	282	
High school or higher	17.1	123	18.8	282	
Ever married	8.9	123	5.7	283	0.223
Age at entry into sex work, years					
<=18	59.0	117	59.4	266	0.932
19+	41.0	117	40.6	266	
Duration in sex work, years					
0-2	62.4	117	65.0	266	0.675
3+	37.6	117	35.0	266	
Frequency of alcohol consumption, in last month					
Less than once a month	11.4	123	27.6	283	0.002
1-3 times a month	13.8	123	15.2	283	
1 to 3 times a week	33.3	123	32.5	283	
Almost every day	17.1	123	11.3	283	
Every day	24.4	123	13.4	283	
Binge-drank, in last month	38.2	123	26.2	283	0.009
No. of times inebriated, in last month					
0 times	51.2	123	66.8	283	0.012
1-3 times	29.3	123	21.5	283	
4-6 times	8.9	123	6.7	283	
7+times	10.6	123	5.0	283	
Ever used drugs	35.8	123	29.0	283	0.137
Has a regular source of income	10.7	122	18.7	283	0.015
Interpersonal					
No. of clients in a typical week, in first month of sex work					
0-3	66.4	119	72.7	271	0.200
4+	33.6	119	27.3	271	
No. of clients, in last week					
0-4	58.3	108	60.5	253	0.710
5+	41.7	108	39.5	253	
No. of transactional sex partners, in first month of sex work					
0-1	56.2	121	66.8	274	0.053
2+	43.8	121	33.2	274	
No. of transactional sex partners, in last week					
0	65.6	122	70.3	273	0.312
1+	34.4	122	29.7	273	
Had sex with an intimate partner, in last month	40.7	118	46.6	281	0.222
Ever been inebriated when had sex, in last month	39.0	123	22.9	280	0.004
Ever had sex with an inebriated partner, in last month	78.1	123	66.0	282	0.017
Ever been high when had sex, in last month	18.2	121	13.9	280	0.226
Structural					
Main place/way met paying clients, in first month of sex work					
Entertainment venue	50.4	123	55.4	280	0.549
Street/bus stop	26.0	123	25.4	280	
Other (e.g. hotel, home)	23.6	123	19.3	280	
Main place/way met paying clients, in most recent month of sex work					
Entertainment venue	58.2	122	59.5	279	0.725
Street/bus stop	18.9	122	15.8	279	
Other (e.g. hotel, home)	22.9	122	24.7	279	
Had a manager or pimp, in first month of sex work	9.8	123	11.0	283	0.707

Coerced or deceived into having sex with first 10 clients after self-identifying as a sex worker	31.2	122	25.8	283	0.250
Lifetime sexual violence	60.0	120	16.7	282	<0.001
Lifetime police assault or arrest	57.4	122	40.1	282	0.003
No. of sex workers that you know personally					
0-5	26.2	122	33.9	283	0.200
6-15	38.5	122	40.6	283	
16-30	21.3	122	15.2	283	
31+	13.9	122	10.3	283	

Table C5. Factors associated with lifetime police assault or arrest in bivariate analysis

	Lifetime police assault or arrest				
	Yes		No		
Individual	**%**	**N**	**%**	**N**	**p-value**
Current age, years					
14-20	50.9	183	63.8	221	0.001
21-24	49.2	183	36.2	221	
Highest level of education completed					
None	30.6	183	29.5	220	0.301
Primary school	55.2	183	49.1	220	
High school or higher	14.2	183	21.4	220	
Ever married	9.8	183	4.1	221	0.016
Age at entry into sex work, years					
<=18	55.2	172	63.2	209	0.055
19+	44.8	172	36.8	209	
Duration in sex work, years					
0-2	56.4	172	70.8	209	<0.001
3+	43.6	172	29.2	209	
Frequency of alcohol consumption, in last month					
Less than once a month	14.7	183	29.0	221	0.012
1-3 times a month	13.7	183	15.4	221	
1 to 3 times a week	36.6	183	29.9	221	
Almost every day	15.3	183	11.3	221	
Every day	19.7	183	14.5	221	
Binge-drank, in last month	35.5	183	25.3	221	0.044
No. of times inebriated, in last month					
0 times	50.8	183	71.0	221	<0.001
1-3 times	31.2	183	18.0	221	
4-6 times	7.6	183	7.2	221	
7+times	10.4	183	3.6	221	
Ever used drugs	34.4	183	28.1	221	0.169
Has a regular source of income	14.2	183	18.2	220	0.225
Interpersonal					
No. of clients in a typical week, in first month of sex work					
0-3	66.5	173	74.1	216	0.061
4+	33.5	173	25.9	216	
No. of clients, in last week					
0-4	54.0	163	64.3	196	0.077
5+	46.0	163	35.7	196	
No. of transactional sex partners, in first month of sex work					
0-1	66.3	178	60.9	215	0.274
2+	33.7	178	39.1	215	
No. of transactional sex partners, in last week					
0	72.5	178	65.6	215	0.101
1+	27.5	178	34.4	215	
Had sex with an intimate partner, in last month	46.9	177	43.6	220	0.484
Ever been inebriated when had sex, in last month	35.2	182	21.9	219	0.004
Ever had sex with an inebriated partner, in last month	76.9	182	63.4	221	0.001
Ever been high when had sex, in last month	17.8	180	13.2	219	0.206
Structural					
Main place/way met paying clients, in first month of sex work					
Entertainment venue	55.0	182	53.4	219	0.712
Street/bus stop	23.6	182	26.9	219	
Other (e.g. hotel, home)	21.4	182	19.6	219	
Main place/way met paying clients, in most recent month of sex work					
Entertainment venue	60.8	181	57.3	218	0.507
Street/bus stop	14.4	181	18.8	219	
Other (e.g. hotel, home)	24.9	181	23.9	219	
Had a manager or pimp, in first month of sex work	12.0	183	9.5	221	0.434

Coerced or deceived into having sex with first 10 clients after self-identifying as a sex worker	28.6	182	26.2	221	0.651
Lifetime sexual violence	34.8	181	25.1	219	0.035
Lifetime physical violence	38.3	183	23.5	221	0.003
No. of sex workers that you know personally					
0-5	27.5	182	35.3	221	0.148
6-15	39.0	182	40.3	221	
16-30	19.8	182	14.9	221	
31+	13.7	182	9.5	221	

References for Appendix C

1. Alemayehu M, Yohannes G, Damte A, et al. Prevalence and predictors of sexual violence among commercial sex workers in Northern Ethiopia. Reprod Health. 2015;12:47
2. Argento E, Muldoon KA, Duff P, Simo A, Deering KN, Shannon K. High prevalence and partner correlates of physical and sexual violence by intimate partners among street and off-street sex workers. PLoS ONE [Electronic Resource]. 2014;9(7):e102129
3. Beattie TSH, Bhattacharjee P, Ramesh BM, et al. Violence against female sex workers in Karnataka state, south India: impact on health, and reductions in violence following an intervention program. BMC Public Health. 2010 Aug 11;10
4. Beletsky L, Lozada R, Gaines T, et al. Syringe confiscation as an HIV risk factor: the public health implications of arbitrary policing in Tijuana and Ciudad Juarez, Mexico. Journal of urban health : bulletin of the New York Academy of Medicine. 2013 Apr;90(2):284-98
5. Berger BO, Grosso A, Adams D, et al. The Prevalence and Correlates of Physical and Sexual Violence Affecting Female Sex Workers in Swaziland. J Interpers Violence. 2016 Feb 12;12:12
6. Bhattacharjee P, Prakash R, Pillai P, et al. Understanding the role of peer group membership in reducing HIV-related risk and vulnerability among female sex workers in Karnataka, India. Aids Care-Psychological and Socio-Medical Aspects of Aids/Hiv. 2013 Jun 20;25:S46-S54
7. Bhattacharjee P, Isac S, McClarty LM, et al. Strategies for reducing police arrest in the context of an HIV prevention programme for female sex workers: evidence from structural interventions in Karnataka, South India. J Int AIDS Soc. 2016;19(4 Suppl 3):20856
8. Blanchard JF, O'Neil J, Ramesh BM, Bhattacharjee P, Orchard T, Moses S. Understanding the social and cultural contexts of female sex workers in Karnataka, India: implications for prevention of HIV infection. The Journal of infectious diseases. 2005 Feb 1;191 Suppl 1:S139-46
9. Blanchard AK, Mohan HL, Shahmanesh M, et al. Community mobilization, empowerment and HIV prevention among female sex workers in south India. Bmc Public Health. 2013 Mar 16;13
10. Carlson CE, Chen J, Chang M, et al. Reducing intimate and paying partner violence against women who exchange sex in Mongolia: results from a randomized clinical trial. J Interpers Violence. 2012 Jul;27(10):1911-31
11. Chersich MF, Luchters SMF, Malonza IM, Mwarogo P, King'ola N, Temmerman M. Heavy episodic drinking among Kenyan female sex workers is associated with unsafe sex,

sexual violence and sexually transmitted infections. Int J STD AIDS. 2007 Nov;18(11):764-9
12. Chersich MF, Bosire W, King'ola N, Temmerman M, Luchters S. Effects of hazardous and harmful alcohol use on HIV incidence and sexual behaviour: a cohort study of Kenyan female sex workers. Global health. 2014;10:22
13. Choi SY. Heterogeneous and vulnerable: the health risks facing transnational female sex workers. Sociol Health Illn. 2011 Jan;33(1):33-49
14. Conners EE, Silverman JG, Ulibarri M, et al. Structural Determinants of Client Perpetrated Violence Among Female Sex Workers in Two Mexico-U.S. Border Cities. Aids Behav. 2016 Jan;20(1):215-24
15. Decker MR, McCauley HL, Phuengsamran D, Janyam S, Seage GR, III, Silverman JG. Violence victimisation, sexual risk and sexually transmitted infection symptoms among female sex workers in Thailand. Sex Transm Infect. 2010 Jun;86(3):236-40
16. Decker MR, Lyons C, Billong SC, et al. Gender-based violence against female sex workers in Cameroon: prevalence and associations with sexual HIV risk and access to health services and justice. Sex Transm Infect. 2016 Jun 8;8:8
17. Deering KN, Chettiar J, Chan K, Taylor M, Montaner JSG, Shannon K. Sex work and the public health impacts of the 2010 Olympic Games. Sex Transm Infect. 2012 June;88(4):301-3
18. Deering KN, Bhattacharjee P, Mohan HL, et al. Violence and HIV Risk Among Female Sex Workers in Southern India. Sex Transm Dis. 2013 Feb;40(2):168-74
19. El-Bassel N, Witte SS, Wada T, Gilbert L, Wallace J. Correlates of partner violence among female street-based sex workers: substance abuse, history of childhood abuse, and HIV risks. AIDS Patient Care STDS. 2001 Jan;15(1):41-51
20. Erausquin JT, Reed E, Blankenship KM. Police-Related Experiences and HIV Risk Among Female Sex Workers in Andhra Pradesh, India. J Infect Dis. 2011 Dec 1;204:S1223-S8
21. Fawole OI, Dagunduro AT. Prevalence and correlates of violence against female sex workers in Abuja, Nigeria. African Health Sciences. 2014;14(2):299-313
22. Fonner VA, Kerrigan D, Mnisi Z, Ketende S, Kennedy CE, Baral S. Social Cohesion, Social Participation, and HIV Related Risk among Female Sex Workers in Swaziland. Plos One. 2014 Jan 31;9(1)
23. George A, Sabarwal S, Martin P. Violence in contract work among female sex workers in Andhra Pradesh, India. J Infect Dis. 2011 01 Dec;204(SUPPL. 5):S1235-S40
24. George A, Sabarwal S. Sex trafficking, physical and sexual violence, and HIV risk among young female sex workers in Andhra Pradesh, India. International Journal of Gynecology & Obstetrics. 2013 Feb;120(2):119-23
25. Go VF, Srikrishnan AK, Parker CB, et al. High prevalence of forced sex among non-brothel based, wine shop centered sex workers in Chennai, India. Aids Behav. 2011 Jan;15(1):163-71
26. Goldenberg SM, Chettiar J, Simo A, et al. Early sex work initiation independently elevates odds of hiv infection and police arrest among adult sex workers in a canadian setting. J Acquir Immune Defic Syndr. 2014;65(1):122-8
27. Gupta J, Reed E, Kershaw T, Blankenship KM. History of sex trafficking, recent experiences of violence, and HIV vulnerability among female sex workers in coastal Andhra Pradesh, India. International Journal of Gynecology & Obstetrics. 2011 Aug;114(2):101-5
28. Hail-Jares K, Chang RC, Choi S, Zheng H, He N, Huang ZJ. Intimate-Partner and Client-Initiated Violence among Female Street-Based Sex Workers in China: Does a Support Network Help? PLoS ONE [Electronic Resource]. 2015;10(9):e0139161
29. Hong Y, Zhang C, Li X, Liu W, Zhou Y. Partner Violence and Psychosocial Distress among Female Sex Workers in China. Plos One. 2013 Apr 23;8(4)
30. Katsulis Y, Durfee A, Lopez V, Robillard A. Predictors of workplace violence among female sex workers in Tijuana, Mexico. Violence Against Women. 2015 May;21(5):571-97

31. Micheni M, Rogers S, Wahome E, et al. Risk of sexual, physical and verbal assaults on men who have sex with men and female sex workers in coastal Kenya. AIDS. 2015 Dec;29 Suppl 3:S231-6
32. Muldoon KA, Akello M, Muzaaya G, Simo A, Shoveller J, Shannon K. Policing the epidemic: High burden of workplace violence among female sex workers in conflict-affected northern Uganda. Global Public Health. 2015 Oct 27:1-14
33. Muldoon KA, Deering KN, Feng CX, Shoveller JA, Shannon K. Sexual relationship power and intimate partner violence among sex workers with non-commercial intimate partners in a Canadian setting. AIDS Care. 2015;27(4):512-9
34. Odinokova V, Rusakova M, Urada LA, Silverman JG, Raj A. Police sexual coercion and its association with risky sex work and substance use behaviors among female sex workers in St. Petersburg and Orenburg, Russia. Int J Drug Policy. 2014 Jan;25(1):96-104
35. Pack AP, L'Engle K, Mwarogo P, Kingola N. Intimate partner violence against female sex workers in Mombasa, Kenya. Cult Health Sex. 2013 Dec 11;11:11
36. Platt L, Grenfell P, Bonell C, et al. Risk of sexually transmitted infections and violence among indoor-working female sex workers in London: The effect of migration from Eastern Europe. Sex Transm Infect. 2011 August;87(5):377-84
37. Reed E, Gupta J, Biradavolu M, Devireddy V, Blankenship KM. The context of economic insecurity and its relation to violence and risk factors for HIV among female sex workers in Andhra Pradesh, India. Public Health Rep. 2010;125(SUPPL. 4):81-9
38. Reed E, Gupta J, Biradavolu M, Devireddy V, Blankenship KM. The role of housing in determining HIV risk among female sex workers in Andhra Pradesh, India: considering women's life contexts. Social Science & Medicine. 2011 Mar;72(5):710-6
39. Reed E, Gupta J, Biradavolu M, Blankenship KM. Migration/mobility and risk factors for HIV among female sex workers in Andhra Pradesh, India: Implications for HIV prevention. Int J STD AIDS. 2012 April;23(4):e7-e13
40. Richter M, Chersich MF, Vearey J, Sartorius B, Temmerman M, Luchters S. Migration status, work conditions and health utilization of female sex workers in three South African cities. J Immigr Minor Health. 2014 Feb;16(1):7-17
41. Saggurti N, Jain AK, Sebastian MP, et al. Indicators of mobility, socio-economic vulnerabilities and HIV risk behaviours among mobile female sex workers in India. Aids Behav. 2012 May;16(4):952-9
42. Schwitters A, Swaminathan M, Serwadda D, et al. Prevalence of rape and client-initiated gender-based violence among female sex workers: Kampala, Uganda, 2012. Aids Behav. 2015 01 Feb;19:S68-S76
43. Semple SJ, Stockman JK, Pitpitan EV, et al. Prevalence and Correlates of Client-Perpetrated Violence against Female Sex Workers in 13 Mexican Cities. PLoS ONE [Electronic Resource]. 2015;10(11):e0143317
44. Shannon K, Kerr T, Strathdee SA, Shoveller J, Montaner JS, Tyndall MW. Prevalence and structural correlates of gender based violence among a prospective cohort of female sex workers. BMJ. 2009 Aug 11;339
45. Shaw SY, Lorway RR, Deering KN, et al. Factors associated with sexual violence against men who have sex with men and transgendered individuals in Karnataka, India. PLoS ONE [Electronic Resource]. 2012;7(3):e31705
46. Sherwood JA, Grosso A, Decker MR, et al. Sexual violence against female sex workers in The Gambia: a cross-sectional examination of the associations between victimization and reproductive, sexual and mental health. BMC Public Health. 2015;15:270
47. Silverman JG, Raj A, Cheng DM, et al. Sex Trafficking and Initiation-Related Violence, Alcohol Use, and HIV Risk Among HIV-Infected Female Sex Workers in Mumbai, India. J Infect Dis. 2011 Dec 1;204:S1229-S34
48. Socias ME, Shoveller J, Bean C, Nguyen P, Montaner J, Shannon K. Universal Coverage without Universal Access: Institutional Barriers to Health Care among Women Sex Workers in Vancouver, Canada. PLoS One. 2016;11(5):e0155828

49. Stulhofer A, Landripet I, Bozic J, Bozicevic I. HIV risks and HIV prevention among female sex workers in two largest urban settings in Croatia, 2008-2014. AIDS Care. 2015 03 Jun;27(6):767-71
50. Suryawanshi D, Sharma V, Saggurti N, Bharat S. Factors associated with the likelihood of further movement among mobile female sex workers in India: A multinomial logit approach. Journal of biosocial science. 2016 Aug;48(4):539-56
51. Ulibarri MD, Strathdee SA, Lozada R, et al. Intimate Partner Violence among Female Sex Workers in Two Mexico-U.S. Border Cities: Partner Characteristics and HIV Risk-behaviors as Correlates of Abuse. Psychol Trauma. 2010 Dec;2(4):318-25
52. Ulibarri MD, Roesch S, Rangel MG, Staines H, Amaro H, Strathdee SA. "Amar te Duele" ("love hurts"): sexual relationship power, intimate partner violence, depression symptoms and HIV risk among female sex workers who use drugs and their non-commercial, steady partners in Mexico. Aids Behav. 2015 Jan;19(1):9-18
53. Wilson KS, Deya R, Masese L, et al. Prevalence and correlates of intimate partner violence in HIV-positive women engaged in transactional sex in Mombasa, Kenya. Int J STD AIDS. 2016 Nov;27(13):1194-203
54. Wirtz AL, Peryshkina A, Mogilniy V, Beyrer C, Decker MR. Current and recent drug use intensifies sexual and structural HIV risk outcomes among female sex workers in the Russian Federation. Int J Drug Policy. 2015 01 Aug;26(8):755-63
55. Zhang C, Li X, Stanton B, et al. Alcohol use and client-perpetrated sexual violence against female sex workers in China. Psychol Health Med. 2013 May 1;18(3):330-42
56. Zhang C, Li X, Su S, et al. Violence against Chinese female sex workers from their stable partners: a hierarchical multiple regression analysis. Health Care Women Int. 2015;36(7):797-815
57. Deering KN, Amin A, Shoveller J, et al. A systematic review of the correlates of violence against sex workers. Am J Public Health. 2014 2014-May;104(5):e42-54

Appendix D: Supplementary information for Chapter 5

Text D1. Model equations

State variables

FSWs

We consider the state variables for FSWs: popn_fsw (sv, pv, paa, age alcohol, hiv)

Where:

- sv (sexual violence), pv (physical violence) and paa (police assault or arrest) each has three possible states: 1 = no experience of violence; 2 = experienced violence recently in the last 6 months; and 3 = experienced violence in the past but not within the last 6 months
- age has two possible states: 1=young (14-24 years), and 2=older (≥25 years)
- alcohol has two possible states: 1 = low alcohol frequency, and 2 = high alcohol frequency (for future use alcohol use was included in the model, but for the analysis in this chapter was not considered i.e. no parameters depend on alcohol group, even where dependency is indicated in the equations below, and while FSWs were split by alcohol use, all outcomes were summed over alcohol use)
- hiv has eleven possible states: 1 = HIV susceptible, 2 = acute HIV infection, 3 = HIV infected with CD4 >350, untreated, 4 = HIV infected with CD4 200-350, untreated, 5 = HIV infected with CD4 <200, untreated, 6 = HIV infected with CD4 >350, on ART, 7 = HIV infected with CD4 200-350, on ART, 8 = HIV infected with CD4 <200, on ART, 9 = HIV infected with CD4 >350, stopped ART, 10 = HIV infected with CD4 200-350, stopped ART, and 11 = HIV infected with CD4 <200, stopped ART.

The derivatives of the state variables for FSWs are written here as popdpdt_fsw (sv, pv, paa, age alcohol, hiv).

Clients

We consider a state variable for clients: popn_client (hiv)

Where:

- hiv has the same states as for FSWs

The derivative of the state variable for clients is written as popdpdt_client (hiv)

Ordinary differential equations (Matlab code)

The model is defined by a set of coupled ordinary differential equations (ODEs), which were programmed in Matlab and solved numerically using the ode45 solver.

FSWs

Violence information

```
for age = 1:N_Age
  for alcohol = 1:N_Alcohol
    for hiv = 1:N_HIVandART
        % ===== No violence yet ===== %
          popdpdt_fsw(1,1,1,age,alcohol,hiv) =   (((RecruitRate_FSW_HIV_turnover(alcohol)) + RecruitRate_FSW_HIV_mortality(alcohol)) * entrySwitch(age,hiv)) - ( ratePV(age,alcohol) + rateNPI(age,alcohol) + rateSV(age,alcohol) ) * popn_fsw(1,1,1,age,alcohol,hiv);
          % ===== Recent sexual violence ===== %
          popdpdt_fsw(2,1,1,age,alcohol,hiv) =   rateSV(age,alcohol)*popn_fsw(1,1,1,age,alcohol,hiv)   + recurrentSV(age,alcohol)*popn_fsw(3,1,1,age,alcohol,hiv)  - ( rateNPI(age,alcohol) + ratePV(age,alcohol) + nonRecent_anyViolence ) * popn_fsw(2,1,1,age,alcohol,hiv);
          % ===== Non-recent sexual violence ===== %
          popdpdt_fsw(3,1,1,age,alcohol,hiv) =   nonRecent_anyViolence*popn_fsw(2,1,1,age,alcohol,hiv) - ( recurrentSV(age,alcohol) + rateNPI(age,alcohol) + ratePV(age,alcohol) ) * popn_fsw(3,1,1,age,alcohol,hiv);
          % ===== Recent physical violence ===== %
          popdpdt_fsw(1,2,1,age,alcohol,hiv) =   ratePV(age,alcohol)*popn_fsw(1,1,1,age,alcohol,hiv)   + recurrentPV(age,alcohol)*popn_fsw(1,3,1,age,alcohol,hiv)  - ( nonRecent_anyViolence + rateSV(age,alcohol) + rateNPI(age,alcohol) ) * popn_fsw(1,2,1,age,alcohol,hiv);
          % ===== Recent sexual violence and recent physical violence ===== %
          popdpdt_fsw(2,2,1,age,alcohol,hiv) =   ratePV(age,alcohol)*popn_fsw(2,1,1,age,alcohol,hiv)   + rateSV(age,alcohol)*popn_fsw(1,2,1,age,alcohol,hiv)   + recurrentPV(age,alcohol)*popn_fsw(2,3,1,age,alcohol,hiv)   + recurrentSV(age,alcohol)*popn_fsw(3,2,1,age,alcohol,hiv)  -  (  (rateNPI(age,alcohol)) + nonRecent_anyViolence + nonRecent_anyViolence ) *  popn_fsw(2,2,1,age,alcohol,hiv) ;
          % ===== Non-recent sexual violence and recent physical violence ===== %
          popdpdt_fsw(3,2,1,age,alcohol,hiv) =   ratePV(age,alcohol)*popn_fsw(3,1,1,age,alcohol,hiv)   + nonRecent_anyViolence*popn_fsw(2,2,1,age,alcohol,hiv)   + recurrentPV(age,alcohol)*popn_fsw(3,3,1,age,alcohol,hiv)  - ( recurrentSV(age,alcohol) + rateNPI(age,alcohol) + nonRecent_anyViolence ) * popn_fsw(3,2,1,age,alcohol,hiv) ;
        % ===== Non-recent physical violence ===== %
          popdpdt_fsw(1,3,1,age,alcohol,hiv) =   nonRecent_anyViolence*popn_fsw(1,2,1,age,alcohol,hiv) - ( recurrentPV(age,alcohol) + rateSV(age,alcohol) +  rateNPI(age,alcohol)  ) * popn_fsw(1,3,1,age,alcohol,hiv) ;
          % ===== Recent sexual violence and non-recent physical violence ===== %
          popdpdt_fsw(2,3,1,age,alcohol,hiv) =   nonRecent_anyViolence*popn_fsw(2,2,1,age,alcohol,hiv)   + rateSV(age,alcohol)*popn_fsw(1,3,1,age,alcohol,hiv)   + recurrentSV(age,alcohol)*popn_fsw(3,3,1,age,alcohol,hiv)   - ( rateNPI(age,alcohol) + nonRecent_anyViolence + recurrentPV(age,alcohol) ) *popn_fsw(2,3,1,age,alcohol,hiv);
```

```
% ===== Non-recent sexual violence and non-recent physical violence ===== %

popdpdt_fsw(3,3,1,age,alcohol,hiv) =   nonRecent_anyViolence*popn_fsw(2,3,1,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(3,2,1,age,alcohol,hiv)  - ( recurrentSV(age,alcohol) +
recurrentPV(age,alcohol) +  rateNPI(age,alcohol) ) *popn_fsw(3,3,1,age,alcohol,hiv);

% ===== Recent police assault or arrest ===== %

 popdpdt_fsw(1,1,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(1,1,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(1,1,3,age,alcohol,hiv) - (   nonRecent_anyViolence  +
rateSV(age,alcohol) + ratePV(age,alcohol) ) * popn_fsw(1,1,2,age,alcohol,hiv);

% ===== Recent sexual violence and recent police assault or arrest ===== %

popdpdt_fsw(2,1,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(2,1,1,age,alcohol,hiv)   +
rateSV(age,alcohol)*popn_fsw(1,1,2,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(2,1,3,age,alcohol,hiv)   +
recurrentSV(age,alcohol)*popn_fsw(3,1,2,age,alcohol,hiv)  - ( nonRecent_anyViolence +
nonRecent_anyViolence +  ratePV(age,alcohol) ) * popn_fsw(2,1,2,age,alcohol,hiv);

% ===== Non-recent sexual violence and recent police assault or arrest ===== %

popdpdt_fsw(3,1,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(3,1,1,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,1,2,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(3,1,3,age,alcohol,hiv)  - ( (recurrentSV(age,alcohol)) +
nonRecent_anyViolence + ratePV(age,alcohol) ) * popn_fsw(3,1,2,age,alcohol,hiv);

% ===== Recent physical violence and recent police assault or arrest ===== %

 popdpdt_fsw(1,2,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(1,2,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(1,2,3,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(1,1,2,age,alcohol,hiv)   +
recurrentPV(age,alcohol)*popn_fsw(1,3,2,age,alcohol,hiv)  - ( nonRecent_anyViolence +
nonRecent_anyViolence + rateSV(age,alcohol) ) * popn_fsw(1,2,2,age,alcohol,hiv);

% === Recent sexual violence and recent physical violence and recent police assault or arrest === %

 popdpdt_fsw(2,2,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(2,2,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(2,2,3,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(2,1,2,age,alcohol,hiv)   +   recurrentPV(age,alcohol)
*popn_fsw(2,3,2,age,alcohol,hiv)   +   rateSV(age,alcohol)*popn_fsw(1,2,2,age,alcohol,hiv)   +
recurrentSV(age,alcohol)*popn_fsw(3,2,2,age,alcohol,hiv)  - ( nonRecent_anyViolence +
nonRecent_anyViolence + nonRecent_anyViolence ) * popn_fsw(2,2,2,age,alcohol,hiv);

% == Non-recent sexual violence and recent physical violence and recent police assault or arrest ==%

popdpdt_fsw(3,2,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(3,2,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(3,2,3,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(3,1,2,age,alcohol,hiv)   +
recurrentPV(age,alcohol)*popn_fsw(3,3,2,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,2,2,age,alcohol,hiv)  - ( recurrentSV(age,alcohol) +
nonRecent_anyViolence + nonRecent_anyViolence ) * popn_fsw(3,2,2,age,alcohol,hiv);

% ===== Non-recent physical violence and recent police assault or arrest ===== %

popdpdt_fsw(1,3,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(1,3,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(1,3,3,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(1,2,2,age,alcohol,hiv)  - (  nonRecent_anyViolence +
recurrentPV(age,alcohol) + rateSV(age,alcohol) ) * popn_fsw(1,3,2,age,alcohol,hiv);
```

```
% == Recent sexual violence and non-recent physical violence and recent police assault or arrest == %

popdpdt_fsw(2,3,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(2,3,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(2,3,3,age,alcohol,hiv)   +
rateSV(age,alcohol)*popn_fsw(1,3,2,age,alcohol,hiv)   +
recurrentSV(age,alcohol)*popn_fsw(3,3,2,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,2,2,age,alcohol,hiv)   - ( nonRecent_anyViolence +
nonRecent_anyViolence + recurrentPV(age,alcohol) ) *  popn_fsw(2,3,2,age,alcohol,hiv);

%= Non-recent sexual violence and non-recent physical violence and recent police assault or arrest =%

popdpdt_fsw(3,3,2,age,alcohol,hiv) =   rateNPI(age,alcohol)*popn_fsw(3,3,1,age,alcohol,hiv)   +
recurrentNPI(age,alcohol)*popn_fsw(3,3,3,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,3,2,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(3,2,2,age,alcohol,hiv)  - (  nonRecent_anyViolence +
recurrentPV(age,alcohol) + recurrentSV(age,alcohol) ) * popn_fsw(3,3,2,age,alcohol,hiv);

% ===== Non-recent police assault or arrest ===== %

popdpdt_fsw(1,1,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(1,1,2,age,alcohol,hiv)  - (
rateSV(age,alcohol) + recurrentNPI(age,alcohol) + ratePV(age,alcohol) ) * popn_fsw(1,1,3,age,alcohol,hiv);

% ===== Recent sexual violence and non-recent police assault or arrest ===== %

popdpdt_fsw(2,1,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(2,1,2,age,alcohol,hiv)   +
rateSV(age,alcohol)*popn_fsw(1,1,3,age,alcohol,hiv)   +
recurrentSV(age,alcohol)*popn_fsw(3,1,3,age,alcohol,hiv)   - ( ratePV(age,alcohol) +
recurrentNPI(age,alcohol) + nonRecent_anyViolence ) * popn_fsw(2,1,3,age,alcohol,hiv);

% ===== Non-recent sexual violence and non-recent police assault or arrest ===== %

popdpdt_fsw(3,1,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(3,1,2,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,1,3,age,alcohol,hiv) - (  recurrentNPI(age,alcohol) +
ratePV(age,alcohol) + recurrentSV(age,alcohol) ) * popn_fsw(3,1,3,age,alcohol,hiv) ;

% ===== Recent physical violence and non-recent police assault or arrest ===== %

popdpdt_fsw(1,2,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(1,2,2,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(1,1,3,age,alcohol,hiv)   +
recurrentPV(age,alcohol)*popn_fsw(1,3,3,age,alcohol,hiv)   - (  recurrentNPI(age,alcohol) +
rateSV(age,alcohol) + nonRecent_anyViolence ) *  popn_fsw(1,2,3,age,alcohol,hiv);

%== Recent sexual violence and recent physical violence and non-recent police assault or arrest ==%

 popdpdt_fsw(2,2,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(2,2,2,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(2,1,3,age,alcohol,hiv)   +
recurrentPV(age,alcohol)*popn_fsw(2,3,3,age,alcohol,hiv)   +
rateSV(age,alcohol)*popn_fsw(1,2,3,age,alcohol,hiv)   +
recurrentSV(age,alcohol)*popn_fsw(3,2,3,age,alcohol,hiv)    - (  nonRecent_anyViolence +
recurrentNPI(age,alcohol) + nonRecent_anyViolence ) * popn_fsw(2,2,3,age,alcohol,hiv) ;

%= Non-recent sexual violence and recent physical violence and non-recent police assault or arrest =%

popdpdt_fsw(3,2,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(3,2,2,age,alcohol,hiv)   +
ratePV(age,alcohol)*popn_fsw(3,1,3,age,alcohol,hiv)   +
recurrentPV(age,alcohol)*popn_fsw(3,3,3,age,alcohol,hiv)   +
nonRecent_anyViolence*popn_fsw(2,2,3,age,alcohol,hiv)  - (   nonRecent_anyViolence +
recurrentSV(age,alcohol) + recurrentNPI(age,alcohol) ) * popn_fsw(3,2,3,age,alcohol,hiv);
```

```
            % ===== Non-recent physical violence and non-recent police assault or arrest ===== %

            popdpdt_fsw(1,3,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(1,3,2,age,alcohol,hiv)   +
            nonRecent_anyViolence*popn_fsw(1,2,3,age,alcohol,hiv) - (  recurrentPV(age,alcohol) +
            recurrentNPI(age,alcohol) + rateSV(age,alcohol) ) * popn_fsw(1,3,3,age,alcohol,hiv);

            %= Recent sexual violence and non-recent physical violence and non-recent police assault or arrest =%

            popdpdt_fsw(2,3,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(2,3,2,age,alcohol,hiv)   +
            nonRecent_anyViolence*popn_fsw(2,2,3,age,alcohol,hiv)   +
            rateSV(age,alcohol)*popn_fsw(1,3,3,age,alcohol,hiv)   +
            recurrentSV(age,alcohol)*popn_fsw(3,3,3,age,alcohol,hiv)    - ( recurrentNPI(age,alcohol) +
            recurrentPV(age,alcohol) + nonRecent_anyViolence ) * popn_fsw(2,3,3,age,alcohol,hiv) ;

            % Non-recent sexual violence and non-recent physical violence and non-recent police assault/arrest %

            popdpdt_fsw(3,3,3,age,alcohol,hiv) =    nonRecent_anyViolence*popn_fsw(3,3,2,age,alcohol,hiv)   +
            nonRecent_anyViolence*popn_fsw(3,2,3,age,alcohol,hiv)   +
            nonRecent_anyViolence*popn_fsw(2,3,3,age,alcohol,hiv)   - ( recurrentNPI(age,alcohol) +
            recurrentPV(age,alcohol) + recurrentSV(age,alcohol) ) * popn_fsw(3,3,3,age,alcohol,hiv) ;

        end

    end

end
```

HIV and ART information

```
for sv=1:N_sv

    for pv=1:N_pv

        for paa=1:N_paa

            for age=1:N_Age

                for alcohol=1:N_Alcohol

                  % Susceptible to HIV

                  popdpdt_fsw(sv,pv,paa,age,alcohol,i_susc) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_susc) - (
                  FOI_fsw(sv,pv,paa,age,alcohol) + mu_fsw (age,alcohol) ) * popn_fsw(sv,pv,paa,age,alcohol,i_susc);

                   % Acute HIV

                  popdpdt_fsw(sv,pv,paa,age,alcohol,i_acute) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_acute) +
                  FOI_fsw(sv,pv,paa,age,alcohol)*popn_fsw(sv,pv,paa,age,alcohol,i_susc) - (  rate_hiv_progression(i_acute) +
                  mu_fsw (age,alcohol) ) * popn_fsw(sv,pv,paa,age,alcohol,i_acute) ;

                  % CD4 >350 treatment naive

                  popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART) =
                  popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART) +
                  rate_hiv_progression(i_acute)*popn_fsw(sv,pv,paa,age,alcohol,i_acute) - (
                  rate_hiv_progression(i_CD4gt350_noART) +
                  rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART) + rate_hiv_mortality (i_CD4gt350_noART)
                  + mu_fsw (age,alcohol) ) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART);
```

% CD4 200-350 treatment naive

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART) + rate_hiv_progression(i_CD4gt350_noART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART) - (rate_hiv_progression(i_CD4200to350_noART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART) + rate_hiv_mortality(i_CD4200to350_noART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART);

% CD4 <200 treatment naive

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART) + rate_hiv_progression(i_CD4200to350_noART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART) - (rate_hiv_progression(i_CD4lt200_noART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART) + rate_hiv_mortality(i_CD4lt200_noART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART);

% CD4 >350 on treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_onART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_onART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_noART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART) - (rate_treatment_failure_fsw (i_CD4gt350_onART) + rate_hiv_mortality(i_CD4gt350_onART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_onART);

% CD4 200-350 on treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_onART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_onART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_noART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART) - (rate_treatment_failure_fsw (i_CD4200to350_onART) + rate_hiv_mortality(i_CD4200to350_onART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_onART) ;

% CD4 <200 on treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_onART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_onART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_noART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART) - (rate_treatment_failure_fsw (i_CD4lt200_onART) + rate_hiv_progression(i_CD4lt200_onART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_onART);

% CD4 >350 stopped/failed treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART) = popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART) + rate_treatment_failure_fsw (i_CD4gt350_onART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_onART) - (rate_hiv_progression(i_CD4gt350_stopART) + rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART) + rate_hiv_mortality(i_CD4gt350_stopART) + mu_fsw (age,alcohol)) * popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART);

```
 % CD4 200-350 stopped/failed treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART) =
popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART) +
rate_hiv_progression(i_CD4gt350_stopART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4gt350_stopART) +
rate_treatment_failure_fsw
(i_CD4200to350_onART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_onART) - (
rate_hiv_progression(i_CD4200to350_stopART) +
rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART) +
rate_hiv_mortality(i_CD4200to350_stopART) + mu_fsw (age,alcohol) ) *
popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART);

% CD4 <200 stopped/failed treatment

popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART) =
popdpdt_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART) +
rate_hiv_progression(i_CD4200to350_stopART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4200to350_stopART)
+ rate_treatment_failure_fsw (i_CD4lt200_onART)*popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_onART) - (
rate_hiv_progression(i_CD4lt200_stopART) +
rate_hiv_treatment_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART) +
rate_hiv_mortality(i_CD4lt200_stopART) + mu_fsw (age,alcohol) ) *
popn_fsw(sv,pv,paa,age,alcohol,i_CD4lt200_stopART);


        end
      end
    end
  end
end
```

Aging information

```
for sv=1:N_sv
  for pv=1:N_pv
    for paa=1:N_paa
      for alcohol=1:N_Alcohol
        for hiv = 1:N_HIVandART
          popdpdt_fsw(sv,pv,paa,i_young,alcohol,hiv) = popdpdt_fsw(sv,pv,paa,i_young,alcohol,hiv) -
          rate_AgeTurnover * popn_fsw (sv,pv,paa,i_young,alcohol,hiv);

          popdpdt_fsw(sv,pv,paa,i_older,alcohol,hiv) = popdpdt_fsw(sv,pv,paa,i_older,alcohol,hiv) + rate_AgeTurnover
          * popn_fsw (sv,pv,paa,i_young,alcohol,hiv);
        end
      end
    end
  end
end
```

Clients

HIV and ART information

% Susceptible to HIV

popdpdt_client(i_susc) = RecruitRate_Client - (FOI_client + mu_client) * popn_client(i_susc);

% Acute HIV

popdpdt_client(i_acute) = FOI_client*popn_client(i_susc) - (rate_hiv_progression(i_acute) + mu_client) * popn_client(i_acute);

% CD4 >350 treatment naive

popdpdt_client(i_CD4gt350_noART) = rate_hiv_progression(i_acute)*popn_client(i_acute) - (rate_hiv_progression(i_CD4gt350_noART) + rate_hiv_treatment_client(i_CD4gt350_noART) + rate_hiv_mortality (i_CD4gt350_noART) + mu_client) * popn_client(i_CD4gt350_noART);

% CD4 200-350 treatment naive

popdpdt_client(i_CD4200to350_noART) = rate_hiv_progression(i_CD4gt350_noART)*popn_client(i_CD4gt350_noART) - (rate_hiv_progression(i_CD4200to350_noART) + rate_hiv_treatment_client(i_CD4200to350_noART) + rate_hiv_mortality(i_CD4200to350_noART) + mu_client) * popn_client(i_CD4200to350_noART);

% CD4 <200 treatment naive

popdpdt_client(i_CD4lt200_noART) = rate_hiv_progression(i_CD4200to350_noART)*popn_client(i_CD4200to350_noART) - (rate_hiv_progression(i_CD4lt200_noART) + rate_hiv_treatment_client(i_CD4lt200_noART) + mu_client) * popn_client(i_CD4lt200_noART);

% CD4 >350 on treatment

popdpdt_client(i_CD4gt350_onART) = rate_hiv_treatment_client(i_CD4gt350_noART)*popn_client(i_CD4gt350_noART) + rate_hiv_treatment_client(i_CD4gt350_stopART)*popn_client(i_CD4gt350_stopART) - (rate_treatment_failure_client (i_CD4gt350_onART) + rate_hiv_mortality(i_CD4gt350_onART) + mu_client) * popn_client(i_CD4gt350_onART);

% CD4 200-350 on treatment

popdpdt_client(i_CD4200to350_onART) = rate_hiv_treatment_client(i_CD4200to350_noART)*popn_client(i_CD4200to350_noART) + rate_hiv_treatment_client(i_CD4200to350_stopART)*popn_client(i_CD4200to350_stopART) - (rate_treatment_failure_client (i_CD4200to350_onART) + rate_hiv_mortality(i_CD4200to350_onART) + mu_client) * popn_client(i_CD4200to350_onART);

% CD4 <200 on treatment

popdpdt_client(i_CD4lt200_onART) = rate_hiv_treatment_client(i_CD4lt200_noART)*popn_client(i_CD4lt200_noART) + rate_hiv_treatment_client(i_CD4lt200_stopART)*popn_client(i_CD4lt200_stopART) - (rate_treatment_failure_client (i_CD4lt200_onART) + rate_hiv_progression(i_CD4lt200_onART) + mu_client) * popn_client(i_CD4lt200_onART);

% CD4 >350 stopped/failed treatment

popdpdt_client(i_CD4gt350_stopART) = rate_treatment_failure_client (i_CD4gt350_onART)*popn_client(i_CD4gt350_onART) - (rate_hiv_progression(i_CD4gt350_stopART) + rate_hiv_treatment_client(i_CD4gt350_stopART) + rate_hiv_mortality(i_CD4gt350_stopART) + mu_client) * popn_client(i_CD4gt350_stopART);

% CD4 200-350 stopped/failed treatment

popdpdt_client(i_CD4200to350_stopART) = rate_hiv_progression(i_CD4gt350_stopART)*popn_client(i_CD4gt350_stopART) + rate_treatment_failure_client (i_CD4200to350_onART)*popn_client(i_CD4200to350_onART) - (rate_hiv_progression(i_CD4200to350_stopART) + rate_hiv_treatment_client(i_CD4200to350_stopART) + rate_hiv_mortality(i_CD4200to350_stopART) + mu_client) * popn_client(i_CD4200to350_stopART);

% CD4 <200 stopped/failed treatment

popdpdt_client(i_CD4lt200_stopART) = rate_hiv_progression(i_CD4200to350_stopART)*popn_client(i_CD4200to350_stopART) + rate_treatment_failure_client (i_CD4lt200_onART)*popn_client(i_CD4lt200_onART) - (rate_hiv_progression(i_CD4lt200_stopART) + rate_hiv_treatment_client(i_CD4lt200_stopART) + mu_client) * popn_client(i_CD4lt200_stopART);

Force of infection (Matlab code)

The force of infection depends on the fraction of sex acts protected by condoms, number of sexual partners and associated HIV prevalence, number of sex acts in a FSW-client partnership and, and infectiousness (i.e. the probability of transmission per sex act from an infected contact, which varies by gender, HIV stage, ART status, and condom use), as follows:

```
%---- Number of FSWs in each risk group----%

nFSW_riskGroup = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

for sv=1:N_SV
  for pv=1:N_PV
    for paa=1:N_PAA
      for age=1:N_Age
        for alcohol=1:N_Alcohol
          nFSW_riskGroup (sv,pv,paa,age,alcohol) = sum (popn_fsw (sv,pv,paa,age,alcohol,:));
        end
      end
    end
  end
end

%---- Number of clients----%

nClient = sum (popn_client);
```

```
%--- Consistent condom use---%

CCU_2015_young = 1 - ICU_2015_young;
CCU_2015_old = 1- ICU_2015_old;

if t < Cond_Start
   CCU_coverage_young = 0;
   CCU_coverage_old = 0;
elseif t < Cond_Plateau
   CCU_coverage_young = (t-Cond_Start)/(Cond_Plateau-Cond_Start) * CCU_2015_young;
   CCU_coverage_old = (t-Cond_Start)/(Cond_Plateau-Cond_Start) * CCU_2015_old;
else
   CCU_coverage_young = CCU_2015_young;
   CCU_coverage_old = CCU_2015_old;
end

%--- Inconsistent condom use---%

ICU_base = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);
ICU_base (:,:,:,1,1) = 1 - CCU_coverage_young;
ICU_base (:,:,:,1,2) = 1 - CCU_coverage_young;
ICU_base (:,:,:,2,1) = 1 - CCU_coverage_old;
ICU_base (:,:,:,2,2) = 1 - CCU_coverage_old;

RR_cond = ones (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);
RR_cond (2,:,:,:,:) = RR_ICU_from_SV;
RR_cond (3,:,:,:,:) = RR_ICU_from_SV;

ICU_prop = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);
ICU_prop (:,:,:,:,:) = ICU_base (:,:,:,:,:) .* RR_cond (:,:,:,:,:);
ICU_prop(ICU_prop > 1)= 1;

%---- Overall fraction of sex acts protected by condoms  ----%
FracActsCond = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);
FracActsCond(:,:,:,:,:) = ( ICU_prop (:,:,:,:,:) * FracActsCond_ICU ) + ( (1 - ICU_prop (:,:,:,:,:)) * FracActsCond_CCU );
```

```
%--- Rho (probability of mixing between FSWs and clients, which is proportionate) ---%

P_FSW = zeros (N_SV,N_PAA,N_PH,N_Age,N_Alcohol);     % total partnerships on offer by FSWs in group

for csv=1:N_SV
   for cpv=1:N_PAA
      for ph=1:N_PH
         for age=1:N_Age
            for alcohol=1:N_Alcohol

                P_FSW (sv,pv,paa,age,alcohol) = pcr_FSW (age,alcohol) * nFSW_riskGroup (sv,pv,paa,age,alcohol);

            end
         end
      end
    end
 end

totP_FSW =  sum(sum(sum(sum(sum(P_FSW (:,:,:,:,:))))));     % total partnerships on offer by all FSWs

rho_fsw = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

rho_fsw (:,:,:,:,:) = P_FSW (:,:,:,:,:) / totP_FSW;



%--- Check balancing of partnerships and adjust if necessary ---%

totP_clients = pcr_Client * nClient;                    % total partnerships on offer by clients

B = totP_clients / totP_FSW;                            % discrepancy in total partnerships for FSWs and clients

if B == 1

   pcr_Client_balance = pcr_Client;

else

   pcr_Client_balance = pcr_Client * ( B ^ -1);     % amend client partner rate if discrepancy

end


%--- In this section the FOI for FSWs is calculated ---%

prob_Condom_FSW = zeros (1,N_HIVandART);

prob_NoCondom_FSW = zeros (1,N_HIVandART);


for hiv = 2:N_HIVandART

   prob_Condom_FSW (hiv) = 1 - (beta_M_to_F * RR_HIVstage(hiv) * (1-efficacy_condom) * (1-efficacy_ART(hiv)));

end


for hiv = 2:N_HIVandART

   prob_NoCondom_FSW (hiv) = 1 - ( beta_M_to_F * RR_HIVstage(hiv) * (1-efficacy_ART(hiv)) );

end
```

```
beta_fsw = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol,N_HIVandART);

for sv=1:N_sv
   for pv=1:N_pv
      for paa=1:N_paa
         for age=1:N_Age
            for alcohol=1:N_Alcohol
               for hiv=2:N_HIVandART

                           beta_fsw (sv,pv,paa,age,alcohol,hiv) =  1 - ( ( prob_Condom_FSW (hiv)  ^ ( FracActsCond
                           (sv,pv,paa,age,alcohol) * numActs ) )  *  ( prob_NoCondom_FSW (hiv)  ^ ( (1 - FracActsCond
                           (sv,pv,paa,age,alcohol)) * numActs ) ) ) ;

               end
            end
         end
      end
   end
end


beta_inf_fsw = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol,N_HIVandART);

for sv=1:N_sv
   for pv=1:N_pv
      for paa=1:N_paa
         for age=1:N_Age
            for alcohol=1:N_Alcohol
               for hiv=2:N_HIVandART

                  beta_inf_fsw (sv,pv,paa,age,alcohol,hiv) = beta_fsw (sv,pv,paa,age,alcohol,hiv) * popn_client (hiv);

               end
            end
         end
      end
   end
end


beta_infN_fsw = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

for sv=1:N_sv
   for pv=1:N_pv
      for paa=1:N_paa
         for age=1:N_Age
            for alcohol=1:N_Alcohol

               beta_infN_fsw (sv,pv,paa,age,alcohol) = sum ( beta_inf_fsw (sv,pv,paa,age,alcohol,:) ) / nClient;

            end
         end
      end
   end
end
```

```
FOI_fsw = zeros(N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

for sv=1:N_sv
   for pv=1:N_pv
      for paa=1:N_paa
         for age=1:N_Age
             for alcohol=1:N_Alcohol

               FOI_fsw (sv,pv,paa,age,alcohol) = pcr_FSW (age,alcohol) * beta_infN_fsw (sv,pv,paa,age,alcohol) ;

            end
         end
      end
   end
end


%--- In this section FOI for Clients is calculated---%

prob_Condom_Client = zeros (1,N_HIVandART);

prob_NoCondom_Client = zeros (1,N_HIVandART);


for hiv = 2:N_HIVandART

   prob_Condom_Client (hiv) = 1 - (beta_F_to_M * RR_HIVstage(hiv) * (1-efficacy_condom) * (1-efficacy_ART(hiv)));

end


for hiv = 2:N_HIVandART

   prob_NoCondom_Client (hiv) = 1 - ( beta_F_to_M * RR_HIVstage(hiv) * (1-efficacy_ART(hiv)) );

end


beta_client = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol,N_HIVandART);

for sv=1:N_sv
   for pv=1:N_pv
      for paa=1:N_paa
         for age=1:N_Age
            for alcohol=1:N_Alcohol
               for hiv=2:N_HIVandART

                        beta_client (sv,pv,paa,age,alcohol,hiv) =  1 - ( ( prob_Condom_Client (hiv)  ^ ( FracActsCond
                        (sv,pv,paa,age,alcohol) * numActs ) )  *  ( prob_NoCondom_Client (hiv)  ^ ( (1 - FracActsCond
                        (sv,pv,paa,age,alcohol)) * numActs ) ) ) ;

               end
            end
         end
      end
   end
end
```

```
beta_inf_client = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol,N_HIVandART);

for sv=1:N_sv
  for pv=1:N_pv
    for paa=1:N_paa
      for age=1:N_Age
        for alcohol=1:N_Alcohol
          for hiv=2:N_HIVandART

                beta_inf_client (sv,pv,paa,age,alcohol,hiv) = beta_client (sv,pv,paa,age,alcohol,hiv) * popn_fsw
                (sv,pv,paa,age,alcohol,hiv);

          end
        end
      end
    end
  end
end


beta_infN_client = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

for sv=1:N_sv
  for pv=1:N_pv
    for paa=1:N_paa
      for age=1:N_Age
        for alcohol=1:N_Alcohol

          beta_infN_client (sv,pv,paa,age,alcohol) = sum ( beta_inf_client (sv,pv,paa,age,alcohol,:) )  / nFSW_riskGroup
         (sv,pv,paa,age,alcohol) ;

        end
      end
    end
  end
end

beta_infNrho_client = zeros (N_SV,N_PV,N_PAA,N_Age,N_Alcohol);

beta_infNrho_client (:,:,:,:,:) = rho_fsw(:,:,:,:,:) .* beta_infN_client (:,:,:,:,:);

FOI_client = pcr_Client_balance * sum(sum(sum(sum(sum(beta_infNrho_client(:,:,:,:,:))))));
```

Initial conditions

At the start of the simulation FSWs were all initialised as young, HIV-susceptible FSWs, with no prior experience of violence, with a proportion in each alcohol use state; while clients started as HIV susceptible. To stabilise the relative size of the FSW age groups and to reach equilibrium prevalence of violence, the model was run for 100 years before HIV was introduced. The start of the HIV epidemic corresponds to 1970 as was specified in the Shannon *et al* modelling study [1]. At that time HIV was seeded in the model by assuming that a small proportion (0.5-2%) of clients and FSWs were HIV infected with CD4>350 at the start of the HIV epidemic. FSWs in each subgroup (by age, experience of violence, alcohol use) were all seeded with the same proportion.

Table D1. HIV prevalence and ART coverage (% of HIV positive) data used to inform the target ranges used in model fitting shown in Table 5.2

Outcome	Population	Year	N	Prevalence (95% CI)[1]	Study/source; study design; location; sampling strategy; age of FSWs
HIV prevalence	Older FSWs	2005	498	30.3% (29.2-37.6%)	Luchters *et al* 2008 [2]; post-intervention cross-sectional survey; Mombasa, Kenya; snowball sampling mean age of 29.5 years, Mombasa
HIV prevalence	Older FSWs	2005-2006	689	36.0% (95%CI: 32.5-40.0%)	Chersich *et al* 2007 [3]; cross-sectional; Mombasa; snowball sampling; mean age of 30.4 years
HIV prevalence	Older FSWs	2005-2006	803	35.2% (95%CI: 31.9-38.7)	Luchters *et al* 2010 [4]; cross-sectional; Mombasa; snowball sampling; median age of 28 years
HIV prevalence	Young FSWs	2015	346	9.8% (95%CI: 6.9-13.5)	Transitions data analysis; cross-sectional study; Mombasa; multi-stage cluster sample; FSWs aged 14-24 years
HIV prevalence	Clients	2004-2005	484	8.0% (95%CI: 5.4-10.4)	PhD thesis, S. Mishra 2014 [5]
HIV prevalence	Clients	2004-2005	71	14.1% (95%CI: 7.0-24.3)	PhD thesis, S. Mishra 2014 [5]
% HIV positive on ART	Young FSWs	2015	34	17.6% (95%CI: 6.8-34.5)	Transitions data analysis; cross-sectional study; Mombasa; multi-stage cluster sample; FSWs aged 14-24 years

[1] Binomial exact 95% confidence intervals were calculated from the available data if no 95%CI was reported

Table D2. Violence prevalence data for young FSWs used to inform the target ranges used in model fitting shown in Table 5.2

Outcome	Population	Year	N	Prevalence (95% CI)[2]	Study/source; study design; location; sampling strategy; age of FSWs
Sexual violence, ever	Young FSWs	2015	402	29.6% (25.2-34.3%)	Transitions data analysis; cross-sectional study; Mombasa, Kenya; multi-stage cluster sample; FSWs aged 14-24 years
Sexual violence, recently[1]	Young FSWs	2015	393	12.0% (8.9-15.6%)	
Physical violence, ever	Young FSWs	2015	406	30.3% (25.9-35.0%)	
Physical violence, recently[1]	Young FSWs	2015	397	17.1% (13.6-21.2%)	
Police assault or arrest, ever	Young FSWs	2015	404	45.3% (40.4-50.3%)	
Police assault or arrest, recently[1]	Young FSWs	2015	397	19.4% (15.6-23.6%)	

[1] In the last 6 months

[2] Binomial exact 95% confidence intervals were calculated from the data

Table D3. HIV prevalence and ART coverage (% HIV positive on ART) data for FSWs and clients that were not used during the fitting procedure

Outcome	Population	Year	N	Prevalence (95% CI)[1]	Study/source; study design; sampling strategy; age of FSWs
HIV prevalence	Older FSWs	1993	1502	56.0% (53.4-58.5%)	Baeten *et al* 2000 [6]; prospective cohort; Mombasa, Kenya; enrolment of FSWs attending a municipal clinic
HIV prevalence	Older FSWs	1994	198	54.0% (46.8-61.1%)	
HIV prevalence	Older FSWs	1995	597	54.6% (50.5-58.7%)	
HIV prevalence	Older FSWs	1996	791	50.9% (47.4-54.5%)	
HIV prevalence	Older FSWs	1997	540	50.9% (46.6-55.2%)	
HIV prevalence	Older FSWs	2000	493	30.6% (26.6-34.9%)	Luchters *et al* 2008 [2]; pre-intervention cross-sectional survey; Mombasa; snowball sampling; mean age of 30 years
HIV prevalence	Older FSWs	2001-2007	1182	51.9% (50.0-54.7%)	Kavanaugh *et al* 2012 [7]; prospective cohort; Mombasa; enrolment of FSWs attending a municipal clinic; 54.1% > age 30 years
HIV prevalence	Older FSWs	2006-2008	176	31.3% (24.5-38.7%)	Van der Elst *et al* 2009 [8]; prospective cohort; Mombasa; peer educators identified participants; median age of 28 years
HIV prevalence	Older FSWs	2011-2012	818	20.3% (17.6-23.2%)	Bengtson *et al* 2014 [9]; baseline survey of longitudinal intervention; Mombasa; convenience, enrolled from three community drop-in centers; age18-54 years (70%>23 years old)
HIV prevalence	Older FSWs	2012-2013	388	22.0% (17.9-26.4%)	Lafort *et al* 2016 [10]; cross-sectional; Mombasa, Kenya; respondent-driven sampling; median age of 26 years
HIV prevalence	Young FSWs	2000	27	15.0% (4.2-33.7%)	Luchters *et al* 2008 [2]; pre-intervention cross-sectional survey; Mombasa; snowball sampling; sub-sample aged 15-19 years
HIV prevalence	Young FSWs	2005	26	15% (4.3-34.9%)	Luchters *et al* 2008 [2]; post-intervention cross-sectional survey; Mombasa; snowball sampling; sub-sample aged 15-19 years
HIV prevalence	Clients	2003	86	4.3% (1.2-11.5%)	Kenya DHS 2003 [11]
HIV prevalence	Clients	2003	355	7.3% (4.8-10.6%)	Kenya DHS 2003 [11]
HIV prevalence	Clients	2008-2009	66	4.1% (1.0-12.7%)	Kenya DHS 2008-2009 [12]
% HIV positive on ART	Older FSWs	2012-2013	73	39.3%[2] (28.5-51.9%)	Lafort *et al* 2016 [10]; cross-sectional; Mombasa; respondent-driven sampling; median age of 26 years
% HIV positive on ART	Older FSWs	2012-2015	405	59.3% (54.3-64.0%)	White *et al* 2016 [13]; cohort study; Mombasa, recruited from the Mombasa Cohort[3], modal age group was 40-49 years

% HIV positive on ART	Clients	2004		2.1%	Kenya 2015 HIV estimates report (data shown are the estimates for all males in Kenya) [14]
% HIV positive on ART	Clients	2005		4.7%	
% HIV positive on ART	Clients	2006		10.6%	
% HIV positive on ART	Clients	2007		14.8%	
% HIV positive on ART	Clients	2008		20.0%	
% HIV positive on ART	Clients	2009		26.8%	
% HIV positive on ART	Clients	2010		32.4%	
% HIV positive on ART	Clients	2011		30.5%	
% HIV positive on ART	Clients	2012		33.3%	
% HIV positive on ART	Clients	2013		34.4%	
% HIV positive on ART	Clients	2014		37.3%	
% HIV positive on ART	Clients	2015		44.2%	

[1] Binomial exact 95% confidence intervals were calculated from the available data if no 95%CI was reported
[2] RDS-adjusted estimate
[3] The Mombasa cohort is a long-term cohort of FSWs established in 1993; from 2004 FSWs enrolled in the Mombasa cohort could receive ART if eligible through either the study research clinic or other clinics in the area

Table D4. Violence prevalence data that were not used in the model fitting procedure

Outcome	Population	Year	N	Prevalence (95% CI)[2]	Source; study design; location; sampling strategy; age of FSWs
Police assault or arrest and physical violence, ever	Young FSWs	2015	404	17.3% (13.8-21.3%)	Transitions data analysis; cross-sectional study; Mombasa, Kenya; multi-stage cluster sample; FSWs aged 14-24 years
Police assault or arrest and physical violence, recently[1]	Young FSWs	2015	388	4.0% (2.4-6.6%)	
Police assault or arrest and sexual violence, ever	Young FSWs	2015	400	15.8% (12.3-19.7%)	
Police assault or arrest and sexual violence, recently[1]	Young FSWs	2015	385	2.3% (1.1-4.4%)	
Physical violence and sexual violence, ever	Young FSWs	2015	402	17.9% (14.2-22%)	
Physical violence and sexual violence, recently[1]	Young FSWs	2015	389	5.9% (3.8-8.7%)	
Police assault or arrest and physical violence and sexual violence, ever	Young FSWs	2015	400	11.0% (8.1-14.5%)	
Police assault or arrest and physical violence and sexual violence, recently[1]	Young FSWs	2015	381	1.8% (0.7-3.7%)	
Police assault or arrest, recently[1]	Older FSWs	2014	693	30.0% (26.6-33.5%)	NASCOP polling booth survey report [15]; national Kenya survey (Mombasa data is reported here); FSWs aged 18 and above
Police assault or arrest, recently[1]	Older FSWs	2015	377	52.0% (46.8-57.1%)	
Sexual violence, recently[1]	Older FSWs	2014	693	17.0% (14.3-20.0%)	
Sexual violence, recently[1]	Older FSWs	2015	377	20.0% (16.0-24.3%)	

Note: There are a number of additional estimates of prevalence of violence among FSWs in Kenya (see Table D6), but due to the varying definitions and time-periods of violence, that were not directly comparable to those used in this modelling analysis, they were not used when comparing model predictions to observed data.
[1] In the last 6 months
[2] Binomial exact 95% confidence intervals were calculated from the data

Table D5. HIV prevalence by experience of violence among young FSWs in 2015

	Transitions data % (95% CI)
Ever sexual violence	
No	8.3 (5.0-12.5)
Yes	12.9 (7.0-21.0)
Ever physical violence	
No	7.5 (4.5-11.6)
Yes	15.2 (9.0-23.6)
Ever police assault or arrest	
No	7.6 (4.3-12.3)
Yes	12.2 (7.4-18.7)

Table D6. Estimates of prevalence of violence (sexual, physical or police-related) among FSWs in Kenya from published studies

Study	Location	Study design	Years[1]	Participant characteristics (N and age)	Details of violence outcome/s measured in study	Time-period of violence outcome	Violence outcome estimate
Elmore-Meegan *et al* 2004 [16]	Nairobi, Kenya	Exploratory survey	2000-2001	475 FSWs; median age of 26 years	1) Forced to have sex unpaid with a client because of threat of or actual use of physical violence 2) Physical assaulted (beaten) by a client	1) Past month 2) Past month	1) 35% 2) 17%
Thomsen *et al* 2006 [17]	Mombasa, Kenya	Prospective study	2004	210 FSWs; average age of 29 years	1) Physically assaulted by a sexual partner	1) Past 12 months	1) 11%
Chersich *et al* 2007 [3]	Mombasa, Kenya	Cross-sectional study	2005-2006	719 FSWs; mean age of 30 years	1) Physically forced to have sex without payment by a client	1) Past 12 months	1) 32.4%
Van der Elst *et al* 2009 [8]	Mombasa, Kenya	Cohort study	2008	139 FSWs (ACASI) and 139 FSWs (FtF); median age of 28 years (ACASI)	1) Been raped	1) Past 3 months (at enrolment)	1) 6.5% (ACASI) and4.4% (FtF)
Tegang *et al* 2010 [18]	Mombasa, Kenya	Cross-sectional study	2007	297 FSWs; median age of 25 years (46% were 15-24 years)	1) Forced to have sex without a condom 2) Forced to have sex without a condom, been beaten or physically abused as a result of doing sex work, or been forced to have sex by a partner using threats or physical violence	1) Ever 2) Ever	1) 48% 2) 77%
Luchters *et al* 2013 [19]	Mombasa, Kenya	Cohort study	2006-2007	400 FSWs; mean age of 25 years	1) Sexual and/or physical violence by an emotional partner (current boyfriend of husband) 2) Slapped or had something thrown at you that could hurt by any partner 3) Physically forced to have sex by any partner when they did not want sex 4) Pushed or shoved by any partner 5) Hit with a fist or something else, kicked, or beaten up by a partner 6) Had sex with a partner as was afraid of what he might do 7) Forced by a partner to do something sexual which she found degrading or humiliating	1) 12 month study period 2) 12 months preceding study; and 12 month study period 3) 12 months preceding study; and 12 month study period 4) 12 months preceding study; and 12 month study period 5) 12 months preceding study; and 12 month study period 6) 12 months preceding study; and 12 month study period 7) 12 months preceding study; and 12 month study period	1) 55.0% 2) 23.5% and 25.6% 3) 22.3% and 19.1% 4) 31.8% and 26.7% 5) 14.3% and 13.6% 6) 17.8% and 31.3% 7) 10.8% and 12.0%
Benoit *et al* 2013 [20]	Kibera, Kenya	Cross-sectional study	2011	27 FSWs (all HIV+); aged 18-45 years	1) Sexually hurt by a partner 2) Physically hurt by a partner	1) Ever 2) Ever	1) 33.3% 2) 44.4%
Chersich *et al* 2014 [21]	Mombasa, Kenya	Cohort study	2006-2007	400 FSWs; mean age of 25 years (22.7% aged 16-20 years)	1) Physically forced to have sex by any partner when you did not want to 2) Pushed, slapped, hit or kicked by a partner	1) Past 12 months 2) Past 12 months	1) 19.2% 2) 36.9%
Pack *et al* 2014 [22]	Mombasa, Kenya	RCT for an alcohol harm	2011-2012	619 FSWs (all moderate risk	1) Any intimate partner (client or non-paying partner) violence (including sexual violence,	1) Last 30 days (at baseline) 2) Last 30 days (at baseline) 3) Last 30 days (at baseline)	1) 78.7% 2) 28.8% 3) 35.1%

		reduction intervention		drinkers scoring 7-19 on AUDIT score); 39.3% aged 18-24 years	physical violence, verbal abuse and financial abuse)[2] 2) Beaten or physically abused by a client 3) Forced to have sex by a client 4) Forced to do other sexual things by a client 5) Forced to have sex without a condom by a client 6) Beaten or physically abused by a non-paying partner 7) Forced to have sex by a non-paying partner 8) Physical or sexual child abuse	4) Last 30 days (at baseline) 5) Last 30 days (at baseline) 6) Last 30 days (at baseline) 7) Last 30 days (at baseline) 8) NA	4) 32.0% 5) 35.7% 6) 30.2% 7) 44.4% 8) 47.2%
L'Engle *et al* 2014 [23]	Mombasa, Kenya	RCT for an alcohol harm reduction intervention	2011-2012	814 FSWs (all moderate risk drinkers scoring 7-19 on AUDIT score); mean age 27.5 years	1) Forced to have sex against her desire by a client 2) Forced to have sex against her desire by a non-paying partner	1) Last 30 days (at baseline; at 6 month follow-up; and at 12 month follow-up) 2) Last 30 days (at baseline; at 6 month follow-up; and at 12 month follow-up)	1) 35%/31% in intervention/ control group; 17%/21% in intervention/ control group; and 14%/19% in intervention/ control group 2) 47%/43% in intervention/ control group; 30%/29% in intervention/ control group; and 23%/25% in intervention/ control group
Bhattacharjee *et al* 2015 [24]	Multi-sites in Kenya (Nairobi, Mombasa, Nakuru, Nyeri, Thika, Kisumu and Eldoret)	Cross-sectional study	2013-2014	3448 FSWs; age >18 years (43.4% aged 18-24 years)	1) Beaten or physically forced to have sexual intercourse 2) Arrested or beaten up by police, criminal elements etc.	1) Past 6 months 2) Past 6 months	1) 22.4% 2) 43.8%
Wilson *et al* 2015 [25]	Mombasa, Kenya	Cross-sectional study	2012-2013	357 FSWs (all HIV+); median age of 39 years	1) Any intimate partner violence (defined as physical, sexual or emotional violence by index partners [current or most recent husband or boyfriend], where physical violence includes being slapped, pushed, hit, kicked, choked, or threatened with a weapon, sexual violence includes forced sex, coerced sex or degrading sexual behaviour, and emotional violence includes being insulted, belittled, intimidated, threatened to hurt someone you care about). 2) Physical violence by index partner 3) Sexual violence by index partner 4) Any sexual abuse by non-index partners 5) Any physical abuse by non-index partners	1) Past year; and ever 2) Past year 3) Past year 4) Past 12 months; and since age 15 5) Past 12 months; and since age 15	1) 14.6%; and 38.2% 2) 10.6% 3) 3.6% 4) 5.1%; and 20.1% 5) 6.5%; and 20.5%

Parcesepe *et al* 2016 [26]	Mombasa, Kenya	RCT for an alcohol harm reduction intervention	2011-2012	816 FSWs (all moderate risk drinkers scoring 7-19 on AUDIT score); mean age of 27 years	1) Sexual violence (forced to have sex when you did not want to) by paying sex partner 2) Physical violence (beaten or physically abused) by paying sex partner 3) Sexual violence (forced to have sex when you did not want to) by non-paying sex partner 4) Physical violence (beaten or physically abused) by non-paying sex partner 5) Childhood physical abuse (assessed by asking “as a child, were you beaten up by your parents or guardians more than other children your age were beaten up by their parents or guardians?”) 6) Childhood sexual abuse (assessed by asking “as a child, were you ever sexually abused?”)	1) Past 30 days (at baseline) 2) Past 30 days (at baseline) 3) Past 30 days (at baseline) 4) Past 30 days (at baseline) 5) NA 6) NA	1) 32.3% 2) 26.9% 3) 44.6% 4) 30.3% 5) 43.3% 6) 12.6%
Parcesepe *et al* 2016 [27]	Mombasa, Kenya	RCT for an alcohol harm reduction intervention	2011-2012	818 FSWs (all moderate risk drinkers scoring 7-19 on AUDIT score); aged 18-54 years (38.6% aged 18-24 years)	1) Physical violence (beaten or physically abused) by paying partners 2) Physical violence (beaten or physically abused) by non-paying partner	1) Past 30 days (baseline, immediately post-intervention; and 6 months post-intervention) 2) Past 30 days (baseline, immediately post-intervention; and 6 months post-intervention)	1) 25.4%/27.7% in intervention/ control group; 4.5%/4.6% in intervention/ control group; and 9.7%/5.1% in intervention/ control group 2) 28.7%/32.0% in intervention/ control group; 21.8%/16.9% in intervention/ control group; and 14.2%/9.4% in intervention/ control group
Thirumurthy *et al* 2016 [28]	Kisumu, Kenya	Cohort study	2015	101 FSWs (all HIV-); all aged 18-39 years (22% aged 18-24 years)	1) Intimate partner violence (physical, sexual and emotional) from any sexual partner	1) Past 12 months	1) 44%
Wilson *et al* 2016 [29]	Mombasa, Kenya	Cohort study	2012-2014	389 FSWs (HIV+); median age of 40 years	1) Any intimate partner violence (IPV) (defined as physical, sexual or emotional violence by index partners [current or most recent husband or boyfriend], where physical violence includes being slapped, pushed, hit, kicked, choked, or threatened with a weapon, sexual violence includes forced sex, coerced sex or degrading sexual behaviour, and emotional violence includes being insulted, belittled, intimidated, threatened to hurt someone you care about). 2) Sexual violence (being forced to have sex or perform a sex act) by someone other than the index partner	1) Past year (at baseline) 2) Past 12 months; and ever (at baseline) 3) Past 12 months; and ever (at baseline) 4) Past 12 months (follow-up visits)	1) 15.9% 2) 8.5%; and 15.9% 3) 7.7%; and 34.5% 4) 22.8%

					3) Physical violence (beaten or physically mistreated) by someone other than the index partner 4) Any gender based violence (IPV and/or any sexual or physical violence by non-index partner)		
Wilson *et al* 2016 [30]	Mombasa, Kenya	Cohort study	2012-2014	214 FSWs (all HIV+ who have initiated ART)	1) Sexual violence (being forced to have sex or perform a sex act) by someone other than the index partner 2) Physical violence (beaten or physically mistreated) by someone other than the index partner	1) Past 12 months; and ever (at baseline) 2) Past 12 months; and ever (at baseline)	1) 6.7%; and 13.6% 2) 6.1%; and 36.0%
White *et al* 2016 [13]	Mombasa, Kenya	Cohort study	2012-2015	405 FSWs (all HIV+); modal age group was 40-49 years	1) Physical violence by intimate partner (current or most recent regular male sex partner) 2) Sexual violence by intimate partner (current or most recent regular male sex partner) 3) Any sexual, physical or psychological violence by intimate partner (current or most recent regular male sex partner) 4) Physical or sexual violence from a partner other than the intimate partner	1) Past 12 months; and ever 2) Past 12 months; and ever 3) Past 12 months; and ever 4) Past 12 months; and ever	1) 14.8%; and 41.4% 2) 5.0%; and 18.2% 3) 20.7%; and 51.2% 4) 12.9%; and 39.4%
Goyette *et al* 2017 [31]	Mombasa, Kenya	Cohort study	2012-2015	404 FSWs (all HIV+)	1) Intimate partner violence	1) Past year	1) 16.6%
Lafort *et al* 2017 [32]	Mombasa, Kenya	Cross-sectional study	2012-2013	400 FSWs; median age 26 years	1) Forced sex	1) Past 12 months	1) 14.9%

[1] Year/s of data collection

[2] See study for further details on violence measures

Note: this table does not include estimates of emotional/verbal abuse (although some estimates of intimate partner violence may include this type of violence), and this table does not include estimates of violence from the grey literature (i.e. national reports)

Abbreviations: FSW –female sex worker; ACASI – audio computer assisted self-interview); FtF – face-to-face

Table D7. Posterior range for calibrated parameters

Parameter	Symbol	Prior range	Posterior median (95% CrI)
FSW population size in Mombasa in 2015	N_{FSW}	6920-11700	9398 (7078-11615)
Rate of leaving sex work per year	μ_{young} μ_{older}	0.065-0.092 0.087-0.125	0.077 (0.065-0.091) 0.106 (0.088-0.124)
Number of clients seen by FSWs per week	C_{young} C_{older}	5.0-6.4 4.0-7.4	5.6 (5.0-6.4) 5.5 (4.1-7.2)
Number of sex acts per client	n^{Acts}	1-2	1.4 (1.0-2.0)
Number of FSWs visited per month	n^{FSW}	3-8	5 (3-8)
ICU from 2006 (i.e. when condom use is assumed to plateau)	$ICU_{youngFSW}$ $ICU_{olderFSW}$	10-28% 14-45%	21% (13%-28%) 32% (15%-45%)
% of sex acts which are protected when reporting CCU	$frac^{CCU}$	75-100%	85% (76-99%)
Relative increase in ICU due to recent and non-recent sexual violence	RR_{cond_SV}	1.19-4.09	3.03 (1.49-4.06)
Rate per year that FSWs experience sexual violence for the first-time	α^{SV}	0.073-0.112	0.091 (0.076-0.109)
Rate per year that FSWs experience physical violence for the first-time	α^{PV}	0.076-0.116	0.094 (0.078-0.114)
Rate per year that FSWs experience police assault or arrest for the first-time	α^{PAA}	0.146-0.217	0.188 (0.155-0.215)
Rate (per year) that FSWs re-experience client sexual violence if previously experienced client sexual violence	ν^{SV}	0.687-1.768	1.191 (0.744-1.680)
Rate (per year) that FSWs re-experience client physical violence if previously experienced client physical violence	ν^{PV}	1.518-3.474	2.724 (1.671-3.413)
Rate per year that FSWs re-experience police harassment if previously experienced police harassment by sub-group	ν^{PAA}	0.882-1.772	1.297 (0.898-1.751)
Fraction of FSWs tested for HIV per year	$fracTest_{2008}$ $fracTest_{2013}$	37-47% 80-92%	42% (37-47%) 86% (80-92%)
Fraction of FSWs initiating ART if diagnosed	$fracInitiate_{young}$ $fracInitiate_{older}$	10-40% 50-90%	24% (10-40%) 68% (52-89%)
Relative decrease in HIV testing among FSWs due to recent and non-recent: - Sexual violence - Physical violence - Police assault or arrest	 RR_{test_SV} RR_{test_PV} RR_{test_PAA}	 0.82-1.0 0.83-1.0 0.89-1.0	 0.92 (0.82-1.00) 0.89 (0.83-0.99) 0.94 (0.89-1.00)
Rate of ART uptake per year among ART-eligible clients	τ_{client}	2006 onwards: 55-65%	59% (55-65%)
Yearly rate of stopping ART among FSWs	κ_{FSW}	0.09-0.24	0.17 (0.09-0.24)
Yearly rate of stopping ART among clients	κ_{client}	0.09-0.16	0.13 (0.09-0.16)
Probability of HIV transmission per sex act in asymptomatic stage (CD4>350) - Male-to-female - Female-to-male	 β_1 β_2	 0.0006-0.0011 0.0001-0.0014	 0.0008 (0.0006-0.0010) 0.0007 (0.0002-0.0014)
Relative risk of HIV transmission (compared to CD4>350) - Acute - CD4 200-350 - CD4 <200	 RR_A $RR_{200\text{-}350}$ RR_{200}	 4.5-18.8 1.0-1.6 4.5-7.0	 9.0 (4.8-18.2) 1.3 (1.0-1.6) 6.1 (4.7-6.9)
Duration in each HIV stage in the absence of ART (years)			

- Acute - CD4 >350 - CD4 200-350 - CD4 <200	$1/\sigma_1$ $1/\sigma_2$ $1/\sigma_3$ dur^{200}	0.1-0.5 4.0-4.8 3.6-4.6 1.4-2.8	0.3 (0.1-0.5) 4.4 (4.0-4.8) 4.2 (3.7-4.6) 2.1 (1.5-2.8)
HIV-related mortality rate per year by HIV stage - CD4 >350 - CD4 200-350	 Φ_2 Φ_3	 0.01-0.022 0.022-0.038	 0.01 (0.01-0.02) 0.03 (0.02-0.04)
Per-act condom efficacy against HIV transmission	Eff_{ART}	78-95%	85% (78-95%)
Per-act effectiveness of ART against HIV transmission	Eff_{cond}	79-96%	88% (79-96%)
Seed (% infected with HIV at the start of the HIV epidemic)	$seed_{1970}$	0.5-2%	1.1% (0.6-1.9%)

Table D8. PRCC between calibrated parameters and 10-year PAF of sexual violence, physical violence, and police assault or arrest (i.e. full PAF) by risk group

	Young FSWs	Older FSWs	Clients
Parameter			
N_{FSW}	0.03	-0.11	-0.13
μ_{young}	-0.21	-0.31	-0.19
μ_{older}	0.13	0.14	0.13
C_{young}	-0.20	-0.19	-0.20
C_{older}	-0.05	-0.26	-0.12
n^{Acts}	-0.34	-0.36	-0.36
n^{FSW}	-0.23	-0.31	-0.34
$ICU_{youngFSW}$	0.48	0.29	0.34
$ICU_{olderFSW}$	0.44	0.15	0.24
$frac^{CCU}$	0.80	0.70	0.77
RR_{cond_SV}	0.93	0.86	0.89
α^{SV}	0.22	0.20	0.18
α^{PV}	-0.19	-0.06	-0.12
α^{PAA}	-0.17	-0.21	-0.21
ν^{SV}	0.03	-0.10	-0.11
ν^{PV}	0.36	0.30	0.24
ν^{PAA}	0.26	0.03	0.07
$fracTest_{2008}$	-0.06	-0.05	-0.03
$fracTest_{2013}$	0.03	-0.05	0.01
$fracInitiate_{young}$	-0.14	-0.11	-0.09
$fracInitiate_{older}$	0.37	0.30	0.29
RR_{test_SV}	-0.05	-0.04	-0.19
RR_{test_PV}	-0.21	-0.24	-0.33
RR_{test_PAA}	-0.17	-0.16	-0.29
τ_{client}	0.04	0.12	0.12
κ_{FSW}	-0.20	-0.17	-0.25
κ_{client}	-0.41	-0.36	-0.28
β_1	-0.39	-0.43	-0.41
β_2	-0.36	-0.40	-0.41
RR_A	0.34	0.12	0.07
$RR_{200\text{-}350}$	-0.04	-0.16	-0.15
RR_{200}	0.06	-0.11	-0.07
$1/\sigma_1$	0.14	-0.22	-0.26
$1/\sigma_2$	-0.07	-0.12	-0.08
$1/\sigma_3$	-0.08	0.12	0.11
dur^{200}	-0.39	-0.47	-0.45
Φ_2	0.11	-0.16	-0.05
Φ_3	0.19	0.08	0.10
Eff_{ART}	0.08	0.19	0.21
Eff_{cond}	0.70	0.60	0.64
$seed_{1970}$	-0.35	-0.33	-0.31

Note: Grey shading highlights PRCC with an absolute value greater than 0.5

Table D9. PRCC between calibrated parameters and 10-year prevented fraction of intervention 1 (i.e. eliminate sexual violence, physical violence and police assault or arrest) by risk group

	Young FSWs	Older FSWs	Clients
Parameter			
N_{FSW}	0.03	-0.10	-0.07
μ_{young}	-0.11	-0.23	-0.23
μ_{older}	0.23	0.27	0.41
C_{young}	-0.03	-0.19	-0.14
C_{older}	-0.05	-0.20	-0.19
n^{Acts}	-0.22	-0.27	-0.20
n^{FSW}	-0.13	-0.22	-0.09
$ICU_{youngFSW}$	0.57	0.33	0.49
$ICU_{olderFSW}$	0.41	0.24	0.38
$frac^{CCU}$	0.77	0.64	0.66
RR_{cond_SV}	0.94	0.84	0.91
α^{SV}	0.23	0.16	0.23
α^{PV}	-0.13	-0.03	-0.10
α^{PAA}	-0.11	-0.15	-0.13
ν^{SV}	0.07	-0.09	0.06
ν^{PV}	0.29	0.22	0.26
ν^{PAA}	0.18	0.03	0.10
$fracTest_{2008}$	-0.03	0.02	0.05
$fracTest_{2013}$	0.02	-0.11	-0.20
$fracInitiate_{young}$	-0.18	-0.14	-0.20
$fracInitiate_{older}$	0.28	0.20	0.20
RR_{test_SV}	-0.06	-0.05	-0.06
RR_{test_PV}	-0.06	-0.18	-0.25
RR_{test_PAA}	-0.08	-0.24	-0.24
τ_{client}	0.05	0.14	-0.01
κ_{FSW}	-0.26	-0.09	-0.28
κ_{client}	-0.32	-0.30	-0.31
β_1	-0.24	-0.30	-0.23
β_2	-0.25	-0.32	-0.24
RR_A	0.28	0.16	0.35
$RR_{200\text{-}350}$	0.00	-0.16	-0.12
RR_{200}	0.11	-0.04	0.04
$1/\sigma_1$	0.08	-0.21	0.10
$1/\sigma_2$	-0.11	-0.04	-0.06
$1/\sigma_3$	0.01	0.17	0.22
dur^{200}	-0.28	-0.41	-0.44
Φ_2	0.13	-0.19	-0.07
Φ_3	0.16	0.09	0.15
Eff_{ART}	0.04	0.06	-0.06
Eff_{cond}	0.66	0.51	0.52
$seed_{1970}$	-0.31	-0.27	-0.29

Note: Grey shading highlights PRCC with an absolute value greater than 0.5

Table D10. PRCC between calibrated parameters and 10-year prevented fraction of intervention 2 (i.e. eliminate sexual violence, physical violence and police assault or arrest in combination with support to address long-term negative effects of violence) by risk group

	Young FSWs	Older FSWs	Clients
Parameter			
N_{FSW}	0.02	-0.11	-0.11
μ_{young}	-0.22	-0.30	-0.19
μ_{older}	0.14	0.14	0.11
C_{young}	-0.18	-0.17	-0.22
C_{older}	-0.05	-0.26	-0.12
n^{Acts}	-0.34	-0.34	-0.35
n^{FSW}	-0.23	-0.29	-0.35
$ICU_{youngFSW}$	0.48	0.27	0.37
$ICU_{olderFSW}$	0.46	0.12	0.25
$frac^{CCU}$	0.79	0.69	0.76
RR_{cond_SV}	0.94	0.86	0.89
α^{SV}	0.23	0.19	0.15
α^{PV}	-0.21	-0.06	-0.12
α^{PAA}	-0.18	-0.20	-0.18
ν^{SV}	0.03	-0.12	-0.18
ν^{PV}	0.34	0.29	0.24
ν^{PAA}	0.27	0.02	0.08
$fracTest_{2008}$	-0.06	-0.06	-0.03
$fracTest_{2013}$	0.04	-0.05	0.03
$fracInitiate_{young}$	-0.15	-0.09	-0.11
$fracInitiate_{older}$	0.37	0.27	0.29
RR_{test_SV}	-0.05	-0.06	-0.20
RR_{test_PV}	-0.21	-0.22	-0.33
RR_{test_PAA}	-0.18	-0.15	-0.32
τ_{client}	0.02	0.11	0.12
κ_{FSW}	-0.22	-0.16	-0.26
κ_{client}	-0.42	-0.36	-0.26
β_1	-0.38	-0.41	-0.40
β_2	-0.35	-0.38	-0.41
RR_A	0.35	0.11	0.07
$RR_{200\text{-}350}$	-0.05	-0.17	-0.15
RR_{200}	0.07	-0.13	-0.04
$1/\sigma_1$	0.15	-0.20	-0.24
$1/\sigma_2$	-0.07	-0.14	-0.10
$1/\sigma_3$	-0.08	0.11	0.10
dur^{200}	-0.39	-0.46	-0.45
Φ_2	0.11	-0.15	-0.03
Φ_3	0.19	0.09	0.10
Eff_{ART}	0.06	0.19	0.18
Eff_{cond}	0.70	0.57	0.62
$seed_{1970}$	-0.35	-0.31	-0.33

Note: Grey shading highlights PRCC with an absolute value greater than 0.5

Table D11. Crude associations between sexual violence and inconsistent condom use with clients over different time-periods of violence (N=200)

	ICU with new clients, last week		
	%	**Crude PR (95% CI)**	**p-value**
Lifetime sexual violence[1]			
No	15.2	1.00 (reference)	
Yes	31.2	2.05 (1.28-4.27)	0.003
Sexual violence, past 6 months			
No	19.0	1.00 (reference)	
Yes	21.2	1.12 (0.56-2.23)	0.756

[1] Results presented previously in Chapter 4

Table D12. Crude associations between FSWs experience of sexual violence and alcohol use and HIV testing uptake in the past 12 months

	HIV test past 12 months		
	%	**Crude PR (95% CI)**	**p-value**
Never experienced sexual violence and low frequency drinking	84.0	1.00 (reference)	
Ever sexual violence and low frequency drinking	86.1	1.03 (0.91-1.15)	0.677
Never sexual violence and high frequency drinking	94.5	1.12 (1.03-1.23)	0.008
Ever sexual violence and high frequency drinking	68.2	0.81 (0.66-1.00)	0.045

Note: High frequency drinking is defined as drinking almost every day or every day in the last month.

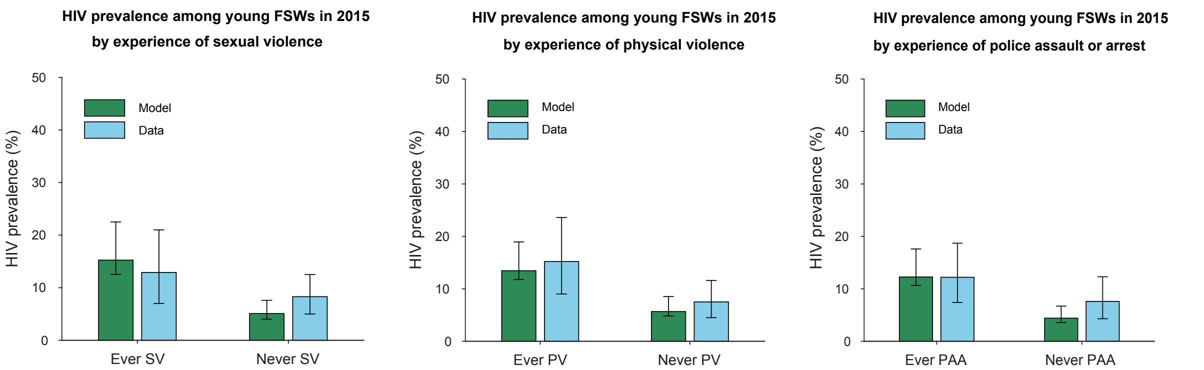


Figure D1. Model projections of HIV prevalence by experience of violence among young FSWs in 2015 compared to Transitions comparison data. Coloured bars represent the median value of the model fits or the point estimate from Transitions data, and error bars represent the 95% credible interval of the model fits or the 95% confidence interval of the point estimate from Transitions data. PAA – police assault or arrest; PV – physical violence; SV – sexual violence.

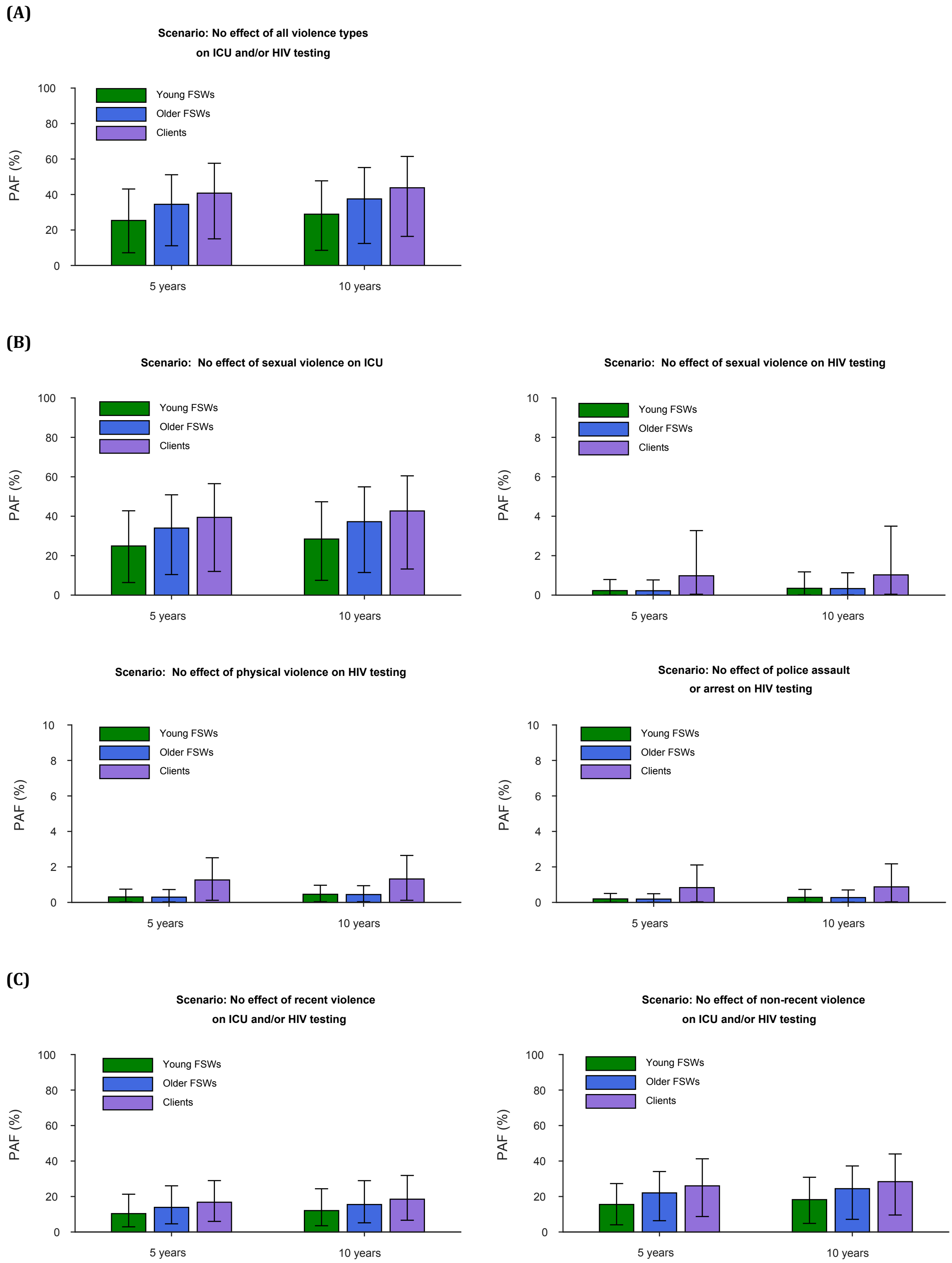


Figure D2. Population attributable fraction (PAF) of violence against FSWs over 2015-2020 and 2015-2025 (i.e. 5-year and 10-year PAF) in the following scenarios where various effects of violence are removed: (A) remove all effects of sexual violence, physical violence and police assault or arrest on ICU and/or HIV testing (i.e. full PAF); (B) remove effects of sexual violence, physical violence and police assault or arrest on ICU and/or HIV testing in turn; (C) remove effects of recent violence and non-recent violence on ICU and/or HIV testing in turn. The PAF calculated among young female sex workers (FSWs), older FSWs, and clients are shown. Coloured bars and error bars represent the median value of the model fits and the 95% credible interval of the model fits, respectively.

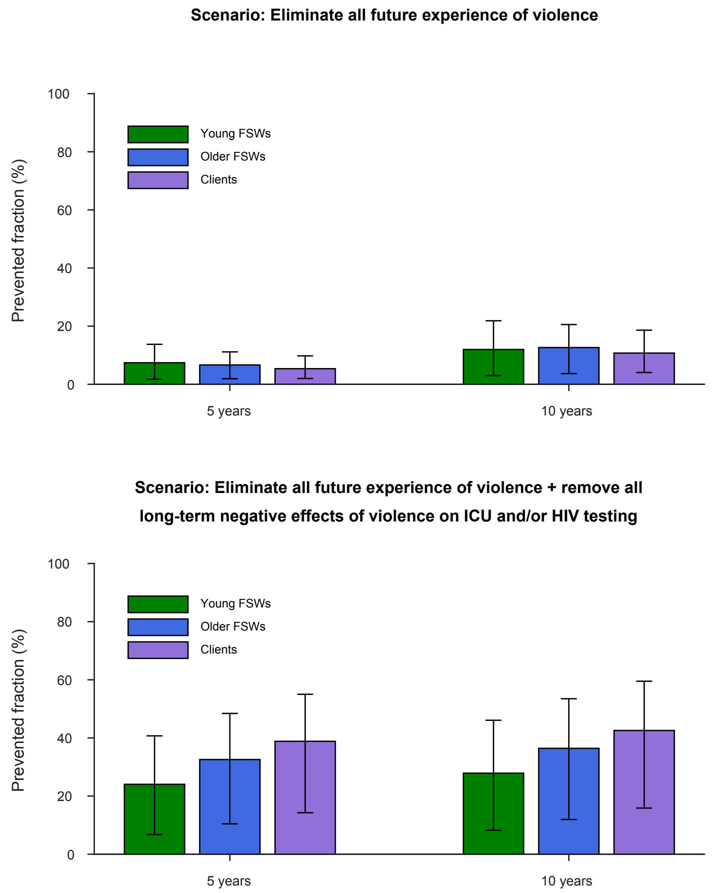


Figure D3. Prevented fraction (i.e. percentage of HIV infections potentially averted) among young FSWs, older FSWs and clients over 5 and 10 years due to the following intervention scenarios: 1) Eliminate all future experiences of violence from 2015; 2) Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured bars and error bars represent the median value of the model fits and the 95% credible interval of the model fits, respectively.

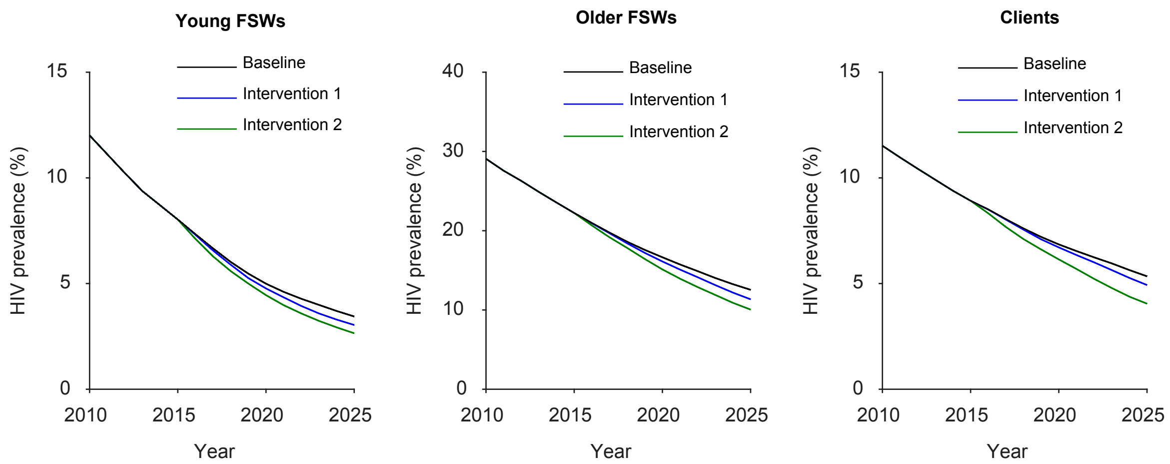


Figure D4. Impact of violence interventions on HIV prevalence among young FSWs, older FSWs and clients. Intervention 1 - Eliminate all future experiences of violence from 2015; Intervention 2 - Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured lines show the median of the model projections.

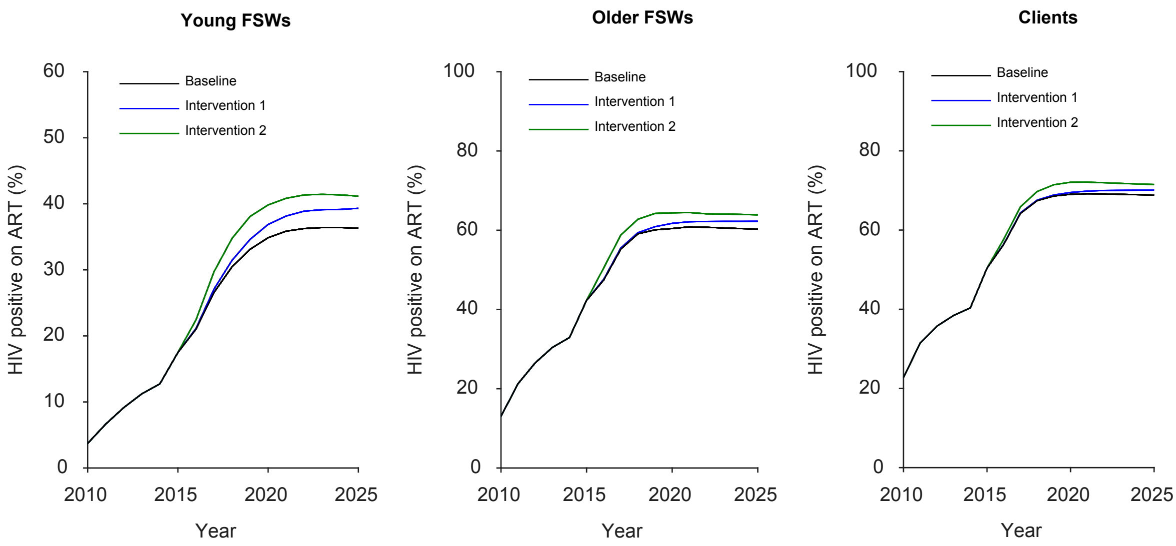


Figure D5. Impact of violence interventions on ART coverage (% of HIV positive on ART) among young FSWs, older FSWs and clients. Intervention 1 - Eliminate all future experiences of violence from 2015; Intervention 2 - Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured lines show the median of the model projections.

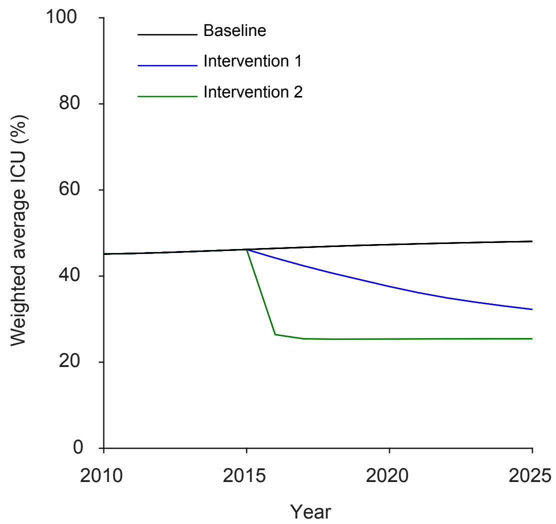


Figure D6. Impact of violence interventions on the weighted average inconsistent condom use (ICU) among FSWs. Intervention 1 - Eliminate all future experiences of violence from 2015; Intervention 2 - Eliminate all future experiences of violence and provide support to remove all the long-term negative effects of violence on ICU and/or HIV testing from 2015. Coloured lines show the median of the model projections.

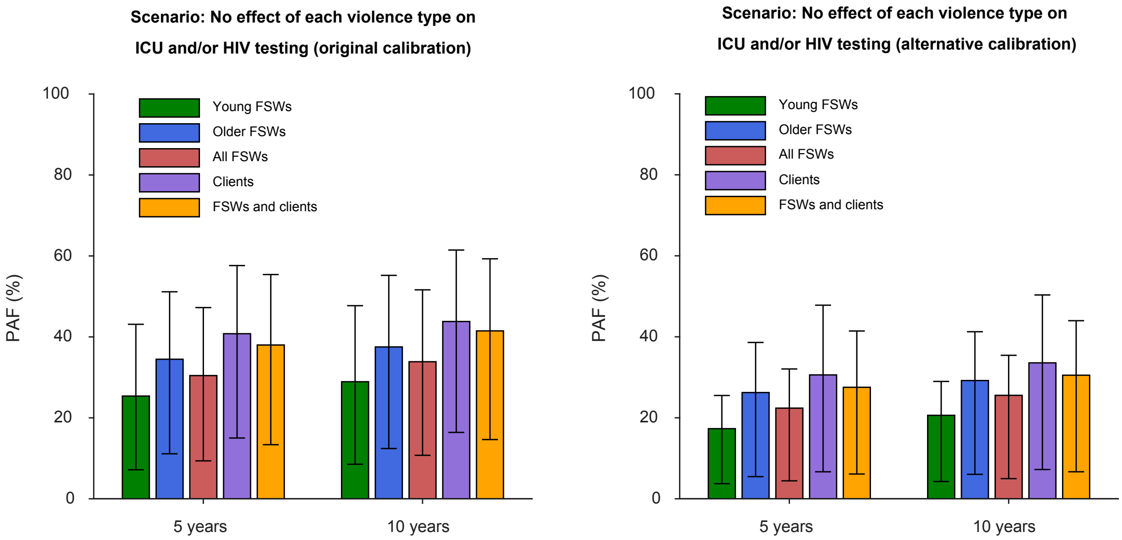


Figure D7. Population attributable fraction (PAF) of violence over 2015-2020 and 2015-2025 (i.e. 5-year and 10-year PAF) in the original and alternative model calibrations. The original calibration assumed increased risk of ICU among those recently and non-recently experiencing sexual while, while the alternative calibration assumed increased risk of ICU among those non-recently exposed to violence only. Estimates for all risk groups are shown for the scenario where all effects of sexual violence, physical violence and police assault or arrest on ICU and/or HIV testing are removed (i.e. full-PAF). Coloured bars represent the median value of the model fits and error bars represent the 95% credible interval of the model fits. Note that the figure shows results from 70 parameter sets that fit the data in the original calibration, and 22 parameter sets that fit the data in the alternative calibration (the alternative calibration was run with 2000 parameter sets of which 22 fit the data, whereas the original calibration was run with 4000 parameter sets of which 70 parameter sets fit the data).

References for Appendix D

1. Shannon K, Strathdee SA, Goldenberg SM, et al. Global epidemiology of HIV among female sex workers: influence of structural determinants. Lancet. 2015 Jan 3;385(9962):55-71
2. Luchters S, Chersich MF, Rinyiru A, et al. Impact of five years of peer-mediated interventions on sexual behavior and sexually transmitted infections among female sex workers in Mombasa, Kenya. BMC Public Health. 2008;8 (no pagination)(143)
3. Chersich MF, Luchters SMF, Malonza IM, Mwarogo P, King'ola N, Temmerman M. Heavy episodic drinking among Kenyan female sex workers is associated with unsafe sex, sexual violence and sexually transmitted infections. Int J STD AIDS. 2007 Nov;18(11):764-9
4. Luchters SMF, Broeck DV, Chersich MF, et al. Association of HIV infection with distribution and viral load of HPV types in Kenya: A survey with 820 female sex workers. BMC Infectious Diseases. 2010 26 Jan;10 (no pagination)(18)
5. Mishra S. Using mathematical models to characterize HIV epidemics for the design of HIV prevention strategies (PhD thesis): Imperial College London; 2014.
6. Baeten JM, Richardson BA, Martin Jr HL, et al. Trends in HIV-1 incidence in a cohort of prostitutes in Kenya: Implications for HIV-1 vaccine efficacy trials. J Acquir Immune Defic Syndr. 2000 15 Aug;24(5):458-64
7. Kavanaugh BE, Odem-Davis K, Jaoko W, et al. Prevalence and correlates of genital warts in kenyan female sex workers. Sex Transm Dis. 2012 November;39(11):902-5
8. van der Elst EM, Okuku HS, Nakamya P, et al. Is audio computer-assisted self-interview (ACASI) useful in risk behaviour assessment of female and male sex workers, Mombasa, Kenya? PLoS ONE. 2009 01 May;4 (5) (no pagination)(e5340)
9. Bengtson AM, L'Engle K, Mwarogo P, King'ola N. Levels of alcohol use and history of HIV testing among female sex workers in Mombasa, Kenya. AIDS Care. 2014;26(12):1619-24
10. Lafort Y, Greener R, Roy A, et al. HIV prevention and care-seeking behaviour among female sex workers in four cities in India, Kenya, Mozambique and South Africa. Tropical Medicine and International Health. 2016 01 Oct;21(10):1293-303
11. Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya], and ORC Macro. Demographic and Health Survey 2003. Calverton, Maryland: CBS, MOH, and ORC Macro: 2004.
12. Kenya National Bureau of Statistics (KNBS) and ICF Macro. Kenya Demographic and Health Survey 2008-09. Calverton, Maryland: KNBS and ICF Macro: 2010.
13. White D, Wilson KS, Masese LN, et al. Alcohol Use and Associations With Biological Markers and Self-Reported Indicators of Unprotected Sex in Human Immunodeficiency Virus-Positive Female Sex Workers in Mombasa, Kenya. Sex Transm Dis. 2016 Oct;43(10):642-7
14. NACC and NASCOP. Kenya HIV Estimates 2015. 2016.
15. National AIDS & STI Control Programme. Second National Behavioural Assessment of Key Populations in Kenya: Polling Booth Survey Report. Nairobi: NASCOP: 2016.
16. Elmore-Meegan M, Conroy RM, Agala CB. Sex workers in Kenya, numbers of clients and associated risks: an exploratory survey. Reprod Health Matters. 2004 May;12(23):50-7
17. Thomsen SC, Ombidi W, Toroitich-Ruto C, et al. A prospective study assessing the effects of introducing the female condom in a sex worker population in Mombasa, Kenya. Sex Transm Infect. 2006 October;82(5):397-402
18. Tegang SP, Abdallah S, Emukule G, et al. Concurrent sexual and substance-use risk behaviours among female sex workers in Kenya's Coast Province: findings from a behavioural monitoring survey. Sahara J. 2010 Dec;7(4):10-6
19. Luchters S, Richter ML, Bosire W, et al. The Contribution of Emotional Partners to Sexual Risk Taking and Violence among Female Sex Workers in Mombasa, Kenya: A Cohort Study. PLoS ONE. 2013 07 Aug;8(8)
20. Benoit C, Roth E, Hallgrimsdottir H, Jansson M, Ngugi E, Sharpe K. Benefits and constraints of intimate partnerships for HIV positive sex workers in Kibera, Kenya. Int J Equity Health. 2013;12(1)

21. Chersich MF, Bosire W, King'ola N, Temmerman M, Luchters S. Effects of hazardous and harmful alcohol use on HIV incidence and sexual behaviour: a cohort study of Kenyan female sex workers. Global health. 2014;10:22
22. Pack AP, L'Engle K, Mwarogo P, Kingola N. Intimate partner violence against female sex workers in Mombasa, Kenya. Cult Health Sex. 2013 Dec 11;11:11
23. L'Engle KL, Mwarogo P, Kingola N, Sinkele W, Weiner DH. A randomized controlled trial of a brief intervention to reduce alcohol use among female sex workers in Mombasa, Kenya. J Acquir Immune Defic Syndr. 2014 Dec 1;67(4):446-53
24. Bhattacharjee P, McClarty LM, Musyoki H, et al. Monitoring HIV Prevention Programme Outcomes among Key Populations in Kenya: Findings from a National Survey. PLoS ONE [Electronic Resource]. 2015;10(8):e0137007
25. Wilson KS, Deya R, Masese L, et al. Prevalence and correlates of intimate partner violence in HIV-positive women engaged in transactional sex in Mombasa, Kenya. Int J STD AIDS. 2016 Nov;27(13):1194-203
26. Parcesepe AM, L'Engle KL, Martin SL, Green S, Suchindran C, Mwarogo P. Early Sex Work Initiation and Violence against Female Sex Workers in Mombasa, Kenya. J Urban Health. 2016 Dec;93(6):1010-26
27. Parcesepe AM, KL LE, Martin SL, et al. The impact of an alcohol harm reduction intervention on interpersonal violence and engagement in sex work among female sex workers in Mombasa, Kenya: Results from a randomized controlled trial. Drug Alcohol Depend. 2016 Apr 1;161:21-8
28. Thirumurthy H, Masters SH, Mavedzenge SN, Maman S, Omanga E, Agot K. Promoting male partner HIV testing and safer sexual decision making through secondary distribution of self-tests by HIV-negative female sex workers and women receiving antenatal and post-partum care in Kenya: a cohort study. The lancet HIV. 2016 Jun;3(6):e266-74
29. Wilson KS, Deya R, Yuhas K, et al. A Prospective Cohort Study of Intimate Partner Violence and Unprotected Sex in HIV-Positive Female Sex Workers in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2054-64
30. Wilson KS, Wanje G, Yuhas K, et al. A Prospective Study of Intimate Partner Violence as a Risk Factor for Detectable Plasma Viral Load in HIV-Positive Women Engaged in Transactional Sex in Mombasa, Kenya. Aids Behav. 2016 Sep;20(9):2065-77
31. Goyette MS, Wilson KS, Deya R, et al. Brief Report: Association Between Menopause and Unprotected Sex in High-Risk HIV-Positive Women in Mombasa, Kenya. Journal of acquired immune deficiency syndromes (1999). 2017 Apr 15;74(5):488-92
32. Lafort Y, Greener R, Roy A, et al. Sexual and reproductive health services utilization by female sex workers is context-specific: results from a cross-sectional survey in India, Kenya, Mozambique and South Africa. Reprod Health. 2017 19 Jan;14(1):1-10