Characterizing HIV epidemiology among female sex workers and their clients in the Middle East and North Africa

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Dedicated to the best family I could have ever wished for and to my soul 'Aya'

DECLARATION

I, **Hiam Chemaitelly**, confirm that the work presented in this thesis is my own. I have developed the methodology for the different studies presented here and led the conduct of analyses and communication of research findings through scientific peer-reviewed publications and presentation in international conferences of relevance. Where information has been derived from other sources, I confirm that this has been indicated in the thesis. I have read and understood the School's definition of plagiarism and cheating given in the Research Degrees Handbook.

Hiam Chemaitelly

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LIST OF ABBREVIATIONS

AIDS	Acquired immunodeficiency syndrome
AMR	Antimicrobial resistance
ART	Anti-retroviral therapy
C. trachomatis	Chlamydia trachomatis
COVID-19	Coronavirus disease 2019
FSW	Female sex worker
GARPR	Global AIDS Response Progress Reporting
HIV	Human immunodeficiency virus
HSV-2	Herpes simplex virus type 2
HSWN	Heterosexual sex work networks
IBBSS	Integrated bio-behavioural surveillance survey(s)
LMIC	Low- and middle-income countries
MENA	Middle East and North Africa
MoT	Modes of Transmission
MSM	Men who have sex with men
N. gonorrhoeae	Neisseria gonorrhoeae
NGO	Non-governmental organizations
NPRP	National Priorities Research Program
PEPFAR	President's Emergency Plan for AIDS Relief
PLHIV	People living with HIV/AIDS
PrEP	Pre-exposure prophylaxis
PWID	People/person who inject(s) drugs
RCT	Randomized controlled trials
ROB	Risk of bias
RR	Relative risk
SAPPH-IRe	Sisters' Antiretroviral Programme for Prevention of HIV: an Integrated Response
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2

SDG	Sustainable Development Goals
STI	Sexually transmitted infection
T. pallidum	Treponema pallidum
T. vaginalis	Trichomonas vaginalis
UNAIDS	Joint United Nations Programme on HIV/AIDS
WHO	World Health Organization
WHO/EMRO	WHO Regional Office for the Eastern Mediterranean

COVID-19 IMPACT STATEMENT

Coronavirus Disease 2019 (COVID-19) for me was a challenge that delayed my PhD by one year, but also an opportunity of a lifetime. With the onset of the COVID-19 epidemic in Qatar in February 2020, I was assigned to be the lead statistician and epidemiologist supporting Qatar's COVID-19 national response. This entailed conduct of numerous analyses to characterize the epidemic throughout three epidemic waves, manage the mega national databases of polymerase chain reaction testing, antibody testing, vaccination, hospitalization (infection severity classification), and death in Qatar, and support the mathematical modelling work aimed at forecasting the healthcare needs and evolution of the epidemic.

This engagement also entailed conduct of studies commissioned by the Ministry of Public Health in Qatar to inform the national response, or suggested or requested by the World Health Organization and the United States Centers for Disease Control and Prevention. I was the lead statistician for all of these studies [1-30], and for most of these, I also designed or co-designed the study and wrote or co-wrote the first draft of the manuscript. Some of these studies were published in prestigious journals such as the *New England Journal of Medicine*, *Nature Medicine*, *JAMA*, *Clinical infectious Diseases*, *Journal of Travel Medicine*, and *Emerging infectious Diseases*. In several of these published papers, I was the first author [1-3,18,21-23]. I also contributed to other studies conducted by colleagues [31-37]. This major engagement led to significant, yet unavoidable, delay in progressing with the last study of my PhD, leading to a one-year extension in completing this thesis.

Involvement in COVID-19 research and national response complemented the set of skills acquired throughout my PhD with additional skills developed through hands-on training on designing and analyzing epidemiological studies such as matched and unmatched cohort (including cross-over) designs and case-control study designs. Moreover, I also co-designed and analyzed cross-sectional surveys using probability sampling, in addition to the application of a wide range of statistical techniques for analyzing epidemiologic studies such as conditional logistic regression, Poisson and cox regressions, survival analysis, competing hazards/Fine-Gray model analysis, design and use of sampling weights, in addition to conventional statistical methods. Additional experience was gained through validation of analyses using different analytical approaches, triangulation of evidence, and sensitivity analyses. Discussions with colleagues enhanced my in-depth understanding of the epidemic dynamics and reinforced infectious disease epidemiology concepts. Importantly, all of these engagements provided me with insights on the type of evidence needed to characterize and monitor the epidemic and to effectively inform the response. This has been the richest and most intense and demanding scientific experience in my career.

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ABSTRACT

Objectives: This thesis aims to address the evidence gap in understanding HIV epidemiology among female sex workers (FSWs) in the Middle East and North Africa (MENA) region by 1) conducting the first comprehensive assessment of HIV epidemic status among FSWs and their clients, and of other key sexually transmitted infections (STIs) among FSWs, 2) investigating the utility of herpes simplex virus type 2 (HSV-2) prevalence in predicting HIV epidemic potential in FSWs, and 3) estimating HIV incidence in heterosexual sex work networks (HSWNs) and assessing the impact of interventions on epidemiological measures of relevance to HIV response.

Methods: Methodologies include systematic reviews, meta-analyses and meta-regressions of HIV/STI prevalence data, ecological analysis of global HSV-2/HIV prevalence data among FSWs, and an individual-based mathematical model simulating HIV transmission dynamics in HSWNs.

Results: The median proportion of reproductive-age women reporting current/recent sex work was 0.6% (range: 0.2-2.4%), and of men reporting currently/recently buying sex was 5.7% (range: 0.3-13.8%). Risk behaviors varied widely within and across countries. The HIV epidemic was concentrated in Djibouti and South Sudan (prevalence ~20%), of intermediate intensity in North Africa and Somalia (1-5%), and limited in other countries (<1%). There was steady growth in odds of HIV prevalence since 2003 at ~15% per year (95% CI: 9-21%).

STI prevalence among FSWs was substantial (relative to general population women), supporting a key role for HSWNs in STI transmission dynamics. Pooled prevalence of current infection was 12.7% (95% CI: 8.5-17.7%) for T. pallidum (syphilis), 14.4% (95% CI: 8.2-22.0%) for C. trachomatis, 5.7% (95% CI: 3.5-8.4%) for N. gonorrhoeae, and 7.1% (95% CI: 4.3-10.5%) for T.

vaginalis, while that of lifetime infection was 23.7% (95% CI: 10.2-40.4%) for HSV-2. Syphilis prevalence varied by MENA subregion and has been declining by 7% per year for three decades.

Analysis of 231 global paired HSV-2/HIV measures identified a strong positive association among FSWs after adjusting for confounders such as region, temporal trend, and condom use. HIV prevalence was negligible where HSV-2 prevalence was ≤20%, but HIV infection odds doubled with each 25% increase in HSV-2 prevalence indicating a threshold effect and utility of HSV-2 in predicting HIV epidemic potential.

The individual-based model was developed, calibrated, tested, and applied to 12 MENA countries with sufficient input data. The estimated number of new infections in 2020 in these countries was 3,471 (range: 1,295-10,308) among FSWs, 6,416 (range: 3,144-14,223) among clients, and 4,717 (range: 3,490-7,288) among client spouses. These infections accounted for 25.1% of total HIV incidence in MENA. Incidence was distributed equally among FSWs, clients, and client spouses. The contribution of incidence in HSWNs to total incidence ranged from 3.3% in Pakistan where injecting drug use is prevalent to 71.8% in South Sudan and 72.7% in Djibouti where sex is the dominant mode of transmission. Scale-up of interventions such as antiretroviral therapy, condom use, and pre-exposure prophylaxis substantially reduced incidence among FSWs, clients, and client spouses either directly or indirectly by reducing onward transmission.

Conclusions: HIV epidemics among FSWs in MENA are emerging, and some are already established. The epidemic has been growing steadily in recent years, but with strong regionalization and heterogeneity. Integrating testing for HSV-2 in HIV surveillance can be useful in predicting HIV epidemic potential particularly in countries where HIV among FSWs is still limited but has potential to grow. Substantial HIV incidence occurs in HSWNs, suggesting

the need for rapidly scaling up comprehensive treatment and prevention services at least for FSWs.

CHAPTER 1. BACKGROUND

1. The global epidemiology of HIV in heterosexual sex work networks

1.1. The global context

The HIV pandemic continues to be a leading global health challenge [1]. Since first discovered, close to 76 million people have been infected with HIV and nearly 33 million have lost their lives to AIDS-related illnesses [2]. In many settings, epidemics have mostly affected key populations at increased risk of HIV exposure and transmission, including female sex workers (FSWs), men who have sex with men (MSM), and people who inject drugs (PWID) [1, 3, 4].

The expansion of HIV treatment and prevention efforts over the last two decades, notably the increased availability of anti-retroviral therapy (ART), has led to substantial declines in HIV incidence and mortality globally [4]. These gains have fuelled an ambitious drive towards ending the HIV/AIDS epidemic as a public health threat by 2030 [5]. To attain this goal, the Joint United Nations Programme on HIV/AIDS (UNAIDS) formulated the 'UNAIDS 2016-2021 Strategy' [6], and more recently the 'UNAIDS 2021-2026 Strategy' [7]. The first strategy aimed to reduce new HIV infections and AIDS-related deaths to fewer than 500,000 by 2020 and to fewer than 200,000 by 2030, as well as to eliminate HIV-related stigma and discrimination by 2020 [6-8]. The call for action entailed scaling-up HIV response among people living with HIV (PLHIV) to achieve coverage levels of 90% for HIV testing, treatment, and sustained viral suppression by 2020 [6], and of 95% by 2030 [6, 8]. A specific emphasis has been placed on increasing the proportion of HIV-positive and HIV-negative key populations with access to tailored HIV combination prevention services to reach the global targets [6].

Despite progress, the global community fell short of meeting set targets, with 1.7 million new HIV infections [7] and 680,000 AIDS-related deaths in 2020 [9]. Importantly, 62% of newly acquired infections among adults were among key populations and their sexual partners [1], indicating persisting gaps in reaching populations most at-risk [4].

The advent of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic presented another challenge to the global HIV response, with a 20% disruption in HIV treatment services (ART) over six months estimated to yield more than 110,000 additional AIDS-related deaths [4]. However, recent empirical evidence from seven African countries supported by the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) suggested overall lower-than-previously-anticipated interruption to services, although wide variability in rapid adoption of mitigation measures was observed across countries [10]. The impact on key populations remains to be fully elucidated but preliminary evidence also suggests widening gaps in increasing these populations' accessibility to HIV services. For example, preliminary reports from 86 countries indicated 40% disruption in delivery of HIV services to FSWs between March-June 2020 [4]. Evidence from Zimbabwe further indicated a lower ability for FSWs to negotiate safer sex and a higher likelihood for exchanging sex for food during the pandemic given the decline in the number of clients [11].

With growing consensus that achieving substantial reduction in HIV-related morbidity and mortality cannot be reached without targeting populations most affected by HIV, a new set of targets was formulated for 2025 with emphasis on addressing inequalities among PLHIV to get back on track to reaching the elimination goal by 2030 [7, 12]. The newly-set targets entail achieving, by 2025, coverage levels of 95% for HIV testing, treatment, and sustained viral suppression among PLHIV, as well as expanding access of reproductive-age women to HIV, sexual, and reproductive health services, and of populations at risk of HIV to effective combination prevention interventions by 95% [7, 12]. Additional targets include reducing to <10% each of the proportion of countries with punitive laws that limit access to HIV services, the proportion of PLHIV experiencing stigma and discrimination, and the proportion of women, PLHIV, and key populations experiencing gender inequality and violence [7, 12].

1.2. Global burden of HIV and other sexually transmitted infections (STIs) among FSWs

Tackling the HIV epidemic among FSWs entails first knowing the size of the population that programs need to cater for. Estimates for the population proportion of FSWs at a national level (that is the proportion of FSWs among adult women of reproductive age) according to the only systematic review found in the literature, albeit out of date, range between 0.7-4.3% in sub-Saharan Africa, 0.2-2.6% in Asia, 0.1-1.5% in Eastern and Central Europe, 0.1-1.4% in West Europe, and 0.2-7.4% in Latin America [13]. Although proportions may seem small, this translates to millions of FSWs being at risk of acquiring HIV and in need of HIV prevention or treatment services.

The mean HIV prevalence among FSWs was estimated globally at 10.4% between the years 2006 and 2017, and regionally at 33.3% (81 datapoints) in Eastern and Southern Africa, 20.1% (46 datapoints) in West and Central Africa, 8.0% (20 datapoints) in Eastern Europe and Central Asia, 7.4% (45 datapoints) in Western and Central Europe and North America, 5.7% (183 datapoints) in Asia and the Pacific, 4.2% (56 datapoints) in Latin America and the Caribbean, and 1.8% (19 datapoints) in the Middle East and North Africa (MENA) [14]. In low- and middle-income countries (LMICs), the odds of HIV acquisition were 13.5-fold higher among FSWs compared with women in the general population [15], highlighting the extent of FSWs' vulnerability to HIV infection.

FSWs are also at increased risk of acquiring other sexually transmitted infections (STIs) [16] but there are few surveillance and epidemiological studies for curable STIs such as *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and *Treponema pallidum* (syphilis) among them [16]. A systematic review of studies between 1995 and 2006 reported global prevalence among FSWs in the range of 0.6-46.2% (30 datapoints) for *Chlamydia trachomatis*, 0.5-41.3% (33 datapoints) for *Neisseria gonorrhoeae*, 0.1-51.0% (20 datapoints) for *Trichomonas vaginalis*, and 1.5-60.5% (31 datapoints) for syphilis [17]. Similarly, a systematic review of studies between 1950 and 2008 contrasting migrant and non-migrant FSWs reported prevalence in the range of 0-19% (24 datapoints) for *Chlamydia trachomatis*, 0-27% (32 datapoints) for *Neisseria gonorrhoeae*, 0-1% (2 datapoints) for *Trichomonas vaginalis*, and 1-18% (14 datapoints) for syphilis, with higher prevalence found among migrant FSWs and those from lower income countries [18]. None of these reviews included data from the MENA region. More recent estimates (2008-2018) were available only for syphilis through the Global AIDS Response Progress Reporting (GARPR) system; these ranged from 0.0-52.3% (31 datapoints) in the African Region, 0.0-18.0% (22 datapoints) in the Region of the Americas, 0.7-17.7% (11 datapoints) in the European Region, and 0.4-17.7% (9 datapoints) in MENA [16].

STIs have been associated with higher sexual risk behaviour [19-24] and increased risk of HIV acquisition [25-27]. Therefore, theoretically, monitoring of STIs can provide insights onto HIV epidemic potential. However, given their curable nature, the aforementioned curable STIs may not be the most reliable markers to this end [28]. An established biological marker of sexual risk behaviour and HIV epidemic potential is herpes simplex virus type 2 (HSV-2), which is almost exclusively transmitted through the sexual route, is more transmissible than HIV, and produces long-lasting antibodies [28-33]. As expected, HSV-2 prevalence levels among FSWs vary across settings based on the structure of heterosexual sex work networks (HSWNs) [30] but are generally high often exceeding 50% [34-36].

1.3. Role of HSWNs in the HIV epidemic

Precise estimates for the contribution of HIV epidemics in HSWNs to HIV incidence have been limited by estimation approaches and the dearth of data on HSWNs structure [37, 38]. Classic methods, using the UNAIDS Modes of Transmission (MoT) model and population attributable fraction (PAF) measures, fail to capture the dynamics of partnerships' formation and dissolution and of HIV transmission within HSWNs including the onward chains of infection transmission over time, and thus often underestimate the contribution of these networks to HIV incidence [37-40]. Dynamic mathematical models applied to generalized HIV epidemics in sub-Saharan Africa estimated the fraction of incident infections attributable to HSWNs over 20 years in the range of 58.3-88.9% in the absence of interventions, and of 13.5-37.6% in countries with medium to high condom use levels [38]. Similarly, a dynamic model incorporating all key populations attributed close to half of HIV incidence during 2010-2019 in South Africa to HSWNs, with most new infections occurring among clients and their sexual partners [41]. Although this approach is yet to be well investigated in countries with concentrated epidemics, the contribution of HSWNs to HIV incidence and number of PLHIV is likely to be also considerable given the large size of the client population and the high potential for onward infection transmission, particularly to stable partners of clients of FSWs [40, 42, 43].

1.4. HIV prevention interventions among FSWs

HIV testing and linkage to care remain the leading challenges against reaching even the 90-90-90 targets among FSWs [4]. A systematic review of HIV testing among FSWs that included ten studies from six countries (Benin, Canada, China, Dominican Republic, Iran, and Kenya) between 2000-2017 [44] reported the proportion of FSWs who underwent testing in the past 12 months in the range of 22.0% in China to 76.1% in Canada, with the most commonly reported barriers being financial or related to stigma and discrimination [44]. The new WHO testing guidelines recommend the use of HIV self-testing as a complementary approach to standard HIV testing after recent evidence suggested its association with higher testing uptake but lower linkage to care among key populations [45, 46]. For instance, a recent systematic review found that although HIV self-testing was associated with 36% increase in testing uptake among FSWs compared to standard HIV testing (Relative risk (RR): 1.36; 95%CI: 1.04-1.78), it resulted in a 16% decrease in linkage to ART (RR: 0.84; 95% CI: 0.75-0.94) [47].

The latest UNAIDS Gap Report further highlighted the suboptimal ART coverage among FSWs compared to general population women in nine out of 12 LMICs with available data for the years 2013-2015 [48]. Inequalities in accessing ART have been also documented among HIV-positive FSWs with a systematic review conducted in 2014 pointing to 80% of FSWs in high income countries reporting ever being on ART compared to only 39% of those in LMICs [49]. Despite limited access to HIV testing and treatment in many settings, considerable levels of adherence to treatment and of viral suppression have been reported among FSWs. In the previous systematic review, adherence to ART was estimated at 76% while viral suppression was assessed at 57% [49]. Recently, a study among HIV-positive FSWs in Iringa, Tanzania revealed that only a third of FSWs were aware of their HIV sero-status, yet, of those, 70% were on ART with most being virally suppressed [50]. A study comparing FSWs to general population women in Manicaland, Zimbabwe further showed that HIV-positive FSWs were 1.6-fold more likely to have been tested for HIV and 2.3-fold more likely to have initiated ART compared to HIV-positive general population women whereas ART adherence was comparable between the two groups [51].

Interestingly, the higher testing uptake among FSWs was mainly attributed to greater self-perceived risk and proximity to testing services [51], affirming that structural factors are often the main hinderance in capturing and retaining HIV-positive FSWs in the HIV testing and treatment cascade.

Recommended HIV combination prevention interventions among FSWs comprise HIV testing services and linkages to ART therapy or pre-exposure prophylaxis (PrEP), condoms and lubricant programming, clinical health services, peer-led outreach services, as well as community empowerment and violence prevention programming [6, 52]. The effectiveness of this multifaceted approach on curbing the HIV epidemic has been demonstrated in multiple settings [52-57]. In Thailand, the nationwide implementation of the ‘100% condom use programme’, which incorporated empowerment of FSWs to refuse unprotected sex along with STI treatment in the early 1990s, increased condom use levels among facility-based FSWs to over 90% by 1993 yielding a marked decline in HIV prevalence among this population from 33.2% in 1994 to 2.8% in 2010, and among antenatal clinic attendees from 1.5% in 2000 to 0.9% in 2009 [53]. The program further resulted in a 95% decline in curable STIs across the country between 1990-2000 [53]. Similar success was observed in Cambodia where the increase in condom use levels among brothel-based FSWs, from 20% in 1996 to over 90% in 2001, was reflected in declining HIV incidence trends among this population from 13.2% in 1999 to 6.5% in 2002 [53]. HIV prevalence also declined among brothel-based FSWs from 42% in 1996 to 14% in 2006, and among the general population from 2.0% in 1998 to 0.6% in 2011 [53]. These programs subsequently evolved to accommodate outreach for the increasingly mobile FSW populations [53]. In India, community-led structural interventions in Calcutta, ‘the Sonagachi project’, increased condom use among FSWs in this red-light district from 3% in 1992 to 90% in 1999, and were linked to an HIV prevalence of 11% among this population in 2000 compared to prevalence levels of 50-90% among FSWs in other regions [55]. A trend of declining syphilis from 25% in 1992 to 0.2% in 1998 in Sonagachi district was also reported [53].

Over the last decade, the large-scale implementation of combination prevention interventions among key populations including FSWs in six Indian states through the Avahan project was estimated to have reduced HIV prevalence among the general population by a range of 2.4-12.7% [56]. A systematic review summarizing the impact of community empowerment interventions among FSWs in LMICs estimated the reduction in HIV prevalence among them at 32.0%, in *Chlamydia trachomatis* prevalence at 25.3%, in *Neisseria gonorrhoeae* prevalence at 38.8%, and in syphilis prevalence at 46.9% [57]. Results further indicated a three-fold increase in condom use among FSWs' clients [57]. More recently, a clinical trial conducted among HIV-positive FSWs in the Dominican Republic highlighted the impact of multi-level interventions on increasing adherence to ART and engagement in protected sexual intercourse among FSWs as well as their sexual partners [54]. Similarly, the SAPPH-IRe trial in Zimbabwe showed that a comprehensive prevention program that includes community mobilization in addition to health and legal services can achieve substantial gains in terms of HIV testing, treatment coverage, and viral suppression among FSWs [58]. The effectiveness of the HIV combination prevention approach has been also demonstrated in mathematical modelling studies [52, 59, 60].

Evidence increasingly suggest that achieving the 90-90-90 targets entails a holistic and extensive approach that also addresses structural barriers, notably stigma, discrimination, violence, punitive laws, criminalization, political disengagement, and the scarcity of funding, which are the main hinderance against FSWs' inclusion and maintenance in the HIV cascade [14, 61, 62].

2. HIV epidemiology in MENA

2.1. MENA definition

The MENA region is defined in this thesis to include countries that featured in the regional definition of at least two of the three international organizations leading HIV efforts in MENA, namely UNAIDS, the WHO, and the World Bank (Appendix I) [42]. The definition encompasses 23 countries extending from Morocco in the West to Afghanistan and Pakistan in the East (Figure 1). This region includes about 10% of the world's population [63].

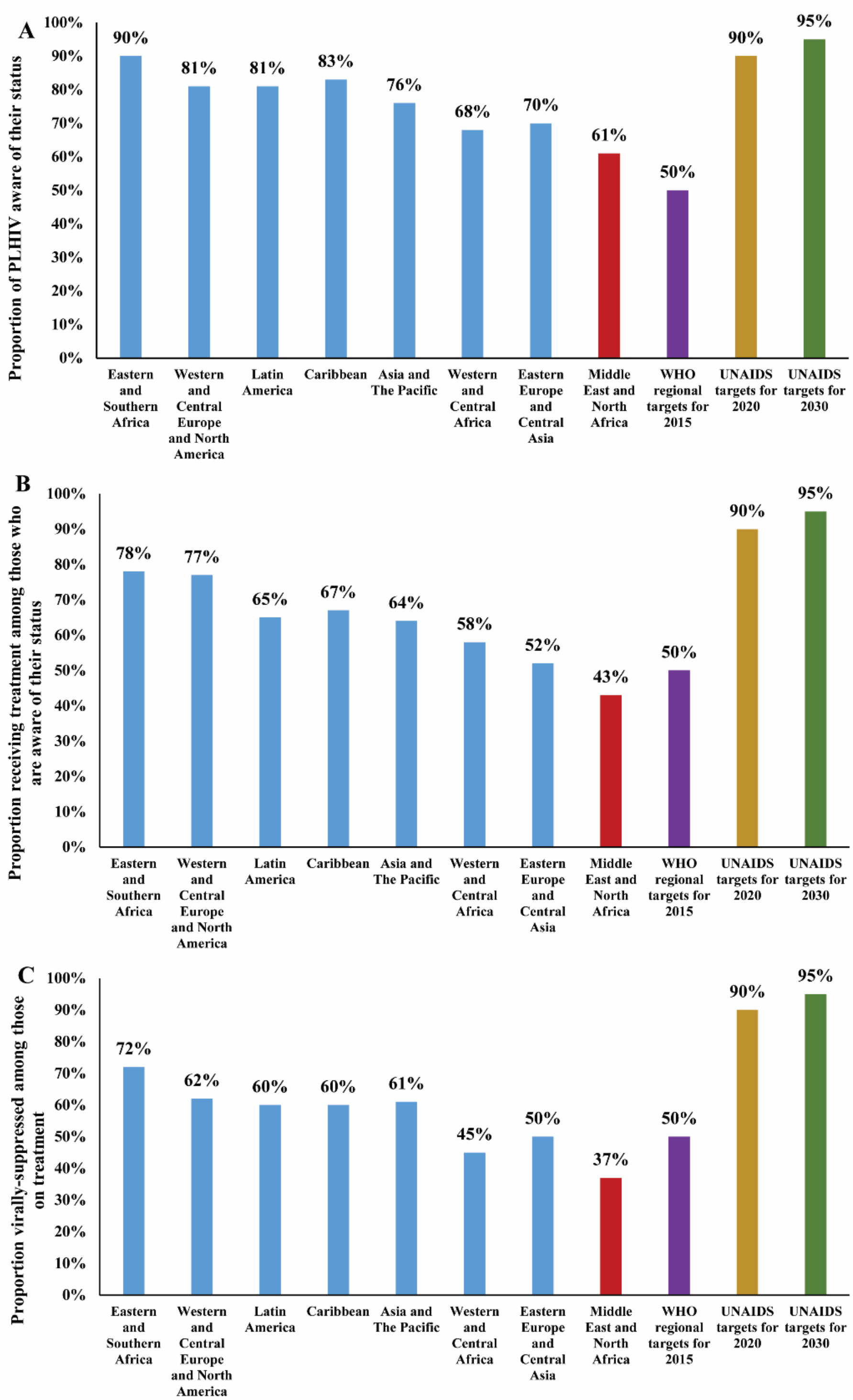
Figure 1. Map of the Middle East and North Africa region. This defintion covers 23 countries including Afghanistan, Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates (UAE), and Yemen. This definition is based on the definitions of the World Health Organization's Regional Office for the Eastern Mediterranean, the Joint United Nations Programme on HIV/AIDS, and the World Bank. Countries were eligible for inclusion if they were part of at least two international organizations' definition for this region (Appendix I).

2.2. Status of HIV epidemic and response in MENA

MENA is a region where HIV incidence and AIDS-related mortality are still rising [4]. The number of new HIV infections in this region increased by 25% since 2010, while that of AIDS-related deaths increased by three-fold since the year 2000 [4]. Of all world regions, MENA has the lowest proportion of PLHIV who are aware of their status, the lowest coverage of ART, and the lowest proportion for viral suppression, assessed respectively at 61%, 43%, and 37% in 2020 [64], far behind even the WHO regional target of 50% ART coverage that was set to be reached in 2015 [65], as well as far behind the 90-90-90 UNAIDS targets by 2020 [6] and the 95-95-95 UNAIDS targets by 2025 [7] (Figure 2).

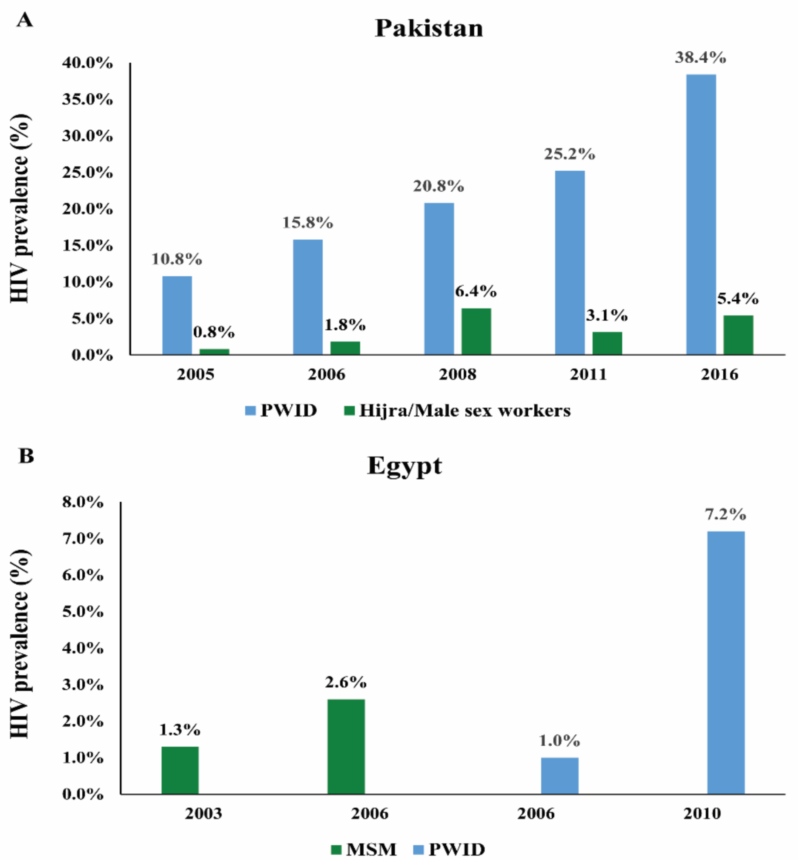
Several factors may have contributed to the region's poor progress towards set targets. For a long time, the region has been perceived as 'a real hole in terms of HIV/AIDS epidemiological data' [66]. Despite recent progress in HIV research and surveillance [67], including conduct of integrated bio-behavioural surveillance surveys (IBBSS) [68, 69], many of these data are, at best, published in country-level reports, or never analysed. The limited availability of a rigorous scientific base that is grounded on sufficient and quality data to inform response to HIV and other STIs in many countries, coupled with ongoing political conflicts, political and socio-cultural sensitivities surrounding sexual activity, and limited resources, have set HIV and STI surveillance and targeted programming low on MENA countries' public health agendas [70]. Programs targeting sexual health, where they exist, remain small in scale and mostly geared towards the general population rather than key populations [70]. The latter continue to be stigmatized and lacking access to comprehensive and confidential services [42, 71, 72]. Almost all programming for key populations, whenever available, is provided by non-governmental organizations that often lack the resources or legal coverage to deliver comprehensive services [42, 72].

Figure 2. HIV testing and treatment cascade across world regions [4] compared to WHO regional targets for 2015 [65], UNAIDS 90-90-90 targets for 2020 [6] and UNAIDS 95-95-95 targets for 2030.



Since 2007, the 'MENA HIV/AIDS Epidemiology Synthesis Project' has maintained an active regional HIV database [42, 73]. The first systematic syntheses of these data documented concentrated and emerging epidemics among MSM [74] and PWID [75], the majority of which emerged within the last two decades [74, 75]. This review provided conclusive evidence of an established HIV epidemic among PWID in Iran among whom HIV prevalence stabilized at 15% [75]. In Pakistan, findings of consecutive IBBSS [74-77] showed a steady increase in HIV prevalence among PWID that was followed by an increase in HIV prevalence among hijra (transgender people)/male sex workers (Figure 3A). In Egypt, the rise in HIV prevalence among MSM [74] was also followed by a rise in prevalence among PWID [75] (Figure 3B).

Figure 3. Trend in HIV prevalence observed in subsequent rounds of integrated bio-behavioural surveillance surveys among MSM and PWID in A) Pakistan and B) Egypt.



Nascent HIV epidemics were also identified among MSM in Morocco (4.4% in 2008), Tunisia (4.9% in 2010), Sudan (9.3% in 2005), and Iran (14.8% in 2007) [74]. Emerging HIV epidemics among PWID were further documented at the subnational level in Afghanistan (range: 0-18.2%) and Morocco (range: 0-37.8%) [75]. Findings of these first systematic analyses of MENA data have been key in informing UNAIDS HIV/AIDS epidemic updates for MENA and in identifying priority countries, populations, and cities for fast-tracking the regional HIV response [6, 78].

2.3. Thesis rationale and scope

This PhD focuses on the second phase of the MENA HIV/AIDS Epidemiology Synthesis Project, and aims to comprehensively characterize the epidemiology of HIV among FSWs and their clients in MENA. Although the size of HSWNs in this region is expected to be much larger than that of MSM or PWID, estimates for the population proportion of FSWs, the volume of clients they serve, and the geographic and temporal trends in HIV infection burden among these populations and their direct sexual contacts are poorly characterized. This evidence gap in our understanding of HIV epidemiology in the MENA region has been highlighted in UNAIDS Gap report which referred to 'a lack of data on the burden of HIV among sex workers in the region' and indicated that 'the epidemic among them is poorly understood', while acknowledging that 'HIV in every country is expected to disproportionately affect sex workers' [79]. The contributions of FSWs and their clients to onward infection transmission and population-level incidence continue to be missing from the regional HIV map and from the strategic and programmatic directives for HIV response in MENA [6]. The potential impact of scaling-up interventions among these populations on the course of the HIV epidemic in terms of the number of new HIV infections and the total number of PLHIV on the short and long runs remains to be explored.

This PhD research was designed to address this evidence gap by improving understanding of the HIV epidemic in HSWNs in the MENA region, and to identify aspects of the epidemic that require immediate policy action by stakeholders. The ultimate goal of this work is to support MENA countries' progress towards achieving elimination of HIV/AIDS as a public health threat by 2030.

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CHAPTER 2. THESIS OBJECTIVES AND STRUCTURE

1. Overall aim

This thesis aims to fill a gap in our understanding of the HIV epidemic in HSWNs in MENA by characterizing comprehensively the epidemiology of HIV among FSWs and their clients, synthesizing evidence on other STIs among FSWs, investigating the utility of HSV-2 as a predictor of HIV epidemic potential among FSWs, and estimating HIV incidence arising in HSWNs, its contribution to population-level incidence, and the potential for reducing it by expanding coverage of select prevention interventions. The goal of the research is to provide the evidence base necessary to inform HIV response as well as key public health research and policy priorities in this region.

Objectives

The specific objectives are:

1) To provide a critical appraisal of the epidemiology of HIV among FSWs and their clients across MENA by systematically reviewing, synthesizing, and summarizing the evidence for size estimation measures, HIV infection burden, sexual and injecting risk behaviour, coverage of prevention and treatment interventions, HIV testing and perception of risk, in addition to identifying sources of heterogeneity, regional variability, and temporal trends in HIV prevalence.

2) To provide a critical appraisal of the epidemiology of STIs among FSWs in MENA by systematically reviewing, synthesizing, and summarizing the evidence for *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, syphilis and Herpes

Simplex Virus type 2 (HSV-2) incidence and/or prevalence, and identifying sources of heterogeneity, regional variability, and temporal trends in STI prevalence where possible.

3) To investigate the utility of HSV-2 as a predictor of HIV epidemic potential among FSWs through an ecological analysis of paired HSV-2 and HIV antibody prevalence data among FSWs globally and to determine the magnitude of the association between these infections factoring in regional, temporal, and condom use differences among FSWs.

4) To estimate, using a novel individual-based mathematical model applied to MENA countries, HIV incidence arising in HSWNs including FSWs, clients, and clients' stable sexual partners (spouses/cohabiting partners), the relative contribution of heterosexual sex versus injecting drug use to incidence among FSWs, the contribution to HIV incidence in HSWNs to incidence in the total adult population, and the impact of achieving different coverage targets for prevention interventions among FSWs on HIV incidence arising in HSWNs.

A brief outline of the research questions and methodology addressing these specific objectives can be found in Table 1.

Table 1. Specific objectives, methodology, and research questions for understanding HIV epidemiology in heterosexual sex work networks (HSWNs) in the Middle East and North Africa (MENA).

Specific objectives	Methodology	Research questions
1. To provide a critical appraisal of the epidemiology of HIV among FSWs and their clients across MENA by systematically reviewing, synthesizing, and summarizing the evidence for size estimation measures and for HIV infection burden in these populations, and identifying sources of heterogeneity, regional variability, and temporal trends in HIV prevalence.	Systematic review, data synthesis, meta-analysis, and meta-regression	<u>Primary research questions</u>: a. What are the sizes of the FSW and client populations across MENA countries? b. What is the incidence and prevalence of HIV among FSWs and their clients across MENA countries? c. Is there evidence for regional and temporal variability in HIV prevalence among FSWs and their clients across MENA? d. What are the sources of between-study heterogeneity in HIV prevalence among FSWs and their clients across MENA? <u>Secondary research questions</u>: e. What is the scope and quality of available evidence for size estimation and for HIV incidence and prevalence among FSWs and their clients? f. What are the characteristics of sexual and injecting risk behaviours among FSWs and their clients?
2. To provide a critical appraisal of the epidemiology of STIs among FSWs in MENA by systematically reviewing, synthesizing, and summarizing the evidence for *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, syphilis and HSV-2 incidence and/or prevalence, and identifying sources of heterogeneity, regional variability, and temporal trends in STI prevalence where possible.	Systematic review, data synthesis, meta-analysis, and meta-regression	<u>Primary research questions</u>: a. What is the incidence and prevalence of STIs (*Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and *Treponema pallidum* (syphilis), and HSV-2) among FSWs across MENA countries? b. Is there evidence for regional and temporal variability in STI prevalence among FSWs across MENA? c. What are the sources of between-study heterogeneity in STI prevalence among FSWs across MENA? <u>Secondary research question</u>: d. What is the scope and quality of available evidence for STI incidence and prevalence among FSWs?
3. To investigate the utility of HSV-2 as a predictor of HIV epidemic potential among FSWs through an ecological analysis of paired HSV-2 and HIV antibody prevalence data among FSWs globally and determine the magnitude of the association between these infections factoring in regional, temporal, and condom use differences among FSWs.	Systematic review, meta-analysis, meta-regression, and statistical analysis	<u>Research questions</u>: a. What is the distribution of paired HSV-2 and HIV prevalence measures among FSWs across world regions? b. How is HIV prevalence among FSWs distributed across different cut-off values for HSV-2 prevalence?

Specific objectives	Methodology	Research questions
		c. Is there evidence for an association between HSV-2 and HIV after adjusting for regional, temporal and condom use differences among FSWs?
4. To estimate, using a novel individual-based mathematical model applied to MENA countries, HIV incidence arising in HSWNs, the relative contribution of heterosexual sex versus injecting drug use to incidence among FSWs, the contribution to HIV incidence in HSWNs to incidence in the total adult population, and the impact of achieving different coverage targets for prevention interventions among FSWs on HIV incidence arising in HSWNs.	Individual-based mathematical model and statistical analysis	Research questions: a. What is the current HIV incidence and incidence rate (in the year 2020) among FSWs, their clients, and clients' stable sexual partners at country-level across MENA? b. What is the relative contribution of heterosexual sex versus injecting drug use to HIV incidence among FSWs across MENA? c. What are the contributions of incident HIV infections arising among FSWs, their clients, and clients' stable sexual partners over the course of one year to total HIV incidence in the adult population at country-level across MENA? d. What is the impact of achieving different coverage targets for select interventions among FSWs on HIV incidence in HSWNs (number of new infections averted) by 2030?

2. Thesis structure and research papers outline

This thesis follows the research paper format and includes four research papers, three of which have been published in peer-reviewed journals [1-3]. The fourth paper is currently submitted [4]. Each research paper was written as a stand-alone manuscript and is presented in a separate chapter. Consequently, there is overlap between thesis chapters, for example, in the discussion of the current state of the HIV epidemic and response in MENA.

Research papers are included in their published format. Each paper is preceded by a cover sheet that provides publication details and highlights my contribution (as first and corresponding author). The latter is followed by a preamble or introduction to the chapter. A summary of findings highlighting the take-home messages from each study is included at the end of each paper/chapter along with 'linking material' that describes how each paper logically led to the subsequent one. Research papers are supported by additional published supplementary material that includes further details on research methodology and results. The latter was included as a separate appendix for each paper. The final chapter contains a general discussion and high-level synthesis of research findings along with recommendations for policy and future research work.

The thesis includes seven chapters structured as follows:

Chapter 1 provides the background for the thesis work. It reviews the global literature on HIV epidemiology among FSWs and their clients and conveys our current understanding of the HIV epidemic in key populations in the MENA region while highlighting the gaps that motivated the design of this thesis.

Chapter 2 describes the thesis overall aim, specific objectives, and structure.

Chapter 3 presents **Research paper 1**, published in *BMC Medicine*. The paper provided an in-depth characterization of HIV epidemiology among FSWs and their clients across MENA countries, and described the sexual and injecting risk environments, through an exhaustive systematic review complemented with meta-analyses and meta-regressions (**objective 1**). While the paper identified established and emerging epidemics among FSWs, it also documented limited prevalence of <1% in several countries. The latter motivated assessment of STIs as biological markers of sexual risk behaviour among FSWs (research paper 2), followed by a demonstration of the utility of HSV-2 as a predictor of HIV epidemic potential in settings where infection circulation among FSWs is still limited (research paper 3). Findings of this systematic review were also used towards parameterization of the individual-based mathematical model constructed to estimate current HIV incidence among FSWs and evaluate the impact of interventions in different MENA countries (research paper 4).

Chapter 4 presents **Research paper 2**, published in the *Journal of Global Health*. The paper provided the first detailed assessment of the epidemiology of key STIs among FSWs in MENA, also through a systematic review complemented with meta-analyses and meta-regressions (**objective 2**). The study suggested a major role for HSWNs in STI transmission across MENA and highlighted the need for strengthening STI surveillance and response targeting FSWs, which continue to be poor in most countries.

Chapter 5 presents **Research paper 3**, published in *Scientific Reports*. The paper demonstrated the utility of HSV-2 as a tool that can predict HIV epidemic potential among FSWs and inform HIV preparedness efforts, particularly in countries where infection circulation among FSWs is still limited (**objective 3**). Given that research paper 2 identified only three studies documenting HSV-2 among FSWs in the region, an ecological analysis of HSV-2/HIV paired measures with a focus on MENA was not possible. Alternatively, this research paper investigated the ecological association between HSV-2 and HIV using paired data identified through a global systematic review of these measures among FSWs.

Chapter 6 presents **Research paper 4**, submitted to the *Lancet HIV*, presents a novel individual-based mathematical model that was constructed to describe HIV transmission dynamics in HSWNs. The model was parameterized using data on HIV prevalence, sexual and injecting risk behaviour, and current coverage of prevention and treatment interventions among FSWs and clients identified in Research paper 1, to estimate, for each MENA country with sufficient data, HIV incidence and incidence rates arising in HSWNs, the relative contribution of heterosexual sex versus injecting drug use to HIV incidence among FSWs, the contribution of HSWNs to total HIV incidence in the adult population, and the impact of select prevention interventions among FSWs on curbing HIV incidence in HSWNs (**objective 4**). The study provided current estimates for HIV incidence data in HSWNs and suggested substantial circulation of HIV in HSWNs along with sizable onward transmission to stable partners of clients of FSWs. Findings further suggested that expansion of select prevention interventions among FSWs, even to suboptimal levels, can yield substantial gains in the number of infections averted in the wider HSWN. Data provided by the study can be instrumental in informing HIV response and programming and in assessing progress towards regional and global HIV elimination targets.

Chapter 7 discusses the main findings of this thesis, describes their implications on HIV and STI policy and programming, and provides recommendations for future research in the region. This chapter further includes an account of thesis main contributions, strengths, and limitations.

3. The role of the candidate

This thesis is part of the second phase of the “MENA HIV/AIDS Epidemiology Synthesis Project”, which was funded by the Qatar National Research Fund (NPRP grant number 9-040-3-008), through an award to Dr. Laith Abu-Raddad, my PhD co-supervisor. Additional infrastructure support was provided by the Biostatistics, Epidemiology, and Biomathematics Research Core at the Weill Cornell Medicine-Qatar.

I am the first and corresponding author on all research papers given my contributions to the design, implementation, analysis, interpretation and synthesis of results of these studies, as well as writing and revision of the first manuscript and subsequent drafts based on co-authors’ and peer-reviewers’ comments.

For research paper 1, I designed the study and revised it based on feedback from my supervisors and a PhD committee advisor. Specifically, I devised the search strategy and its conceptual framework, determined the inclusion and exclusion criteria, devised the methodology for the quality assessment of studies, conducted the systematic literature review including screening of articles and extraction, analysis, and synthesis of data, and wrote the first draft of the article and revised it based on feedback from co-authors and peer-reviewers.

For research paper 2, I conceived and designed the study, conducted all steps of the systematic literature review as described above, analysed and synthesised the data, wrote the first draft of the article and revised it based on feedback from co-authors and peer-reviewers.

For research paper 3, I had access to a database of an earlier systematic review examining paired HSV-2 and HIV prevalence measures in different populations globally, but given the need to update this database with more recent data for FSWs, differences in methodology in terms of the definition of FSWs as well as variables to be factored in the analysis, I re-implemented all the steps of the systematic literature review process including data extraction. I analysed and synthesised the data, wrote the first draft of the article and revised it based on feedback from co-authors and peer-reviewers.

For research paper 4, I co-conceived the study, designed the study and model, coded the mathematical model, conducted the model parameterization, generated simulations, wrote the first draft of the article, and revised it based on feedback from co-authors. This paper included other co-authors who provided technical programming assistance given the complexity of coding the structure of sexual networks. The paper is also co-authored by other collaborators from the WHO Regional Office for the Eastern Mediterranean (EMRO) and UNAIDS who facilitated access to data and provided insights on policy implications of research findings.

Further details of my contribution and the role of co-authors can be found in the research papers.

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CHAPTER 3. RESEARCH PAPER 1-HIV EPIDEMIOLOGY AMONG FSWS AND CLIENTS IN MENA

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Student ID Number	LSH395506	**Title**	Mrs
First Name(s)	Hiam		
Surname/Family Name	Chemaitelly		
Thesis Title	Characterizing HIV epidemiology among female sex workers and their clients in the Middle East and North Africa		
Primary Supervisor	Professor Helen Weiss		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	BMC Medicine		
When was the work published?	24 June 2019		
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1. Preamble

This chapter provides an in-depth characterization of the status of the HIV epidemic among FSWs and their clients across MENA through a systematic synthesis of evidence for population-size estimates and HIV incidence and prevalence data, derivation of summary estimates for HIV prevalence in these populations, investigation of regional-level associations with prevalence and sources of heterogeneity between studies, assessment of temporal trends, and synthesis of data on sexual and injecting risk behaviours among FSWs (**addresses objective 1 of thesis**). The study was motivated by evidence of emerging HIV epidemics among MSM [1] and PWID [2] in MENA over the last two decades [1, 2], and persisting gaps in our knowledge of the status of the epidemic among FSWs [3] despite the large size of HSWNs relative to those of MSM and PWID.

The objectives of this study were addressed through a systematic review of evidence for population-size estimates for FSWs and clients, sex work population proportions, HIV incidence, and HIV prevalence in FSWs and clients retrieved through searching over ten international, regional, and country-level databases that incorporated country-level and international organizations' reports as well as routine data reporting [4, 5], meta-analyses pooling HIV prevalence measures at both the country and regional levels, and meta-regression analyses examining associations with HIV prevalence factoring in regional and temporal heterogeneities as well as studies' quality assessment domains.

Further published details on study methodology and results can be found in Appendix II. Unpublished preparatory work for this study such as the conceptual framework and results of the systematic review of systematic reviews of studies among FSWs and clients globally that were used to devise the search strategy can be found in Appendix III, detailed study selection criteria can be found in Appendix IV, and an overview of available quality assessment tools screened to determine studies' quality assessment domains can be found in Appendix V.

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HIV epidemiology among female sex workers and their clients in the Middle East and North Africa: systematic review, meta-analyses, and meta-regressions

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Abstract

Background: HIV epidemiology among female sex workers (FSWs) and their clients in the Middle East and North Africa (MENA) region is poorly understood. We addressed this gap through a comprehensive epidemiological assessment.

Methods: A systematic review of population size estimation and HIV prevalence studies was conducted and reported following PRISMA guidelines. Risk of bias (ROB) assessments were conducted for all included studies using various quality domains, as informed by Cochrane Collaboration guidelines. The pooled mean HIV prevalence was estimated using random-effects meta-analyses. Sources of heterogeneity and temporal trends were identified through meta-regressions.

Results: We identified 270 size estimation studies in FSWs and 42 in clients, and 485 HIV prevalence studies in 287,719 FSWs and 69 in 29,531 clients/proxy populations. Most studies had low ROB in multiple quality domains. The median proportion of reproductive-age women reporting current/recent sex work was 0.6% (range = 0.2–2.4%) and of men reporting currently/recently buying sex was 5.7% (range = 0.3–13.8%). HIV prevalence ranged from 0 to 70% in FSWs (median = 0.1%) and 0–34.6% in clients (median = 0.4%). The regional pooled mean HIV prevalence was 1.4% (95% CI = 1.1–1.8%) in FSWs and 0.4% (95% CI = 0.1–0.7%) in clients. Country-specific pooled prevalence was < 1% in most countries, 1–5% in North Africa and Somalia, 17.3% in South Sudan, and 17.9% in Djibouti. Meta-regressions identified strong subregional variations in prevalence. Compared to Eastern MENA, the adjusted odds ratios (AORs) ranged from 0.2 (95% CI = 0.1–0.4) in the Fertile Crescent to 45.4 (95% CI = 24.7–83.7) in the Horn of Africa. There was strong evidence for increasing prevalence post-2003; the odds increased by 15% per year (AOR = 1.15, 95% CI = 1.09–1.21). There was also a large variability in sexual and injecting risk behaviors among FSWs within and across countries. Levels of HIV testing among FSWs were generally low. The median fraction of FSWs that tested for HIV in the past 12 months was 12.1% (range = 0.9–38.0%).

Conclusions: HIV epidemics among FSWs are emerging in MENA, and some have reached stable endemic levels, although still some countries have limited epidemic dynamics. The epidemic has been growing for over a decade, with strong regionalization and heterogeneity. HIV testing levels were far below the service coverage target of "UNAIDS 2016–2021 Strategy."

Keywords: HIV, Sexually transmitted infections, Sex workers, Sex work, Prevalence, Incidence, Population size, Risk group size, Middle East and North Africa

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Background

The Middle East and North Africa (MENA) is one of only two regions where HIV incidence and AIDS-related mortality are rising [1]. Between 2000 and 2015, the increase in the number of new infections was estimated at over a third, while that of AIDS-related deaths, at over threefold [1–3]. MENA has been described as "a real hole in terms of HIV/AIDS epidemiological data" [4], with unknown status and scale of epidemics in multiple countries [5–7].

Despite recent progress in HIV research and surveillance in MENA [8], including the conduct of integrated bio-behavioral surveillance surveys (IBBSS) [5, 9], many of these data are, at best, published in country-level reports, or never analyzed. Since 2007, the "MENA HIV/AIDS Epidemiology Synthesis Project" has maintained an active regional HIV database [6]. The first systematic syntheses of HIV data documented concentrated and emerging epidemics among men who have sex with men (MSM) [10] and people who inject drugs (PWID) [11]. The majority of these epidemics emerged within the last two decades [10, 11].

Although the size of commercial heterosexual sex networks is expected to be much larger than the risk networks of MSM and PWID [6, 7], estimates for the population proportion of female sex workers (FSWs), volume of clients they serve, and geographic and temporal trends in infection remain to be established. This evidence gap was highlighted in the latest gap report by the Joint United Nations Programme on HIV/AIDS (UNAIDS) [3], indicating "a lack of data on the burden of HIV among sex workers in the region" and stressing that "the epidemic among them is poorly understood" though "HIV in every country is expected to disproportionately affect sex workers" [3].

This study characterizes HIV epidemiology among FSWs and their clients in MENA by (1) systematically reviewing and synthesizing all available published and unpublished records documenting population size estimates, population proportions, HIV incidence, and HIV prevalence (including in proxy populations of clients such as male sexually transmitted infection (STI) clinic attendees); (2) estimating, for each population, the pooled mean HIV prevalence per country and regionally; (3) identifying the regional-level associations with prevalence, sources of heterogeneity, and temporal trends; and (4) synthesizing the key measures of sexual and injecting risk behaviors.

Methods

Search strategy and selection criteria

Evidence for population size estimate, population proportion, HIV incidence, and HIV prevalence in FSWs and clients was systematically reviewed as per Cochrane's Collaboration guidelines [12]. Findings were reported following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [13] (checklist in Additional file 1: Table S1). MENA definition here includes 23 countries extending from Pakistan to Morocco (Additional file 1: Figure S1), based on the convention in HIV research [6, 7, 10, 11] and on World Health Organization (WHO), UNAIDS, and World Bank definitions [6]. MENA was also classified by subregion comprising Eastern MENA (Afghanistan, Iran, Pakistan), the Fertile Crescent (Egypt, Iraq, Jordan, Lebanon, Palestine, Syria), the Gulf (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen), the Horn of Africa (Djibouti, Somalia, recently independent South Sudan), and North Africa (Algeria, Libya, Morocco, Sudan, Tunisia).

Systematic searches were performed, up to July 29, 2018, on ten international-, regional-, and country-level databases; abstract archives of International AIDS Society conferences [14]; and Synthesis Project database which includes country-level and international organizations' reports and routine data reporting [6, 7] (Additional file 1: Box S1). No language or year restrictions were used.

Titles and abstracts of unique citations were screened for relevance, and full texts of relevant/potentially relevant citations were retrieved for further screening. Any document/report including outcomes of interest based on primary data was eligible for inclusion. Case reports, case series, editorials, commentaries, and studies in populations (such as "vulnerable women") where overlap with FSWs is implied but engagement in sex work is not explicitly indicated were excluded. Reference lists of reviews and all relevant documents were hand searched for eligible reports.

In this article, the term *study* refers to a specific outcome measure (population size estimate, incidence, or prevalence) in a specific population. Therefore, one report could contribute multiple studies, and one study could be published in different reports. Duplicate study results were included only once using the more detailed report.

Data extraction and synthesis

Data extraction was performed by HC and double extraction by MH, with discrepancies settled by consensus or by contacting authors. Data were extracted from full texts by native speakers (extraction list in Additional file 1: Box S2).

Population size estimates and population proportions were grouped based on being of national coverage or for specific subnational settings, and distinguishing between current FSWs/clients and history of sex work/ex-client. For FSWs, population proportion is defined as the proportion of all reproductive-age women that are engaged in sex work, that is the exchange of sex for money (sex work as a profession) [15, 16], and for clients, as the proportion of men buying sex from FSWs using money. Studies with mixed or non-representative samples (samples biased towards oversampling FSWs with no estimate adjustment) were excluded.

Due to the paucity of studies directly looking at HIV prevalence in clients of FSW, HIV prevalence studies in male STI clinic attendees, or mixed-sex samples of predominantly men (> 60%), were used as a proxy for HIV prevalence in clients of FSWs [17, 18].

Based on meta-analysis results for the pooled HIV prevalence in FSWs, epidemics were classified as *concentrated* (prevalence > 5%), *intermediate-intensity* (prevalence between 1 and 5%), and *low-level* (prevalence < 1%), as informed by epidemiological relevance and existing conventions [19–21].

HIV incidence studies were identified and reported. Additional contextual information was extracted from FSW studies included in the review. These include age, age at sexual debut, age at sex work initiation, sex work duration, marital status, and HIV/AIDS knowledge and perception of risk, as well as behavioral measures of condom use, injecting drug use, sexual partnerships, and HIV testing.

Data were summarized using medians and ranges.

Quality assessment

Risk of bias (ROB) assessments for population size estimates/population proportions and for HIV prevalence were conducted as informed by Cochrane Collaboration guidelines [12] (criteria in Additional file 1: Table S2). Briefly, size estimation studies were classified as having "low" versus "high" ROB on each of the three domains assessing the (1) validity of sex work definition/engagement in paid sex (clear/valid definition; otherwise), (2) rigor of estimation methodology (likely-to-yield representative estimate; otherwise), and (3) response rate (≥ 60%; < 60%).

Prevalence studies were similarly classified on each of the four domains assessing the (1) validity of sex work definition/engagement in paid sex (clear/valid definition; otherwise), (2) rigor of sampling methodology (probability-based; non-probability-based), (3) response rate (≥ 60% or ≥ 60% of target sample size reached for studies using respondent-driven or time-location sampling; < 60%), and (4) type of HIV ascertainment (biological assays; self-report).

Studies with missing information for a specific domain were classified as having "unclear" ROB for that domain. Measures only extracted from routine databases were considered of unknown quality, as original reports were not available for assessing ROB, and were not included in the quality assessment. The impact of quality domains on observed prevalence was examined in meta-regression (described below).

Meta-analyses

Pooled mean HIV prevalence in FSWs and client populations were estimated using random-effects meta-analyses, by country and for the whole region. Variances were stabilized using Freeman-Tukey-type arcsine square-root transformation [22, 23]. Weighting was performed using the inverse-variance method [23, 24]. Pooling was performed using Dersimonian-Laird random-effects models to allow for sampling variation and true heterogeneity [25, 26]. Overall prevalence measures were replaced by their stratified measures where applicable.

Heterogeneity was assessed using Cochran's Q statistic to confirm the existence of heterogeneity, I^2 to estimate the magnitude of between-study variation, and prediction intervals to estimate the 95% interval of distribution of true effect sizes [26, 27].

Meta-analyses were implemented in R version 3.4.2 [28].

Meta-regression analyses

Random-effects meta-regression analyses were conducted to identify the regional-level associations with HIV prevalence in FSWs, sources of between-study heterogeneity, and temporal trend. Independent variables considered a priori were country/subregion, FSW population type, sample size, median year of data collection, sampling methodology, response rate, validity of sex work definition, and HIV ascertainment (details in Additional file 1: Table S3). The same factors (as applicable) were considered for clients' meta-regression analyses.

To avoid the exclusion of studies with zero prevalence, an increment of 0.1 was added to the number of events in all studies to calculate the log-transformed odds, that is prevalence/(1 − prevalence), and corresponding variance [29]. Factors showing strong evidence for an association with the odds (p value ≤ 0.10) in univariable analysis were included in the multivariable analysis.

Meta-regressions were implemented in Stata/SE v.15.1 [30].

Results

Search results and scope of evidence

Figure 1 shows the study selection process. A total of 16,131 citations were identified through databases. After excluding duplicates and title and abstract screening, full texts of 336 unique citations were screened, and 87 reports were eligible for inclusion. Hand-searching of reference lists of relevant reports yielded eight additional eligible reports. Searching US Census Bureau and UNAIDS databases yielded 173 additional measures. Sixty-three detailed country-level reports, 11 of which replaced eligible articles, and 134 additional measures were further identified through Synthesis Project database. In sum, data from 147 eligible reports and 307 additional measures were included. These yielded in total 312 size estimation, 6 HIV incidence, and 554 HIV prevalence measures in FSWs and clients.

Evidence for population size and/or population proportion of FSWs was available for 12 out of 23 MENA countries (270 studies). Population size/population proportion of clients was available in 42 studies from 10 countries. All 6 HIV incidence studies were among FSWs. A total of 485 HIV prevalence studies were identified in 287,719 FSWs from 17 countries and 69 HIV prevalence studies in 29,531 clients (or proxy populations) from 10 countries. Prevalence

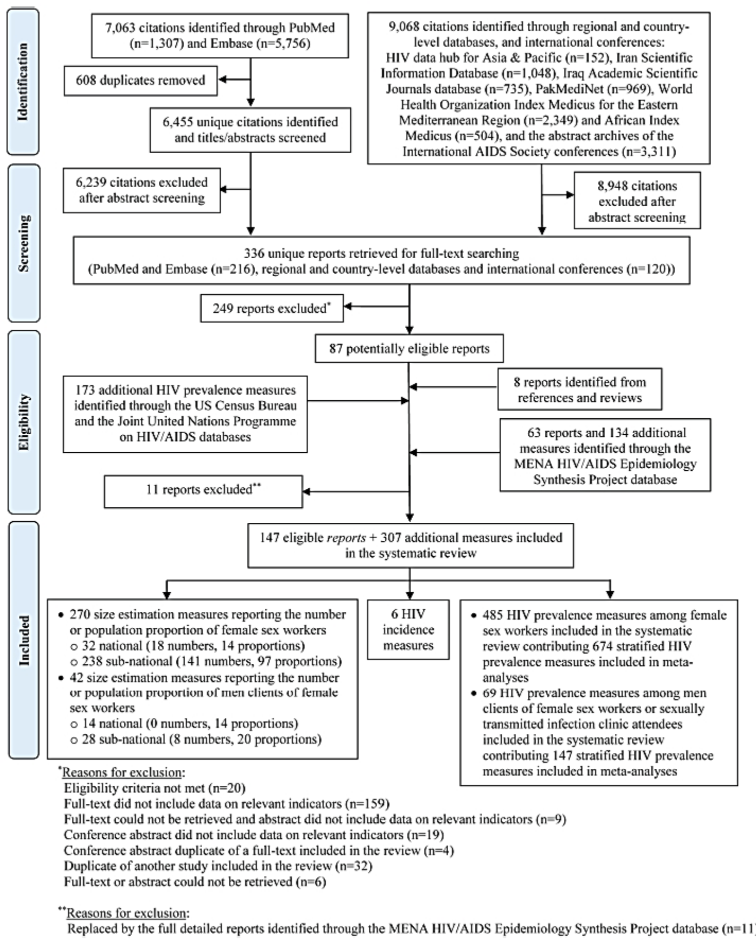

Fig. 1 Flow chart of the study selection process in the systematic review following PRISMA guidelines [13]

measures in FSWs and clients contributed respectively 674 and 147 stratified measures for the meta-analyses (overall prevalence measures were replaced by their strata in meta-analyses). For all types of measures, there was a high heterogeneity in data availability across countries.

Population size estimates and population proportions of FSWs and clients

Table 1 and Additional file 1: Table S4 show the population size estimate and population proportion studies for FSWs and clients at the national and subnational levels, respectively. At the national level, the median number of current/recent FSWs (engaged in sex work in the past year) was 58,934 (range = 2218 in Djibouti to 167,501 in Pakistan), and the median population proportion (out of reproductive-age women aged 15–49 years) was 0.6% (range across studies = 0.2% in Egypt to 2.4% in Iran). The median population proportion of current/recent clients (buying sex from FSWs in the past year) based on diverse samples of general population men was 5.7% (range across studies = 0.3% in Sudan to 13.8% in Lebanon).

With high heterogeneity in estimation methodology, time frame, and scope between and within countries, it was deemed not meaningful to generate country-specific or regional-pooled estimates for the size/population proportions.

HIV incidence overview

There were six incidence studies among FSWs (three from each of Somalia and Djibouti; data not shown). Three studies reported zero seroconversions [51, 52].

Table 1 Estimates of some national representation for the number and population proportion of FSWs, and the number and population proportion of clients of FSWs, in the Middle East and North Africa (MENA) reported by identified studies

	Country	Author, year [citation]	Year(s) of data collection	Estimation methodology	Sample type	Reported size estimate				
						Time frame	*N*	Range	%*	Range*
FSWs	Egypt	Bahaa, 2010 [31]	2004–2008	Convenience sample (self-report)	Women seeking VCT testing	NR	NR	NR	0.4	NR
		Jacobsen, 2014 [32]	2014	Enumeration (time-location geographical mapping)	FSWs in urban locations	Current	22,986	6460–26,792	0.24	NR
	Djibouti	WHO, 2011 [33]	2009	NR	FSWs	NR	1000	NR	NR	NR
		WHO, 2011 [33]	2011	Capture-recapture	FSWs	Current	2218	NR	NR	NR
	Iran	WHO, 2011 [33]	2010	Network scale-up	General pop	Current	80,000	NR	NR	NR
		Sharifi, 2017 [34]	2015	Multiplier unique object	FSWs	Current	19,800	10,900–38,100	0.31	0.17–0.58
		Sharifi, 2017 [34]	2015	Network scale-up	General pop	Current	98,500	87,000–109,400	1.54	1.36–1.71
		Sharifi, 2017 [34]	2015	Wisdom of the crowds	FSWs	Current	152,200	93,400–21,4300	2.38	1.46–3.35
	Lebanon	Kahhaleh, 2009 [35]	1996	Pop-based survey (self-report)	General pop (15–49 years)	Past 12 M	NR	NR	0.54	NR
		Kahhaleh, 2009 [35]	2004	Pop-based survey (self-report)	General pop (15–49 years)	Past 12 M	NR	NR	0.53	NR
	Morocco	WHO, 2011 [33]	2010	NR	FSWs	Current	67,000	NR	NR	NR
		Bennani, 2013 [36]	2011	Multiplier unique object	FSWs	Past 6 M	85,000	NR	NR	NR
		MOH, 2013 [37]	2013	Pop-based survey (self-report)	Young women (15–24 years)	Lifetime	NR	NR	6.9	NR
		MOH, 2013 [37]	2013	Pop-based survey (self-report)	Young women (15–24 years)	Current	NR	NR	2.4	NR
	Pakistan	NACP, 2005 [38] (round I)	2005	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, and street-based FSWs	Current	35,050	30,300–39,800	0.78	NR
		Emmanuel, 2010 [39] (round II)	2006	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, and street-based FSWs	Current	167,501	NR	0.44	NR
		Emmanuel, 2013 [40, 41] (round IV)	2011–2012	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, and street-based FSWs	Current	89,178	78,778–99,592	0.72	NR
		NACP, 2017 [42] (round V)	2016–2017	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, and street-based FSWs	Current	64,829	57,734–70,428	NR	NR
	Sudan	AFROCENTER Group, 2005 [43]	2005	Self-report (convenience sample)	Young women	NR	NR	NR	0.4	NR
	Syria	WHO, 2011 [33]	2011	NR	FSWs	Current	50,000	NR	NR	NR
	Tunisia	WHO, 2011 [33]	2005	NR	FSWs	Current	NR	1000–5000	NR	NR
		WHO, 2011 [33]	2009	NR	FSWs	Current	10,000	NR	NR	NR
		WHO, 2011 [33]	2011	NR	FSWs	Current	25,500	NR	NR	NR
	Yemen	MOH, 2010 [44]	NR	Enumeration (time-location geographical mapping)	FSWs	Current	58,934	NR	NR	1.16–2.10

Table 1 Estimates of some national representation for the number and population proportion of FSWs, and the number and population proportion of clients of FSWs, in the Middle East and North Africa (MENA) reported by identified studies *(Continued)*

	Country	Author, year [citation]	Year(s) of data collection	Estimation methodology	Sample type	Reported size estimate				
						Time frame	*N*	Range	%*	Range*
Clients of FSWs	Afghanistan	Todd, 2007 [45]	2005–2006	Pop-based survey (self-report)	TB patients receiving treatment	Lifetime	NR	NR	3.57	NR
		Todd, 2012 [46]	2010–2011	Pop-based survey (self-report)	Army recruits	Lifetime	NR	NR	12.5	NR
	Egypt	Bahaa, 2010 [31]	2004–2008	Convenience sample (self-report)	Men seeking VCT testing	NR	NR	NR	0.9	NR
	Lebanon	Kahhaleh, 2009 [35]	1996	Pop-based survey (self-report)	General pop (15–49 years)	Past 12 M	NR	NR	9.7	NR
		Adib, 2002 [47]	1999	Pop-based survey (self-report)	Military conscripts	Past 12 M	NR	NR	13.84	NR
		Kahhaleh, 2009 [35]	2004	Pop-based survey (self-report)	General pop (15–49 years)	Past 12 M	NR	NR	5.65	NR
	Morocco	MOH, 2007 [48]	2007	Pop-based survey (self-report)	Young men (15–24 years)	Lifetime	NR	NR	35.3	NR
		MOH, 2007 [48]	2007	Pop-based survey (self-report)	Young men (15–24 years)	Current	NR	NR	2	NR
		MOH, 2013 [37]	2013	Pop-based survey (self-report)	Young men (15–24 years)	Lifetime	NR	NR	10.5	NR
		MOH, 2013 [37]	2013	Pop-based survey (self-report)	Young men (15–24 years)	Current	NR	NR	0.3	NR
	Pakistan	Mir, 2013 [49]	2007	Pop-based survey (self-report)	Urban men (16–45 years)	Lifetime	NR	NR	11.9	NR
		Mir, 2013 [49]	2007	Pop-based survey (self-report)	Urban men (16–45 years)	Past 12 M	NR	NR	5.8	NR
	Sudan	NACP, 2004 [50]	2004	Convenience sample (self-report)	Military personnel	NR	NR	NR	0.3	NR
		AFROCENTER Group, 2005 [43]	2005	Convenience sample (self-report)	Young men	NR	NR	NR	0.5	NR

The table is sorted by year(s) of data collection

Abbreviations: *FSWs* female sex workers, *M* months, *MOH* Ministry of Health, *NACP* National AIDS Control Programme, *NR* not reported, *Pop* population, *TB* tuberculosis, *VCT* voluntary counseling and testing, *WHO* World Health Organization

*The decimal places of the population proportion figures are as reported in the original reports

One study from Somalia reported a cumulative incidence of 2.6% after 6 months of follow-up [51]. The other two from Djibouti—among predominantly Ethiopian FSWs (91%)—reported a cumulative incidence of 3.4% [51] and 11.6% [51] after 3 and 9 months of follow-up, respectively. All incidence studies were conducted before the year 2000 and were limited in scale and scope.

HIV prevalence overview

HIV prevalence in FSWs ranged from 0 to 70%, with a median of 0.1% (Tables 2 and 3 and Additional file 1: Table S5). There was a high heterogeneity, with almost half of the studies (46.8%) reporting zero prevalence. The median prevalence was 0% (range = 0–14%), 2.0% (range = 0–47.1%), and 18.8% (range = 0–70%) in countries with low-level (prevalence < 1%), intermediate-intensity (prevalence 1–5%), and concentrated epidemics (prevalence > 5%), respectively (epidemic classification based on the results of meta-analyses; see below and Table 5). Ranges indicated pockets of higher HIV prevalence, even in countries with low-level and intermediate-intensity epidemics.

In clients/male STI clinic attendees, HIV prevalence ranged from 0 to 34.6%, with a median of 0.4% (Table 4) . Studies also showed high heterogeneity with 37.7% reporting zero prevalence. The median prevalence was 0% (range = 0–1.1%), 0.6% (range = 0–9.6%), and 7.4% (range = 0.8–34.6%) in countries with low-level, intermediate-intensity, and concentrated epidemics, respectively. Ranges indicated pockets of higher HIV prevalence in countries with intermediate-intensity epidemics.

Quality assessment

Additional file 1: Tables S6-S9 show the summarized and study-specific quality assessments for the size estimation and HIV prevalence studies in FSWs and clients. Almost all size estimation studies used clear/valid sex work definitions, and > 70% used rigorous size estimation methodologies. Similarly, > 70% of prevalence studies in FSWs used clear/valid sex work definitions and probability-based sampling for participants' recruitment. Meanwhile, > 85% of prevalence studies in clients used convenience sampling.

Overall, studies were of reasonable quality. The majority of size estimation studies in FSWs and clients had low ROB on ≥ 2 quality domains (94.4% and 82.1%, respectively), and none had high ROB on ≥ 2 domains. Similarly, 85.0% of prevalence studies in FSWs and 39.4% of studies in clients had low ROB on ≥ 2 domains (studies among STI clinic attendees mostly used convenience sampling, and few reported on contact with FSWs), while 0.7% and 6.1% had high ROB on ≥ 2 domains, respectively.

Pooled mean HIV prevalence

The pooled mean HIV prevalence for the MENA region was 1.4% (95% confidence interval (CI) = 1.1–1.8%) in FSWs and 0.4% (95% CI = 0.1–0.7%) in clients (Table 5). A difference was observed between the median prevalence and the pooled mean prevalence due to the high clustering of prevalence measures close to zero.

In FSWs, the national-level pooled mean prevalence was 0 or < 1% in most countries (low-level epidemics); between 1 and 5% (intermediate-intensity epidemics) in Algeria, Libya, Morocco, Somalia, and Sudan; and > 5% (concentrated epidemics) in Djibouti (17.9%, 95% CI = 13.6–22.6%) and South Sudan (17.3%, 95% CI = 8.7–28.1%).

In clients/male STI clinic attendees, the national-level pooled mean prevalence was mostly 0 or < 1%. However, high prevalence was estimated in Djibouti (5.4%, 95% CI = 1.5–10.8%) and South Sudan (13.5%, 95% CI = 4.5–28.8%).

There was evidence for the heterogeneity in effect size (prevalence) in meta-analyses. p value for Cochran's Q statistic was mostly < 0.0001, prediction intervals were wide, and I^2 was often > 50% indicating that most between-study variability is due to the true differences in prevalence across studies rather than chance.

Associations with prevalence, sources of between-study heterogeneity, and temporal trend

Univariable meta-regressions for FSWs demonstrated strong evidence for an association with odds for subregion, population type, sample size, year of data collection, and response rate (Table 6). Meanwhile, there was poor evidence for an association with sampling methodology, validity of sex work definition, and HIV ascertainment, which were hence dismissed from inclusion in the multivariable model. Most variability in odds was explained by subregion (adjusted R^2 = 39.8%).

Multivariable analysis indicated strong subregional differences and explained 49.2% of the variation (Table 6). Compared to Eastern MENA, the adjusted odds ratio (AOR) ranged from 0.2 (95% CI = 0.1–0.4) for the Fertile Crescent to 45.4 (95% CI = 24.7–83.7) for the Horn of Africa. Studies with a larger sample size (≥ 100) showed lower odds (AOR = 0.4, 95% CI = 0.2–0.6).

Compared with studies with data collection pre-1993, studies conducted after 2003 showed strong evidence for higher odds (AOR = 2.0, 95% CI = 1.2–3.3). Notably, the trend of increasing odds was evident only after controlling for the strong confounding effect of the subregion. The trend for each subregion was also overall increasing, though the strength of evidence varied across subregions

Table 2 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using probability-based sampling

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence*	
								%	95% CI
Afghanistan	SAR AIDS HDS, 2008 [53]	2006–2007	Jalalabad	Community	TLS	FSWs	45	0	NR
	SAR AIDS HDS, 2008 [53]	2006–2007	Mazar-i-Sharif	Community	TLS	FSWs	87	0	NR
	NACP, 2010 [54] (round I)	2009	Kabul	Community	RDS	FSWs	368	0	NR
	NACP, 2012 [55] (round II)	2012	Herat	Community	RDS	FSWs	344	0.9	NR
	NACP, 2012 [55] (round II)	2012	Kabul	Community	RDS	FSWs	333	0	NR
	NACP, 2012 [55] (round II)	2012	Mazar-i-Sharif	Community	RDS	FSWs	355	0	NR
Egypt	MOH, 2006 [56] (round I)	2006	Cairo	Community	Conv**	FSWs	118	0.8	NR
	MOH, 2010 [57] (round II)	2010	Cairo	Community	Conv**	FSWs	200	0	NR
Iran	Navadeh, 2012 [58]	2010	Kerman	Community	RDS	FSWs	139	0	NR
	Sajadi, 2013 [59] (round I)	2010	National	Facilities serving vulnerable women	MCS	FSWs	817	4.5	NR
	Kazerooni, 2014 [60]	2010–2011	Shiraz	Community	RDS	FSWs	278	4.7	NR
	Moaeyedi-Nia, 2016 [61]	2012–2013	Tehran	Community	RDS	FSWs	161	5	NR
	Mirzazadeh, 2016 [62] (round II)	2015	National	Facilities serving vulnerable women	MCS	FSWs	1337	2.1	0.9–4.6
	Karami, 2017 [63]	2016	Tehran	Community	TLS	FSWs	369	4.6	NR
Jordan	WHO, 2011 [33] (round I)	2009	National	Community	RDS	FSWs	225	0	NR
	MOH, 2014 [64] (round II)	2013	Amman	Community	RDS	FSWs	358	0.6	NR
	MOH, 2014 [64] (round II)	2013	Irbid	Community	RDS	FSWs	102	0	NR
	MOH, 2014 [64] (round II)	2013	Zarqa	Community	RDS	FSWs	212	0.5	NR
Lebanon	Mahfoud, 2010 [65]	2007–2008	Greater Beirut	Community	RDS	FSWs	95	0	NR
Libya	Valadez, 2013 [66] (round I)	2010–2011	Tripoli	Community	RDS	FSWs	69	15.7	3.2–32.6
Morocco	MOH, 2012 [67]	2011–2012	Agadir	Community	RDS	FSWs	364	5.1	2.1–8.6
	MOH, 2012 [67]	2011–2012	Fes	Community	RDS	FSWs	359	1.8	0–2.1
	MOH, 2012 [67]	2011–2012	Rabat	Community	RDS	FSWs	392	0	NR
	MOH, 2012 [67]	2011–12	Tanger	Community	RDS	FSWs	319	1.4	0.4–3.3
Pakistan	Bokhari, 2007 [68]	2004	Lahore	Red-light district	SyCS	FSWs	378	0.5	NR
	NACP, 2005 [38] (round I)	2005	Faisalabad	Community	RDS and TLS	Kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2005 [38] (round I)	2005	Hyderabad	Community	SyRS, RDS, and TLS	Brothel, kothikhana, home, and street-based FSWs	400	0	NR

Table 2 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using probability-based sampling *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence*	
								%	95% CI
	NACP, 2005 [38] (round I)	2005	Karachi	Community	SyRS, RDS, and TLS	Brothel, kothikhana, home, and street-based FSWs	400	0.8	NR
	NACP, 2005 [38] (round I)	2005	Lahore	Community	SyRS, RDS, and TLS	Brothel, kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2005 [38] (round I)	2005	Multan	Community	Conv (take all), RDS, and TLS	Brothel, kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2005 [38] (round I)	2005	Peshawar	Community	MCS	Kothikhana, home, and street-based FSWs	359	0	NR
	NACP, 2005 [38] (round I)	2005	Quetta	Community	RDS and MCS	Kothikhana, home, and street-based FSWs	411	0.7	NR
	NACP, 2005 [38] (round I)	2005	Sukkur	Community	RDS and TLS	Kothikhana, home, and street-based FSWs	368	0	NR
	NACP, 2007 [69] (round II)	2006	Bannu	Community	SyRS and MCS	Kothikhana, home, and street-based FSWs	194	0	NR
	NACP, 2007 [69] (round II)	2006	Faisalabad	Community	SyRS and MCS	Kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2007 [69] (round II)	2006	Gujranwala	Community	SyRS and MCS	Kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2007 [69] (round II)	2006	Hyderabad	Community	SyRS and MCS	Brothel, kothikhana, home, and street-based FSWs	398	0.3	NR
	NACP, 2007 [69] (round II)	2006	Karachi	Community	SyRS and MCS	Brothel, kothikhana, home, and street-based FSWs	403	0	NR
	NACP, 2007 [69] (round II)	2006	Lahore	Community	SyRS and MCS	Brothel, kothikhana, home, and street-based FSWs	425	0.02	NR
	NACP, 2007 [69] (round II)	2006	Larkana	Community	SyRS and MCS	Brothel, kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2007 [69] (round II)	2006	Multan	Community	SyRS and MCS	Brothel, kothikhana, home, and street-based FSWs	400	0	NR
	NACP, 2007 [69] (round II)	2006	Peshawar	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	423	0	NR
	NACP, 2007 [69] (round II)	2006	Quetta	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	398	0	NR
	NACP, 2007 [69] (round II)	2006	Sargodha	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	400	0	NR
	NACP, 2007 [69] (round II)	2006	Sukkur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	400	0	NR
	Hawkes, 2009 [70]	2007	Abbottabad	Community	RDS	FSWs	107	0	NR
	Hawkes, 2009 [70]	2007	Rawalpindi	Community	RDS	FSWs	426	0	NR

Table 2 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using probability-based sampling *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence*	
								%	95% CI
	Khan, 2011 [71]	2007	Lahore	Community	RDS	FSWs	730	0.7	NR
	NACP, 2010 [72] (special IBBSS among FSWs)	2009	Punjab and Sindh	Community	SyRS and MCS	FSWs	2197	1.0	NR
	NACP, 2012 [40] (round IV)	2012	DG Khan	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	375	0.5	0.1–1.9
	NACP, 2012 [40] (round IV)	2012	Faisalabad	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	376	0	NR
	NACP, 2012 [40] (round IV)	2012	Haripur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	211	0.9	0.3–3.4
	NACP, 2012 [40] (round IV)	2012	Karachi	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	377	1.9	0.9–3.8
	NACP, 2012 [40] (round IV)	2012	Lahore	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	375	0.5	0.1–1.9
	NACP, 2012 [40] (round IV)	2012	Larkana	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	375	1.9	0.9–3.8
	NACP, 2012 [40] (round IV)	2012	Multan	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	375	0.3	0.05–1.5
	NACP, 2012 [40] (round IV)	2012	Peshawar	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	367	0	NR
	NACP, 2012 [40] (round IV)	2012	Quetta	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	345	0	NR
	NACP, 2012 [40] (round IV)	2012	Rawalpindi	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	375	0	NR
	NACP, 2012 [40] (round IV)	2012	Sargodha	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	345	0.3	0.05–1.6
	NACP, 2012 [40] (round IV)	2012	Sukkur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	375	0.8	0.3–2.3
	NACP, 2017 [42] (round V)	2016–2017	Bahawalpur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	351	0	NR
	NACP, 2017 [42] (round V)	2016–2017	Bannu	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	196	1.5	1–4.4
	NACP, 2017 [42] (round V)	2016–2017	DG Khan	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	0.8	0.3–2.4
	NACP, 2017 [42] (round V)	2016–2017	Gujranwala	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	304	0.7	0.2–2.4
	NACP, 2017 [42] (round V)	2016–2017	Gujrat	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	250	0.4	0.1–2.2

Table 2 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using probability-based sampling *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence* %	HIV prevalence* 95% CI
	NACP, 2017 [42] (round V)	2016–2017	Hyderabad	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	2.2	1.1–4.3
	NACP, 2017 [42] (round V)	2016–2017	Karachi	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	387	2.6	1.4–4.7
	NACP, 2017 [42] (round V)	2016–2017	Kasur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	0	NR
	NACP, 2017 [42] (round V)	2016–2017	Larkana	Community	SyRS and MCS	Brothel, kothikhana, home, street-based, and other FSWs	364	4.1	2.5–6.7
	NACP, 2017 [42] (round V)	2016–2017	Mirpurkhas	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	4.1	2.5–6.7
	NACP, 2017 [42] (round V)	2016–2017	Nawabshah	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	3.8	2.3–6.4
	NACP, 2017 [42] (round V)	2016–2017	Peshawar	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	265	3	1.5–5.8
	NACP, 2017 [42] (round V)	2016–2017	Quetta	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	0	NR
	NACP, 2017 [42] (round V)	2016–2017	Rawalpindi	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	0.3	0.1–1.5
	NACP, 2017 [42] (round V)	2016–2017	Sheikhupura	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	363	1.7	1.1–4.9
	NACP, 2017 [42] (round V)	2016–2017	Sialkot	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	193	0	NR
	NACP, 2017 [42] (round V)	2016–2017	Sukkur	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	364	8.8	6.3–12.2
	NACP, 2017 [42] (round V)	2016–2017	Turbat	Community	SyRS and MCS	Kothikhana, home, street-based, and other FSWs	72	0	NR
Somalia	Testa, 2008 [73] (round I)	2008	Hargeisa	Community	RDS	FSWs	237	5.2	2.5–8.5
	IOM, 2017 [74] (round II)	2014	Hargeisa	Community	RDS	FSWs	96	4.8	0.2–9.3
Sudan	Elkarim, 2002 [75]	2002	National	Community	MSysRS	FSWs	367	4.4	NR
	Abdelrahim, 2010 [76]	2008	Khartoum	Community	RDS	FSWs	321	0.9	0.1–2.2
	NACP, 2010 [77]	2008–09	Gezira	Community	RDS	FSWs	267	0.1	NR
	NACP, 2012 [78]	2011	Alshamalia	Community	RDS	FSWs	305	0.3	0–1
	NACP, 2012 [78]	2011	Blue Nile	Community	RDS	FSWs	279	1.5	0–3
	NACP, 2012 [78]	2011	Gadarif	Community	RDS	FSWs	282	0.6	0–1
	NACP, 2012 [78]	2011	Gezira	Community	RDS	FSWs	296	0.7	0–1
	NACP, 2012 [78]	2011	Kassala	Community	RDS	FSWs	288	5.0	2–8
	NACP, 2012 [78]	2011	Khartoum	Community	RDS	FSWs	287	0	NR

Table 2 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using probability-based sampling *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence* %	HIV prevalence* 95% CI
	NACP, 2012 [78]	2011	North Darfur	Community	RDS	FSWs	303	0.7	0–3
	NACP, 2012 [78]	2011	North Kordofan	Community	RDS	FSWs	296	1	0–3
	NACP, 2012 [78]	2011	Red Sea	Community	RDS	FSWs	293	7.7	4–12
	NACP, 2012 [78]	2011	River Nile	Community	RDS	FSWs	291	0.7	0–2
	NACP, 2012 [78]	2011	Sinnar	Community	RDS	FSWs	303	0.7	0–2
	NACP, 2012 [78]	2011	South Darfur	Community	RDS	FSWs	299	0.2	0–1
	NACP, 2012 [78]	2011	West Darfur	Community	RDS	FSWs	284	1	0–3
	NACP, 2012 [78]	2011	White Nile	Community	RDS	FSWs	288	1.3	0–3
	MOH, 2016 [79]	2015–2016	Juba, South Sudan	Community	RDS	FSWs	835	37.9	33.6–42.2
Tunisia	Hsairi, 2012 [80]	2009	Tunis, Sfax, and Sousse	Community	RDS	Street-based FSWs	703	0.4	NR
	Hsairi, 2012 [80]	2011	Tunis	Community	TLS	Street-based FSWs	357	0.6	0–1.3
	Hsairi, 2012 [80]	2011	Sfax	Community	TLS	Street-based FSWs	284	0	NR
	Hsairi, 2012 [80]	2011	Sousse	Community	TLS	Street-based FSWs	347	1.2	0.02–2.3
Yemen	Stulhofer, 2008 [81] (round I)	2008	Aden	Community	RDS	FSWs	244	1.3	0–2.9
	MOH, 2014 [82] (round I)	2010–2011	Hodeida	Community	RDS	FSWs	301	0	NR

The table is sorted by year(s) of data collection

Abbreviations: *CI* confidence interval, *Conv* convenience, *FSWs* female sex workers, *IBBSS* integrated bio-behavioral surveillance survey, *IOM* International Organization for Migration, *MCS* multistage cluster sampling, *MOH* Ministry of Health, *MSyRS* multistage systematic random sampling, *NACP* National AIDS Control Programme, *NR* not reported, *RDS* respondent-driven sampling, *SAR AIDS HDS* South Asia Region AIDS Human Development Sector, *SyCS* systematic cluster sampling, *SyRS* systematic random sampling, *TLS* time-location sampling, *WHO* World Health Organization

*The decimal places of the prevalence figures are as reported in the original reports, but prevalence figures with more than one decimal places were rounded to one decimal place, with the exception of those below 0.1%. Most studies did not report the 95% CIs associated with prevalence

**Integrated bio-behavioral surveillance survey with sampling initially planned as respondent-driven but ended up being a convenience for logistical reasons

Table 3 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using non-probability sampling

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence*	
								%	95% CI
Afghanistan	Todd, 2010 [83]	2006–2008	Jalalabad, Kabul, and Mazar-i-Sharif	Community and NGO	Conv	FSWs	520	0.2	0.01–1.1
Djibouti	Rodier, 1993 [84]	1987	Djibouti	STI clinic	Conv	Street-based FSWs	66	4.6	NR
	Rodier, 1993 [84]	1987	Djibouti	STI clinic	Conv	Bar hostesses	221	1.4	NR
	Constantine, 1992 [52]	1988	Djibouti	NR	Conv	FSWs	33	18.2	NR
	Rodier, 1993 [84]	1988	Djibouti	STI clinic	Conv	Street-based FSWs	78	9.0	NR
	Rodier, 1993 [84]	1988	Djibouti	STI clinic	Conv	Bar hostesses	255	2.7	NR
	Rodier, 1993 [84]	1990	Djibouti	STI clinic	Conv	Street-based FSWs	116	41.7	NR
	Rodier, 1993 [84]	1990	Djibouti	STI clinic	Conv	Bar hostesses	180	5.0	NR
	Couzineau, 1991 [85]	1991	Djibouti	STI clinic	Conv	Street-based FSWs	300	43	NR
	Couzineau, 1991 [85]	1991	Djibouti	STI clinic	Conv	Bar girls	397	13.1	NR
	Rodier, 1993 [84]	1991	Djibouti	STI clinic and residences	Conv	Street-based FSWs	292	36.0	NR
	Rodier, 1993 [84]	1991	Djibouti	STI clinic and residences	Conv	Bar hostesses	360	15.3	NR
	Philippon, 1997 [86]	1995	Djibouti	STI clinic	Conv	Street-based FSWs	176	49	NR
	Marcelin, 2002 [87]	1998–1999	Djibouti	STI clinics	Conv	Street-based FSWs	43	70	NR
	Marcelin, 2002 [87]	1998–1999	Djibouti	STI clinics	Conv	FSWs working in luxury bars	123	7	NR
Egypt	Sheba, 1988 [88]	1986–1987	Multiple cities	NR	Conv	FSWs	87	0	NR
	Watts, 1993 [89]	1986–1990	Urban areas	Medical facilities	Conv	FSWs	349	0	NR
	Kabbash, 2012 [90]	2009–2010	Greater Cairo	Community	Conv	FSWs	431	0	NR
Iran	Jahani, 2005 [91]	2002	NR	Detainment center/prison	Conv	FSWs detained by the police	149	0	NR
	Kassaian, 2012 [92]	2009–2010	Isfahan	Prison, drop-in centers, and community	Conv	FSWs	91	0	NR
	Taghizadeh, 2015 [93]	2014	Sari, Mazandaran	Drop-in center	Conv	FSWs at a drop-in center	184	4	NR
	Asadi-Ali, 2018 [94]	2015	Northern Iran	Counseling center, drop-in center, and community	Conv	FSWs	133	1.5	NR
Lebanon	Naman, 1989 [95]	1985–1987	NR	NR	Conv	FSWs	291	0.3	NR
Morocco	MOH, 2008 [96]	2007	Agadir, Rabat/Sale, Tanger	NGO clinic	Conv	FSWs presenting for consultation	141	1.4	0.1–2.5
Pakistan	Iqbal, 1996 [97]	1987–1994	Lahore	Hospital	Conv	FSWs	21	0	NR
	Baqi, 1998 [98]	1993–1994	Karachi	VCT	Conv	FSWs in red-light district	77	0	NR

Table 3 HIV prevalence in FSWs in the Middle East and North Africa (MENA), as reported in studies using non-probability sampling *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prevalence*	
								%	95% CI
	Anwar, 1998 [99]	NR	Lahore	NR	NR	FSWs	103	1.9	NR
	Bokhari, 2007 [68]	2004	Karachi	Community	Snowball	FSWs in red-light district	421	0	NR
	Shah, 2004 [100]	2004	Hyderabad	Community	Conv	FSWs	157	0	NR
	Shah, 2004 [101]	2004	Sindh	Sentinel surveillance	Conv	FSWs	163	1.2	NR
	Akhtar, 2008 [102]	2007	Faisalabad	Community	NR	FSWs	246	0	NR
	Raza, 2015 [103]	2014	Rawalpindi	Clinics	Conv	FSWs	NR	0	NR
Somalia	Jama, 1987 [104]	1985–1986	Mogadishu	Camp	Conv	FSWs attending health education program	85	0	NR
	Burans, 1990 [105]	NR	Mogadishu	NR	Conv	FSWs	89	0	NR
	Scott, 1991 [106]	1989	Merka, Kismayu	NR	Conv	FSWs	57	0	NR
	Corwin, 1991 [107]	1990	Chismayu, Merca, Mogadishu	NR	Conv	FSWs	302	3	NR
	Jama Ahmed, 1991 [51]	1991	Mogadishu	PHC	Conv	FSWs	155	0.6	NR
Sudan	Burans, 1990 [108]	1987	Port Sudan	NR	Conv	FSWs	203	0	NR
	McCarthy, 1995 [109]	NR	Juba, South Sudan	NR	Conv	FSWs	50	16	NR
Tunisia	Bchir, 1988 [110]	1987	Sousse	NR	Conv	FSWs	42	0	NR
	Hassen, 2003 [111]	NR	Sousse	PHC	Conv	Legal FSWs	51	0	NR
	Znazen, 2010 [112]	2007	Tunis, Sousse, and Gabes	Medical facilities	Conv	Legal FSWs undergoing routine testing	183	0	NR

The table is sorted by year(s) of data collection or year of publication if the year of data collection was not reported
Abbreviations: *CI* confidence interval, *Conv* convenience, *FSWs* female sex workers, *MOH* Ministry of Health, *NGO* non-governmental organization, *NR* not reported, *PHC* primary healthcare centers, *STI* sexually transmitted infection, *VCT* voluntary counseling and testing
*The decimal places of the prevalence figures are as reported in the original reports, but prevalence figures with more than one decimal places were rounded to one decimal place, with the exception of those below 0.1%. Most studies did not report the 95% CIs associated with prevalence

Table 4 HIV prevalence in clients of FSWs (or proxy populations of clients of FSWs such as male STI clinic attendees) in the Middle East and North Africa (MENA)

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev*		Sexual contacts
								%	95% CI	
Algeria	MOH, 2009 [113]	2004	Oran	Sent. surv.	Conv	STI clinic attendees	41	4.9	NR	NR
	MOH, 2009 [113]	2004	Tamanrasset	Sent. surv.	Conv	STI clinic attendees	105	0	0	NR
	MOH, 2009 [113]	2004	Tizi-Ouzou	Sent. surv.	Conv	STI clinic attendees	11	9.1	NR	NR
	MOH, 2009 [113]	2007	National	Sent. surv.	Conv	STI clinic attendees	571	3.3	NR	NR
Djibouti	Rodier, 1993 [84]	1987	Djibouti	STI clinic	Conv	STI clinic attendees	252	0.8	NR	NR
	Rodier, 1993 [84]	1988	Djibouti	STI clinic	Conv	STI clinic attendees	249	0.8	NR	NR
	Fox, 1989 [114]	NR	NR	NR	Conv	Clients of FSWs	105	1.0	NR	Clients of FSWs
	Rodier, 1993 [84]	1990	Djibouti	STI clinic	Conv	STI clinic attendees	106	1.9	NR	NR
	OMS, 2001 [115]	1990	NR	STI clinic	Conv	STI clinic attendees	NR	2.2	NR	NR
	Rodier, 1993 [84]	1991	Djibouti	STI clinic	Conv	STI clinic attendees	193	10.4	NR	NR
	OMS, 2001 [115]	1991	NR	STI clinic	Conv	STI clinic attendees	NR	9.2	NR	NR
	MOH, 1993 [116]	1992	NR	Sent. surv.	Conv	STI clinic attendees	NR	11.6	NR	NR
	MOH, 1993 [116]	1993	NR	Sent. surv.	Conv	STI clinic attendees	411	14.4	NR	NR
	MOH, 2002 [117]	2001–2002	Djibouti	STI clinic	Conv	STI clinic attendees	237	34.6	NR	NR
	Bortolotti, 2007 [6, 118]	2006	Djibouti	STI clinic	Conv	STI clinic attendees	72	5.6	1.5–13.6	NR
Egypt	Sheba, 1988 [88]	1986–1987	Multiple cities	STI clinic	Conv	STI clinic attendees	302	0	NR	NR
	Sadek, 1991 [119]	1987–1988	Cairo	STI clinic	Conv	STI clinic attendees	140	0.7	NR	NR
	Sadek, 1991 [119]	1989–1990	Cairo	STI clinic	Conv	STI clinic attendees	125	0.8	NR	NR
	Fox, 1994 [120]	1993	Alexandria	STI clinic	Conv	STI clinic attendees	200	0	NR	NR
	Fox, 1994 [120]	1993	Cairo	STI clinic	Conv	STI clinic attendees	300	0.3	NR	NR
	Saleh, 2000 [121]	1998–2000	Alexandria	STI clinic	Conv	STI clinic attendees	295	0	NR	NR
Kuwait	NAP, 1999 [122]	1984–1998	Sabah, Kuwait	STI clinic	Conv	STI clinic attendees	3097	0.02	NR	NR
	Murzi, 1989 [123]	1988	Kuwait	STI clinic	Conv	STI clinic attendees	305	0	NR	NR
	Al-Owaish, 2000 [124]	1996–1997	Kuwait	STI clinic	SyRS	STI clinic attendees (Kuwaiti)	617	0	NR	23% reported contact with FSWs, 1% with MSWs, 35% with girlfriend, 12% with a mix of the above
	Al-Owaish, 2000 [124]	1996–1997	Kuwait	STI clinic	SyRS	STI clinic attendees (non-Kuwaiti)	1367	0	NR	61% reported contact with FSWs, 0.5% with MSWs, 28.5% with girlfriend, 3% with a mix of the above

Table 4 HIV prevalence in clients of FSWs (or proxy populations of clients of FSWs such as male STI clinic attendees) in the Middle East and North Africa (MENA) *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev*		Sexual contacts
								%	95% CI	
	Al-Owaish, 2002 [125]	2002	Kuwait	STI clinic	Conv	STI clinic attendees (non-Kuwaiti)	599	0	NR	NR
	Al-Mutairi, 2007 [126]	2003–2004	Kuwait	STI clinic	Conv	STI clinic attendees (predom. men)	520	0	NR	79% reported contact with FSWs
Morocco	Heikel, 1999 [127]	1992–1996	Casablanca	STI clinic	Conv	STI clinic attendees	1131	0.9	NR	NR
	Manhart, 1996 [128]	1996	Agadir, Tanger, and Marrakech	STI clinic	Conv	STI clinic attendees	223	1.4	NR	NR
	Alami, 2002 [129]	2001	Rabat, Sale, Beni Mellal, and Marrakech	Sent. surv.	Conv	STI clinic attendees	422	0	NR	70.7% reported new sexual partner, 47% multiple sexual partners in the past 3 months
	MOH, 2001 [130]	2001	Marrakech, Beni Mellal, and Rabat, Sale	Sent. surv.	Conv	STI clinic attendees	422	0	NR	NR
	Khattabi, 2005 [131]	2004	National	Sent. surv.	Conv	STI clinic attendees	NR	0.4	NR	NR
	MOH, 2013 [132]	2006	National	Sent. surv.	Conv	STI clinic attendees	1180	0.2	NR	NR
	MOH, 2013 [132]	2007	National	Sent. surv.	Conv	STI clinic attendees	986	0.4	NR	NR
	MOH, 2013 [132]	2008	National	Sent. surv.	Conv	STI clinic attendees	1237	0.5	NR	NR
	MOH, 2013 [132]	2009	National	Sent. surv.	Conv	STI clinic attendees	1103	0.3	NR	NR
	MOH, 2013 [132]	2010	National	Sent. surv.	Conv	STI clinic attendees	1181	0.7	NR	NR
	MOH, 2013 [133]	2011	Fes, Meknes, and Laayoune Boujdour	VCT	Conv	STI clinic attendees	88	2.3	NR	NR
	MOH, 2013 [132]	2012	National	Sent. surv.	Conv	STI clinic attendees	1070	0.3	NR	NR
	MOH, 2013 [133]	2012	National	VCT and STI clinic	Conv	STI clinic attendees	1297	0.4	NR	NR
Pakistan	Mujeeb, 1993 [134]	NR	Karachi	STI clinic	Conv	STI clinic attendees	32	0	NR	NR
	Memon, 1997 [135]	1994–1995	Hyderabad	STI clinic	Conv	STI clinic attendees (predom. men)	50	0	NR	NR
	NAP, 1996 [136]	1995	Karachi	STI clinic	Conv	STI clinic attendees (predom. men)	402	0	NR	NR
	NAP, 1996 [136]	1995	Lahore	STI clinic	Conv	STI clinic attendees (predom. men)	295	0	NR	NR
	Rehan, 2003 [137]	1999	Karachi	STI clinic	Conv	STI clinic attendees	138	0	NR	43% reported contact with FSWs, 12% with casual heterosexual contact, 11.6% with MSM, 18.4% reported bisexuality
	Rehan, 2003 [137]	1999	Lahore	STI clinic	Conv	STI clinic attendees	148	0	NR	NR

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Table 4 HIV prevalence in clients of FSWs (or proxy populations of clients of FSWs such as male STI clinic attendees) in the Middle East and North Africa (MENA) *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev*		Sexual contacts
								%	95% CI	
	Rehan, 2003 [137]	1999	Peshawar	STI clinic	Conv	STI clinic attendees	93	1.1	NR	NR
	Rehan, 2003 [137]	1999	Quetta	STI clinic	Conv	STI clinic attendees	86	0	NR	NR
	Bhutto, 2011 [138]	2000–2009	Larkana	STI clinic	Conv	STI clinic attendees	4288	0.06	NR	83% reported a history of contact with FSWs
	Bokhari, 2007 [68]	2004	Karachi	Trucking agencies	SRS	Truck driver clients of FSWs	120	0	NR	Subsample including only clients of FSWs
	Razvi, 2014 [139]	2010–2014	Abbottabad	STI clinic	Conv	STI clinic attendees	465	1.1	NR	8% refused to answer, 70% of the rest reported contact with FSWs, 21% with MSM, 7.5% with married women
	NAP, 2012 [140]	2011	Balochistan	Mines	SRS	Mine workers clients of FSWs	381	0	NR	Subsample including only men reporting contact with FSWs at last sex
Somalia	Ismail, 1990 [141]	1986	Mogadishu	STI clinic	Conv	STI clinic attendees	101	0	NR	54% reported contact with FSWs
	Scott, 1991 [106]	1989	Mogadishu	STI clinic	Conv	STI clinic attendees	50	0	NR	NR
	Burans, 1990 [105]	NR	Mogadishu	NR	Conv	STI clinic attendees (80% soldiers)	45	0	NR	40% reported contact with FSWs
	Corwin, 1991 [107]	1990	Chismayu, Merca, and Mogadishu	NR	Conv	Partners of FSWs	26	0	NR	Partners of FSWs
	Duffy, 1999 [142]	1999	Hargeisa	Sent. surv.	Conv	STI clinic attendees	106	0.9	NR	NR
	WHO, 2005 [143]	2004	Bossasso	Sent. surv.	Conv	STI clinic attendees	78	1.3	NR	NR
	WHO, 2005 [143]	2004	Hargeisa	Sent. surv.	Conv	STI clinic attendees	52	9.6	NR	NR
	WHO, 2005 [143]	2004	Mogadishu	Sent. surv.	Conv	STI clinic attendees	46	4.4	NR	NR
	UNHCR, 2007 [144]	2006–2007	Dadaab refugee camp	STI clinic	Conv	STI clinic attendees	199	0.5	NR	NR
	Ismail, 2007 [145]	2007	Hargeisa	STI clinic	Conv	STI clinic attendees	108	7.4	NR	NR
	NAP, 2010 [146]	2007	Puntland	Sent. surv.	Conv	STI clinic attendees	NR	1.5	NR	NR
Sudan	McCarthy, 1989 [147]	1987	Port Sudan and Suakin	NR	Conv	Clients of FSWs	157	0	NR	Subsample including only clients of FSWs
	McCarthy, 1989 [148]	1987–1988	Gederef, Port Sudan, Kassala, Omdurman, and Juba	Outpatient military clinics	Conv	Soldiers clients of FSWs	398	2.5	NR	Subsample including only soldiers reporting a history of contact with FSWs

Table 4 HIV prevalence in clients of FSWs (or proxy populations of clients of FSWs such as male STI clinic attendees) in the Middle East and North Africa (MENA) *(Continued)*

Country	Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev*		Sexual contacts
								%	95% CI	
	McCarthy, 1995 [109]	NR	Juba, South Sudan	STI clinics	Conv	STI clinic attendees clients of FSWs	37	13.5	NR	Subsample including only men reporting contact with FSWs in the past 10 years
	US Cens. Bureau, 2017 [149]	2004	Khartoum	Sent. surv.	Conv	STI clinic attendees	72	1.4	NR	NR
	US Cens. Bureau, 2017 [149]	2004	Red Sea	Sent. surv.	Conv	STI clinic attendees	164	1.8	NR	NR
Yemen	Abdol-Quauder, 1993 [150]	1992	Sanaa	STI clinic	Conv	STI clinic attendees	30	0	NR	NR

The table is sorted by year(s) of data collection or year of publication if the year of data collection was not reported

Abbreviations: *Cens* Census, *CI* confidence interval, *Conv* convenience, *FSWs* female sex workers, *MENA HIV ESP* MENA HIV/AIDS Epidemiology Synthesis Project, *MOH* Ministry of Health, *NAP* National AIDS Program, *NR* not reported, *OMS* Organisation Mondiale de la Sante, *Predom.* predominantly, *Prev* prevalence, *Sent. surv.* sentinel surveillance, *SRS* simple random sampling, *STI* sexually transmitted infection, *SyRS* systematic random sampling, *UNHCR* United Nations Higher Commission for Refugees, *VCT* voluntary counseling and testing, *WHO* World Health Organization

*The decimal places of the prevalence figures are as reported in the original reports, but prevalence figures with more than one decimal places were rounded to one decimal place, with the exception of those below 0.1%. Most studies did not report the 95% CIs associated with prevalence

Table 5 Results of meta-analyses on studies reporting HIV prevalence in FSWs and their clients (or proxy populations of clients such as male STI clinic attendees) in the Middle East and North Africa (MENA) by epidemic type

		Country	Studies (*N*)	Samples		HIV prevalence		Pooled mean HIV prevalence**		Heterogeneity measures		
				Tested	HIV positive	Median* (%)	Range* (%)	%	95% CI	*Q* (*p* value)[†]	I^2[‡] (%; 95% CI)	Prediction interval[£] (95%)
FSWs	Low-level	Afghanistan	9	3578	7	0	0–0.90	0.03	0.00–0.18	7.59 ($p = 0.4744$)	0.0 (0.0–62.9)	0.00–0.22
		Bahrain	1	724	6	0.83	–	0.83[¥]	0.30–1.80	–	–	–
		Egypt	33	7222	16	0	0–1.49	0.03	0.00–0.14	36.26 ($p = 0.2765$)	12.8 (0.0–43.4)	0.00–0.34
		Iran	32	17,277	211	0.02	0–14.00	0.99	0.34–1.88	569.63 ($p < 0.0001$)	94.6 (93.2–95.6)	0.00–8.84
		Iraq	29	15,852	1	0	0–0.07	0.00	0.00–0.00	6.24 ($p = 1.0000$)	0.0 (0.0–0.0)	0.00–0.00
		Jordan	7	1024	4	0	0–1.33	0.00	0.00–0.31	3.43 ($p = 0.7537$)	0.0 (0.0–48.9)	0.00–0.48
		Lebanon	11	11,589	12	0.07	0–2.40	0.00	0.00–0.07	18.82 ($p = 0.0426$)	46.9 (0.0–73.6)	0.00–0.33
		Pakistan	81	26,678	217	0	0–8.80	0.35	0.18–0.57	368.57 ($p < 0.0001$)	78.3 (73.3–82.3)	0.00–3.06
		Syria	56	97,071	12	0	0–0.20	0.00	0.00–0.00	32.37 ($p = 0.9936$)	0.0 (0.0–0.0)	0.00–0.00
		Tunisia	53	22,224	59	0	0–2.30	0.02	0.00–0.11	124.81 ($p < 0.0001$)	58.3 (43.6–69.2)	0.00–0.89
		Yemen	10	1767	34	0.25	0–7.00	0.82	0.00–2.91	63.01 ($p < 0.0001$)	85.7 (75.6–91.7)	0.00–11.67
	Intermediate-intensity	Algeria	33	4241	179	2.00	0–20.00	2.39	1.02–4.15	215.22 ($p < 0.0001$)	85.1 (80.1–88.9)	0.00–15.05
		Libya	4	1249	28	8.43	1.08–18.18	4.86	0.81–11.37	34.41 ($p < 0.0001$)	91.3 (80.8–96.0)	0.00–47.09
		Morocco	200	40,507	804	1.07	0–52.90	1.11	0.83–1.41	851.66 ($p < 0.0001$)	76.6 (73.3–79.6)	0.00–5.98
		Somalia	17	2015	57	0.35	0–47.06	1.64	0.42–3.39	61.50 ($p < 0.0001$)	74.0 (57.7–83.8)	0.00–10.24
		Sudan[€]	22	7207	128	0.95	0–7.70	1.30	0.76–1.96	98.06 ($p < 0.0001$)	78.6 (68.1–85.6)	0.00–5.26
	Concentrated	Djibouti	68	22,028	4618	18.75	0–70.00	17.89	13.62–22.60	5127.36 ($p < 0.0001$)	98.7 (98.6–98.8)	0.00–63.91
		South Sudan	8	5466	1108	18.50	2.82–37.90	17.32	8.66–28.14	554.81 ($p < 0.0001$)	98.7 (98.3–99.1)	0.00–61.99
		All countries	674	287,719	7501	0.26	0–70.00	1.44	1.14–1.76	24,605.29 ($p < 0.0001$)	97.3 (97.2–97.4)	0.00–16.49
Clients of FSWs	Low-level	Egypt	6	1362	3	0.17	0–0.80	0.09	0.00–0.42	4.82 ($p = 0.4386$)	0.0 (0.0–73.7)	0.00–0.60
		Kuwait	6	6505	1	0	0–0.02	0.00	0.00–0.04	0.36 ($p = 0.9963$)	0.0 (0.0–0.0)	0.00–0.07
		Pakistan	12	6498	9	0	0–1.10	0.00	0.00–0.10	14.93 ($p = 0.1857$)	26.3 (0.0–62.6)	0.00–0.42
		Yemen	1	30	0	0	–	0.00[¥]	0.00–11.57	–	–	–

Table 5 Results of meta-analyses on studies reporting HIV prevalence in FSWs and their clients (or proxy populations of clients such as male STI clinic attendees) in the Middle East and North Africa (MENA) by epidemic type *(Continued)*

	Country	Studies (*N*)	Samples		HIV prevalence		Pooled mean HIV prevalence**		Heterogeneity measures		
			Tested	HIV positive	Median* (%)	Range* (%)	%	95% CI	Q (p value)†	I^2‡ (%; 95% CI)	Prediction interval£ (95%)
Intermediate-intensity	Algeria	7	728	22	7.29	0–25.80	3.51	0.32–8.90	39.79 ($p < 0.0001$)	84.9 (70.8–92.2)	0.00–27.63
	Morocco	84	10,348	47	0	0–8.00	0.00	0.00–0.05	76.30 ($p = 0.6854$)	0.0 (0.0–19.9)	0.00–0.05
	Somalia	11	1010	21	0.94	0–9.62	1.38	0.25–3.11	25.74 ($p = 0.0041$)	61.1 (25.0–79.9)	0.00–8.46
	Sudan€	4	791	14	1.61	0–2.51	1.22	0.16–2.97	7.02 ($p = 0.0711$)	57.3 (0.0–85.8)	0.00–11.65
Concentrated	Djibouti	15	2222	217	2.20	0–34.60	5.36	1.53–10.81	244.98 ($p < 0.0001$)	94.3 (92.0–95.9)	0.00–35.23
	South Sudan	1	37	5	13.5	–	13.5¥	4.54–28.77	–	–	–
	All countries	147	29,531	339	0	0–34.60	0.38	0.14–0.71	977.96 ($p < 0.0001$)	85.1 (82.9–87.0)	0.00–6.60

Abbreviations: *CI* confidence interval, *FSWs* female sex workers
*These medians and ranges are calculated on the stratified HIV prevalence measures
**Missing sample sizes for measures (or their strata) were imputed using median sample size calculated from studies with available information. Analyses excluding these studies had no impact on study findings
†Q—the Cochran's Q statistic is a measure assessing the existence of heterogeneity in effect size (here, HIV prevalence) across studies
‡I^2—a measure assessing the magnitude of between-study variation that is due to the differences in effect size (here, HIV prevalence) across studies rather than chance
£Prediction interval—a measure estimating the 95% interval of the distribution of true effect sizes (here, HIV prevalence)
Based on results of meta-analyses for FSWs, countries were classified as having low-level HIV epidemic (prevalence < 1%), intermediate-intensity HIV epidemic (prevalence 1–5%), and concentrated HIV epidemic (prevalence > 5%)
¥Point estimate as only one study was available
€Before 2011, South Sudan was part of Sudan, and thus, earlier measures from Sudan were based on studies that may have included participants from both Sudan and South Sudan

Table 6 Results of meta-regression analyses to identify associations with HIV prevalence, sources of between-study heterogeneity, and trend in HIV prevalence in FSWs in the Middle East and North Africa (MENA)

Variables		Studies	Samples	Univariable analyses			Multivariable analysis		
		Total *N*	Total *N*	OR (95% CI)	LR test *p* value[€]	Variance explained $R^{2£}$ (%)	AOR (95% CI)	*p* value	LR test *p* value[¥]
Country/subregion*									
Eastern MENA	Afghanistan, Iran, Pakistan	122	47,533	1.00	< 0.001	39.80	1.00		< 0.001
Fertile Crescent	Egypt, Iraq, Jordan, Lebanon, Syria	136	132,758	0.17 (0.10–0.27)			0.21 (0.12–0.36)	< 0.001	
Bahrain and Yemen	Bahrain and Yemen	11	2491	2.60 (0.78–8.67)			1.77 (0.52–6.01)	0.357	
Horn of Africa	Djibouti, Somalia, South Sudan	93	29,509	33.45 (19.77–56.58)			45.43 (24.66–83.68)	< 0.001	
North Africa	Algeria, Libya, Morocco, Sudan, Tunisia	312	75,428	3.14 (2.09–4.72)			2.90 (1.80–4.68)	< 0.001	
Population type	Street-based, venue-based, and other FSWs[†]	619	220,363	1.00	0.002	1.29	1.00		0.163
	Bar girls	55	67,356	0.33 (0.17–0.67)			0.66 (0.37–1.18)	0.163	
Total sample size of tested FSWs	< 100 participants	75	4008	1.00	0.001	1.54	1.00		< 0.001
	≥ 100 participants	599	283,711	0.36 (0.20–0.65)			0.35 (0.21–0.56)	< 0.001	
Median year of data collection**	< 1993	104	36,038	1.00	0.001	1.96	1.00		0.005
	1993–2002	169	98,221	0.31 (0.17–0.56)			1.18 (0.71–1.95)	0.522	
	≥ 2003	401	153,460	0.57 (0.33–0.97)			2.03 (1.24–3.33)	0.005	
Sampling methodology	Non-probability sampling	570	254,072	1.00	0.217	0.08	–	–	–
	Probability-based sampling	104	33,647	0.72 (0.42–1.21)			–	–	–
Response rate	≥ 60%	96	31,161	1.00	0.043	0.64	1.00		0.544
	< 60%/unclear	62	14,102	2.76 (1.24–6.13)			1.17 (0.60–2.27)	0.645	
	Not applicable[‡]	516	242,456	1.37 (0.80–2.37)			1.33 (0.79–2.23)	0.279	
Validity of sex work definition	Clear and valid definition	117	36,431	1.00	0.161	0.25	–	–	–
	Poorly defined/unclear	41	8832	2.35 (0.96–5.73)			–	–	–
	Not applicable[‡]	516	242,456	1.15 (0.70–1.90)			–	–	–
HIV ascertainment	Biological assays	157	44,894	1.00	0.786	0	–	–	–
	Self-report, unclear, and not applicable[‡]	517	242,825	0.94 (0.60–1.47)			–	–	–

Abbreviations: *AOR* adjusted odds ratio, *CI* confidence interval, *FSWs* female sex workers, *LR* likelihood ratio, *OR* odds ratio

*Countries were grouped based on geography and similarity in HIV prevalence levels. Given the large fraction of studies with zero HIV prevalence, particularly in the Fertile Crescent, an increment of 0.1 was added to a number of events in all studies when generating log odds, and Eastern MENA was thus used also as a statistically better reference. While this choice of increment was arbitrary, other increments yielded the same findings, though some of the effect sizes changed in scale

**Year grouping was driven by independent evidence identifying the emergence of HIV epidemics among both men who have sex with men [10] and people who inject drugs [11] in multiple MENA countries around 2003. Missing values for year of data collection (only six stratified measures) were imputed using data for year of publication adjusted by the median difference between year of publication and median year of data collection (for studies with complete information)

[†]A large fraction of studies did not separate the different forms of female sex workers, and thus it was not possible to analyze these as separate categories

[‡]Measures extracted only from routine databases with no reports describing the study methodology were not included in the ROB assessment

[€]Predictors with *p* value ≤ 0.1 were considered as showing strong evidence for an association with (prevalence) odds and were hence included in the multivariable analysis

[£]Adjusted R^2 in the final multivariable model = 49.21%

[¥]Predictors with *p* value ≤ 0.1 in the multivariable model were considered as showing strong evidence for an association with (prevalence) odds not shown). Including the year of data collection as a linear term, instead of a categorical variable, using only post-2003 data indicated strong evidence for increasing HIV odds (AOR = 1.15, 95% CI = 1.09–1.21, $p < 0.0001$; not shown). No association was found with the population type or response rate.

Meta-regression analyses for clients demonstrated similar results to those of FSWs, but with wider CIs considering the smaller number of prevalence studies (Additional file 1: Table S10). There was evidence that subregion was associated with HIV odds in clients, but no evidence that sample size or year of data collection explained the between-study heterogeneity.

Sex work context and sexual and injecting risk behaviors

For the detailed sex work context and behavioral measures, we provide here (for brevity) only a high-level summary of key measures.

Sex work context

Across studies, the mean age of FSWs ranged from 19.5 to 37.4, with a median of 27.8 years. Mean age at sexual debut ranged from 14.0 to 22.5 years (median = 17.5), and mean age at sex work initiation ranged from 17.5 to 27.5 years (median = 22.7). Mean duration of sex work ranged from 0.7 to 14.3 years (median = 5.5). A median of 28.0% (range = 0.9–76.6%) of FSWs were single, 30.1% (range = 0–65.5%) were divorced, and 7.0% (range = 0–27.2%) were widowed.

Reported condom use

There was high heterogeneity in reported condom use among FSWs by sexual partnership type and across and within countries (Additional file 1: Table S11). Condom use at last sex with clients ranged from 1.2 to 94.8% (median = 44.0%). Consistent condom use with clients ranged from 0 to 95.2% (median = 26.3%) among all FSWs and from 38.2 to 45.3% (median = 42.3%) among FSWs reporting condom use with clients.

Median condom use at last sex with regular clients was 55.9% (range = 25.5–92.0%) and that with one-time clients was 58.3% (range = 28.5–96.0%). Less condom use at last sex was found with non-paying partners (median = 22.0%, range = 4.9–78.3%). There was also variability in condom use at last *anal* sex (range = 0–86.5%), though low levels were generally reported (median = 18.5%).

The median fraction of FSWs who reported having a condom at the time of study interview was 12.5% (range = 0–66.1%).

Clients and partners

Studies varied immensely in types of measures reporting data on clients and partners. Some reported a mean number of regular/non-regular clients, but over various time frames. Others reported different distributions for the number of clients (and by client type), also over various time frames. Summarizing the evidence was therefore challenging, given the large type of measure variability.

This being said, the mean number of clients in the past month ranged from 4.4 to 114.0, with a median of 34.0 clients. Median fraction of FSWs reporting (during the past month) < 5 clients, 5–9 clients, and 10+ clients was 28.5%, 28.1%, and 19.1%, respectively. FSWs were equally likely to report regular and one-time clients during the past month (medians = 80.0% and 81.0%, ranges = 54.3–92.4% and 59.2–97.5%, respectively).

FSWs reported a distribution of sex acts in the past week, with a median of 41.2% reporting 1–2 acts, 32.0% reporting 3–4 acts, and 12.9% reporting 5+ acts. Anal sex with clients in the past month was reported by a median of 8.0% (range = 2.3–100%).

Median fraction of FSWs that are married/cohabiting was 45.3% (range = 0–99.6%), while that of FSWs reporting non-paying partners was 48.5% (range = 6.8–86.2%). The mean number of non-paying partners in the past month ranged between 1 and 3, with about two thirds reporting only one partner.

Only few studies investigated group sex: 7.7% [90] of FSWs reported ever engaging in group sex, 6.2% [68] and 12.9% [68] reported group sex in the past month, and 10.0% [58] in the past week.

Injecting risk behavior, sex with PWID, and substance use

There was a large variability in injecting risk behavior and substance use among FSWs, but the highest levels of injecting drug use were reported in Iran and Pakistan (Additional file 1: Table S12). Median of *current/recent* injecting drug use was 2.1% (range = 0–26.6%), but the majority of studies were from Pakistan. Studies in Iran reported a *history* of injecting drug use in the range of 6.1–18.0% (median of 13.6%) among all FSWs and range of 16.4–25.5% (median of 22.3%) among only ever/active drug users. A history of injecting drug use was reported by < 1% (median) of all FSWs (range = 0%–11.8%) in the rest of MENA countries.

Fraction of FSWs reporting current/recent sex with PWID ranged from 0.5 to 13.6% within Afghanistan and 0–54.9% within Pakistan, with medians of 5.2% and 5.6%, respectively. Sex with PWID was reported at 23.6% [93] among FSWs in Iran.

Close to a third of FSWs reported ever using drugs (median = 27.0%, range = 1.7–90.7%). A median of 8.9% reported current/recent drug use (range = 0.6–59.0%). Any substance use before/during sex was reported by 37.8% (median, range = 1.0–88.1%). Alcohol use before/during sex was reported by 44.1% (median, range = 3.0–70.7%).

Knowledge of HIV/AIDS and perception of risk

Knowledge of HIV/AIDS was generally high among FSWs across MENA (Additional file 1: Table S13). Vast majority of FSWs ever heard of HIV (median = 81.9%, range = 25.4–100%) and were aware of sexual (median = 72.0%, range = 50.8–94.9%) and injecting (median = 88.7%, range = 11.5–99.6%) modes of transmission, but to a lesser extent of condoms as a prevention method (median = 51.6%, range = 14.1–89.8%)—condoms were more perceived as a contraception method. Levels of knowledge, however, varied often substantially within the same country.

Overall, FSWs did not perceive themselves at high risk of HIV acquisition (Additional file 1: Table S14). Perception of HIV risk was reported as at-risk (median = 34.6%, range = 22.8–48.5), low-risk (median = 18.3%, range = 7.1–46.9), medium-risk (median = 16.4%, range = 5.3–36.1), and high-risk (median = 14.4%, range = 5.9–32.0).

HIV testing

HIV testing among FSWs varied across countries, but was generally low, with a median fraction of 17.6% (range = 4.0–99.4%) ever tested for HIV (Additional file 1: Table S15). Only a median of 12.1% (range = 0.9–38.0%) of all FSWs tested for HIV in the past 12 months, and nearly two thirds of those who ever tested did so in the past 12 months (median = 59.2%, range = 33.3–82.0%). Majority of FSWs who ever tested were aware of their status (median = 91.9%, range = 60.0–99.0%).

Discussion

Through an extensive, systematic, and comprehensive assessment of HIV epidemiology among FSWs and clients, including data presented in the scientific literature for the first time, we found that HIV epidemics among FSWs have already emerged in MENA, and some appear to have reached their peak. Based on a synthesis and triangulation of evidence from studies on a total of 300,000 FSWs and 30,000 clients, a strong regionalization of epidemics has been identified. In Djibouti and South Sudan, the HIV epidemic is concentrated with a prevalence of ~ 20% in FSWs. In Algeria, Libya, Morocco, Somalia, and Sudan, the epidemic is of intermediate-intensity (prevalence 1–5%). Strikingly, in the remaining countries with available data, the prevalence is < 1%, and most often zero.

A key finding is that HIV prevalence in FSWs has been (overall) growing steadily since 2003. This is the same time in which independent evidence has identified the emergence of major epidemics among both PWID [11] and MSM [10] in MENA. It is probable that the epidemics among these key populations have been bridged to FSWs. An example is Pakistan, where the prevalence among FSWs was < 1% in almost all cities in three consecutive IBBSS rounds between 2005 and 2012 [38, 40, 69]. However, prevalence ranging from 1.5 to 8.8% was documented in half of the cities in the latest round in 2016–2017 [42]. These emerging epidemics among FSWs were preceded by large and growing epidemics first among PWID [11] and then among MSM [10, 11].

Some of the FSW epidemics, particularly those in Djibouti and South Sudan, emerged much earlier, most likely by late 1980s [6], mainly affected by geographic proximity and stronger population links to sub-Saharan Africa (SSA) [6]. Djibouti is a port country and the major trade route for Ethiopia and a station for large international military bases [6, 151]. The majority of FSWs operating in Djibouti are Ethiopians catering to the Ethiopian truck drivers transporting shipments from the Djibouti port [84–86]. South Sudan is socio-culturally part of SSA, with a major fraction of FSWs coming from Uganda, Congo, and Kenya [79]. In these MENA countries, HIV in commercial heterosexual sex networks (CHSNs) is well-established and epidemics are concentrated—though at levels lower than the hyper-endemic epidemics observed in SSA [152].

Unlike the epidemics among PWID and MSM [10, 11], the FSW epidemics have been overall growing rather slowly, with the prevalence being mostly < 5%. Strikingly, a considerable fraction of countries still do not appear to have much HIV transmission in CHSNs, with consistently very low prevalence, quite often even at zero level—46.8% of studies in FSWs reported zero prevalence, and 7 out of 18 countries had a pooled mean prevalence of zero or nearly zero. One explanation for the observed low HIV prevalence could be that HIV has not yet been effectively introduced into CHSNs—it took decades for HIV to be effectively introduced into PWID [11] and MSM [10] networks. Another possible factor pertains to the structure of CHSNs, characterized apparently by low connectivity [6, 153, 154], which reduces the risk of HIV being introduced, or efficiently/sustainably transmitted. Unlike PWID and MSM, FSWs are also exposed to HIV mainly through their clients, who have a lower risk of exposure to HIV than themselves, thus possibly contributing to slower epidemic growth [6].

Other factors may also contribute to explaining the observed low HIV prevalence. The synthesized evidence suggests a lower risk environment for FSWs in MENA, compared to other regions. The reported number of clients is rather low at a median of 34 per month, at the lower end of global range [155–158]. Close to half of commercial sex acts are protected through condom use, with no difference between regular and one-time clients, despite noted variability across and within countries. HIV/AIDS knowledge also varies, but is generally substantial, with the majority of FSWs being aware of sexual and injecting modes of transmission, and over half are aware of condoms as a prevention method. Injecting drug use and sex with PWID is low in most countries, except for countries in Eastern MENA, notably Afghanistan, Iran, and Pakistan. Serological markers for hepatitis C virus (a marker of injecting risk) [159–161] are also low in FSWs, assessed at a median of 1.1% (range = 0–9.9%, not shown), with the highest measures reported in Iran [61, 162]. These relatively lower levels of risk behavior than other regions [163–165] stand in contrast to what has been observed in PWID and MSM in MENA [10, 11].

Importantly, with the efficacy of 60% in randomized clinical trials [166–169], male circumcision, which is essentially at universal coverage across MENA [170], may have also slowed, or even substantially reduced HIV transmission in CHSNs leading to the observed low HIV prevalence [171]. Incidentally, the two most affected countries—South Sudan and Djibouti—are nearly the only two major settings where male circumcision is at low coverage in MENA, either nationally, as is the case for South Sudan [170], or among clients of FSWs, as is the case for Ethiopian truckers and international military personnel stationed in Djibouti [151, 170]. Though HIV prevalence will probably continue to increase among FSWs and clients, the high levels of male circumcision coupled with lower levels of risk behavior may prevent significant epidemics, as seen elsewhere [172–174], from materializing in CHSNs in multiple MENA countries.

HIV prevalence in FSWs in few countries, particularly in Eastern MENA, may not necessarily reflect heterosexual as much as iatrogenic exposures through injecting drug use. Specifically, in Iran and Pakistan, countries with large HIV epidemics among PWID [11], a considerable fraction of FSWs report current/recent/history (14% in Iran and 2% in Pakistan) of injecting drug use. High prevalence of sex work is also reported in women engaging in injecting drug use [93, 175, 176]. Current/recent/history of sex with PWID is also common (24% in Iran and 6% in Pakistan). The overlap between these key populations suggests a potential for HIV to be bridged from PWID networks to CHSNs, as seem to have occurred in Pakistan recently [42, 177, 178].

Population proportion of current/recent FSWs ranged from 0.2 to 2.4% across studies with a median of 0.6%, while that of current/recent clients ranged from 0.3 to 13.8% with a median of 5.7%, both on the lower end of global range [179, 180]. Though these population proportions may seem small, the size of CHSNs is much larger than that of PWID and MSM [10, 11, 181]. This suggests that CHSNs could be a main driver of HIV incidence in many countries despite the low HIV prevalence in FSWs. An example is Morocco where the mode of transmission analyses estimated that over half of HIV incidence is driven by CHSNs, despite an HIV prevalence of only ~ 2% in FSWs [182–184]. The role of CHSNs is even more significant in countries with concentrated epidemics. In Djibouti, for example, the large HIV epidemic among FSWs was mirrored shortly after by a rapid rise in prevalence among clients (as proxied by male STI clinic attendees; Table 4), leading eventually to a prevalence > 1% in pregnant women [6].

HIV response to the epidemic in CHSNs in MENA continues to be weak and limited in scope and scale [185]. Criminality [151, 185] and stigma [186–188] associated with sex work persist as barriers to surveillance and targeted programming [189–191], leading even to the resistance to acknowledge the existence of sex work [192]. These challenges are compounded by the diverse typologies and increased mobility of FSWs [41, 70, 151]. Across MENA, only 18% of FSWs reported ever testing for HIV, and fewer (12%) reported testing in the past 12 months, far below the 90% service coverage target of "UNAIDS 2016–2021 Strategy" [193]. Programs, including healthcare provision, where they exist, are nearly always implemented by non-governmental organizations (NGOs), who often lack the resources or legal coverage to deliver comprehensive prevention interventions [6, 185].

There are, however, notable exceptions. Morocco has established an evidence-informed national strategy and rapidly scaled up provision of comprehensive services for at-risk populations, including outreach peer education programs as well as testing and case management services [183, 185]. Voluntary counseling and testing centers were established nationwide, with FSWs estimated to constitute about a quarter of attendees in 2007 [183, 194]. Findings of the 2011–2012 IBBSS indicated that over a third of FSWs ever tested for HIV, the vast majority of whom were aware of their status [67]. Condom use at last sex also increased from 37% in 2003 to a median of 50% in 2011 (Additional file 1: Table S11). Morocco's success has been grounded on a strong multisectorial response where NGOs, in partnership with the government, play a leading role in implementing interventions [185]. In Iran, the large expansion of harm reduction services, including the first women-operated services in MENA [11], is a promising step for targeting FSWs most at risk.

This study is limited by gaps in evidence. Epidemic status among FSWs remains unknown in six countries, as no data were identified. Others (Bahrain and Libya) also had limited data to warrant a meaningful characterization of the epidemic. The high heterogeneity of epidemics within countries suggests that caution is needed when interpreting data without a representative national coverage. For instance, while concentrated epidemics among FSWs are documented in southern Morocco [67, 195] and southern Algeria [113, 196–198], these do not appear to be representative of FSWs at the national level [42, 67, 74, 78, 81, 82, 113, 195–199]. Hidden epidemics or outbreaks may also exist in specific geographies within the country, but not necessarily elsewhere. Data varied over time with high quality and volume of evidence available mostly post-2000, thanks to the expansion and funding of IBBSS studies. While the pooled prevalence estimates were meant to provide a summary of the relative standing of MENA countries in the HIV epidemic, the large between-study heterogeneity suggests that caution is warranted when interpreting these estimates. Studies in clients of FSWs/proxy populations remain limited with wide variability in evidence availability across MENA.

A considerable fraction of studies used convenience sampling, although meta-regression indicated no difference in the prevalence by sampling methodology. This may be explained by FSWs being more "visible" [151, 200] compared to PWID [11] and MSM [10]. A sizable fraction of studies was from routine data reporting with no sufficient documentation of study methodology. However, most of these country-level program data were presumably based on rigorous case definitions following WHO guidelines [6]. There is also a possibility that a fraction of studies may have enrolled women without a strict and valid definition for sex work, yet meta-regression findings showed no effect for the validity of sex work definition on HIV prevalence. There was also no evidence that other study-specific quality domains, including HIV ascertainment method and response rate, had an effect on prevalence. A considerable fraction of studies reported zero prevalence, thus an increment of 0.1 was added to a number of events to be able to conduct the meta-regressions. While this choice of increment was arbitrary, other increments yielded the same findings, though some of the effect sizes changed in scale. There was evidence for a small-study effect in meta-regression suggesting potential publication bias towards studies reporting higher prevalence.

Conclusions

HIV epidemics among FSWs are emerging in MENA, with some already established. The epidemic has been growing steadily in recent years, with strong regionalization and heterogeneity. A contributing factor to epidemic growth appears to be the epidemics that emerged among PWID [11] and MSM [10] nearly two decades ago. Strikingly, a large fraction of countries still do not appear to have any significant epidemic dynamics in CHSNs. These findings demonstrate the need for expanding surveillance systems, including the conduct of repeated IBBSS studies with national coverage to monitor HIV prevalence trends and to detect the emergence of epidemics. There is also a pressing need for mapping and size estimation studies to delineate the diverse typologies of sex work and to ensure evidence-informed response with adequate coverage of interventions.

Achieving "UNAIDS 2016–2021 Strategy" [193] service coverage targets entails reaching out to the increasingly dispersed FSW population [41, 70, 151]. Building on Morocco's success, this would be best achieved through NGOs leading the provision of comprehensive interventions, with governmental support, even if discrete. Extending harm reduction services to women PWID is also critical to curb HIV burden in FSWs most at risk, specifically in Eastern MENA. The window of opportunity for detecting epidemics at their nascence, and for controlling incidence in CHSNs, should not be missed.

Additional file

Additional file 1: Supplementary information including further details and additional results for the systematic review and meta-analytics of HIV infection in female sex and their clients workers in the Middle East and North Africa. **Tables S1-S15. Figure S1. Box S1-S2.** (DOCX 1819 kb)

Abbreviations

AOR: Adjusted odds ratio; CHSNs: Commercial heterosexual sex networks; CI: Confidence interval; FSWs: Female sex workers; IBBSS: Integrated bio-behavioral surveillance surveys; MENA: Middle East and North Africa; MSM: Men who have sex with men; NGOs: Non-governmental organizations; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analyses; PWID: People who inject drugs; ROB: Risk of bias; SI: Supplementary Information; SSA: Sub-Saharan Africa; STI: Sexually transmitted infection; UNAIDS: Joint United Nations Programme on HIV/AIDS; WHO: World Health Organization

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Authors' contributions

HC designed the study, conducted the systematic review of the literature, performed the data analyses, and wrote the first draft of the article. MH double extracted the data. CC contributed to the study design. HAW contributed to the study design, data analyses, and drafting of the article. LJA conceived the study and contributed to the study design, data analyses, and drafting of the article. All authors contributed to the discussion and interpretation of the results and to the writing of the manuscript. All authors have read and approved the final manuscript.

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Availability of data and materials

All data are within the paper and its supplementary information.

Ethics approval and consent to participate

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Competing interests

The authors declare that they have no competing interests.

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2. Summary of findings

The study identified over 300 size estimation studies for FSWs and clients, in addition to over 500 HIV prevalence measures on close to 300,000 FSWs and 30,000 clients in 17 of the 23 MENA countries. The key finding of public health significance is identifying the emergence of HIV epidemics among FSWs in the region, with some epidemics already in an established phase. The study found that the epidemic has been growing in recent years, at a rate of about 15% per year, but with strong regionalization and heterogeneity. The triangulation of evidence further suggested the epidemics among MSM and PWID as contributors to epidemic onset and growth in FSWs. The study documented wide heterogeneity in sexual and injecting risk behaviours among FSWs within and across countries and found levels of HIV testing among FSWs to be far below the service coverage target of the 'UNAIDS 2016-2021 Strategy'.

Notably, despite the growing trend of HIV over the last decade, limited HIV circulation was found in a number of countries. The latter motivated the design of research paper 2, which aimed to gain further understanding of the potential for the emergence of HIV epidemics in HSWNs by assessing the levels of other STIs, commonly used as biomarkers of sexual risk behaviour. This study also motivated the design of research paper 3 which aimed at demonstrating the utility of HSV-2 as a predictor of HIV epidemic potential among FSWs, particularly in areas where HIV prevalence is still limited. Finally, data and results of this study laid the foundation for the design and conduct of research paper 4 which aimed to estimate and gain further understanding of HIV incidence arising in HSWNs in MENA.

Chapter 3 references

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CHAPTER 4. RESEARCH PAPER 2-SEXUALLY TRANSMITTED INFECTIONS AMONG FSWS IN MENA

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Student ID Number	LSH395506	**Title**	Mrs
First Name(s)	Hiam		
Surname/Family Name	Chemaitelly		
Thesis Title	Characterizing HIV epidemiology among female sex workers and their clients in the Middle East and North Africa		
Primary Supervisor	Professor Helen Weiss		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	Journal of Global Health		
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1. Preamble

This chapter provides a detailed epidemiological investigation of infection with *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and herpes simplex virus type 2 (HSV-2) among FSWs in MENA through a systematic synthesis of evidence for infection levels with these STIs, derivation of summary estimates for current and/or ever infection prevalence, and investigation of regional-level associations with prevalence (was only possible for syphilis), temporal trend, and of sources of heterogeneity between studies (**addresses objective 2 of thesis**). The study was motivated by i) findings of research paper 1 of emerging HIV epidemics in HSWNs in several MENA countries, yet still limited HIV circulation in others and a relatively low level of reported sexual risk behaviour among some FSWs in some countries, and ii) the utility of STIs as objective proxy biomarkers of sexual risk behaviour [1, 2] and as a tool for understanding the structure of sexual networks [1, 3]. Further, the considerable HIV prevalence identified in some of the FSW populations in MENA in research paper 1 highlighted an evidence gap regarding the STI prevalence among them.

This study aimed to fill this evidence gap and to further our understanding of the broader sexual health, prevention, and treatment needs of FSWs by providing the first systematic characterisation of STI epidemiology among FSWs in the region. The objectives were addressed through a systematic review of evidence for current and/or ever infection with *T. pallidum* (syphilis), *C. trachomatis*, *N. gonorrhoeae, T. vaginalis*, and HSV-2 in FSWs, retrieved through searching over ten international, regional, and country-level databases that incorporated country-level and international organizations' reports as well as routine data reporting [4], meta-analyses pooling measures of current and of ever infection for each STI at the regional and subregional levels as well as over different time periods, and meta-regression analyses examining associations and regional and temporal heterogeneities in syphilis prevalence across MENA.

Further published details on study methodology and results can be found in Appendix VI.

Electronic supplementary material:
The online version of this article contains supplementary material.

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PAPERS

Epidemiology of *Treponema pallidum*, *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and *Herpes simplex* virus type 2 among female sex workers in the Middle East and North Africa: systematic review and meta-analytics

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Background The epidemiology of sexually transmitted infections (STIs) and the role of commercial heterosexual sex networks in driving STI transmission in the Middle East and North Africa (MENA) region remain largely unknown.

Objective To characterize the epidemiology of *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and *Herpes simplex* virus type 2 (HSV-2) among female sex workers (FSWs) in MENA using an in-depth quantitative assessment.

Methods A systematic review on ten international, regional, and country-level databases was conducted, and reported following PRISMA guidelines. Pooled prevalences of current and/or ever infection for each STI were estimated using random-effects meta-analyses. Sources of between-study heterogeneity were investigated through random-effects meta-regressions.

Results One *T. pallidum* incidence study and 144 STI prevalence studies were identified for 45 812 FSWs in 13 MENA countries. The pooled prevalence of current infection was 12.7% (95% confidence interval (CI) = 8.5%-17.7%) for *T. pallidum*, 14.4% (95% CI = 8.2%-22.0%) for *C. trachomatis*, 5.7% (95% CI = 3.5%-8.4%) for *N. gonorrhoeae*, and 7.1% (95% CI = 4.3%-10.5%) for *T. vaginalis*. The pooled prevalence of ever infection (seropositivity using antibody testing) was 12.8% (95% CI = 9.4%-16.6%) for *T. pallidum*, 80.3% (95% CI = 53.2%-97.6%) for *C. trachomatis*, and 23.7% (95% CI = 10.2%-40.4%) for HSV-2. The multivariable meta-regression for *T. pallidum* infection demonstrated strong subregional differences, with the Horn of Africa and North Africa showing, respectively 6-fold (adjusted odds ratio (AOR): 6.4; 95% CI = 2.5-16.7) and 5-fold (AOR = 5.0; 95% CI = 2.5-10.6) higher odds of infection than Eastern MENA. There was also strong evidence for declining *T. pallidum* odds of infection at 7% per year (AOR = 0.93; 95% CI = 0.88-0.98). Study-specific factors including diagnostic method, sample size, sampling methodology, and response rate, were not associated with syphilis infection. The multivariable model explained 48.5% of the variation in *T. pallidum* prevalence.

Conclusions STI infection levels among FSWs in MENA are considerable, supporting a key role for commercial heterosexual sex networks in transmission dynamics, and highlighting the health needs of this neglected and vulnerable population. Syphilis prevalence in FSWs appears to have been declining for at least three decades. Gaps in evidence persist for multiple countries.

The burden of sexually transmitted infections (STIs) and sequelae remains a major global health concern [1]. Nearly one million persons are infected with a curable STI every day [2], and about half a billion are living with *Herpes simplex* virus type 2 (HSV-2) [3]. The largely asymptomatic nature of STIs, particularly for women, leaves most individuals unaware of their infection [1]. STIs have been associated with HIV acquisition [4-6], and poor reproductive health outcomes including pelvic inflammatory disease, ectopic pregnancy, infertility, and perinatal deaths [1,7].

Commercial heterosexual sex networks (CHSNs) are believed to play a critical role in STI transmission [8-10]. STIs have been demonstrated as proxy biomarkers of sexual risk behaviour [11,12], and as a powerful tool for understanding the structure of sexual networks and predicting HIV epidemic potential [11-13]. However, unlike HIV, STI epidemiology in CHSNs remains, globally, a neglected area of research [1]. Programmatically, STI surveillance among female sex workers (FSWs) continues to be weak and infection levels poorly quantified [1]. Sexual propagation of STIs along CHSNs is also poorly understood given the dearth or limited validity of self-reported sexual behaviour data [13-15].

To attend to the United Nations' Sustainable Development Goals (SDGs) and targets [16], particularly SDG3 target of "ensuring universal access to sexual and reproductive health services" [16], and to reduce the global burden of disease attributed to STIs, the World Health Organization (WHO) has recently formulated the "Global Health Sector Strategy on STIs" [6]. The goal of this strategy is to eliminate STIs as a major public health concern by 2030 through an integrated approach for prevention and control [6]. Milestones for 2020 include achieving 70% coverage for comprehensive STI prevention services among key populations [6]. The strategy's first strategic direction entails "understanding the STI epidemic as a basis for advocacy, political commitment, national planning, resource mobilization and allocation, implementation, and programme improvement" [6].

Despite remarkable progress in HIV research [17], and an understanding of the role of FSWs [18], people who inject drugs (PWID) [19], and men who have sex with men (MSM) [20], in the HIV epidemic in the Middle East and North Africa (MENA) region, the epidemiology of STIs and the role of CHSNs in driving STI transmission remain largely unknown [21]. The two global reviews of STI epidemiology in FSWs had no data for any of the 23 MENA countries [22,23]. A large volume of STI data in the region resides in databases that were never analyzed, or in country-level reports that were never published in the scientific literature [24,25].

Against this background, our study aimed to characterize the epidemiology of key STIs among FSWs in MENA by 1) systematically reviewing and synthesizing all available published and unpublished evidence for *Treponema pallidum* (henceforth referred to as syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and HSV-2 incidence and/or prevalence, 2) estimating, for each STI, the pooled mean prevalence of current and/or ever (seropositivity using antibody testing) infection, and 3) identifying sources of between-study heterogeneity, and regional and temporal trends associated with STI prevalence.

METHODS

We conducted a systematic review and an in-depth quantitative assessment to characterize STI epidemiology among FSWs in MENA. Details of the study methodology (including specific statistical analyses) can be found in subsequent sections.

Search strategy and selection criteria

Evidence for syphilis, *C. trachomatis*, *N. gonorrhaoeae*, *T. vaginalis*, and HSV-2 immunoglobulin G (IgG) incidence and/or prevalence among FSWs in MENA was systematically reviewed, informed by Cochrane's Collaboration guidelines [26]. Findings were reported following Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [27] (checklist in Table S1 in **Online Supplementary Document**). The MENA definition covers 23 countries—Afghanistan, Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates (UAE), and Yemen—based on convention in HIV research [19,20,24,25], and definitions of WHO, Joint United Nations Programme on HIV/AIDS (UNAIDS), and World Bank [24].

Systematic searches were performed up to September 20, 2018, on international databases (PubMed and Embase), regional and national databases (WHO Global Health Observatory data repository [28], WHO

African Index Medicus database, WHO Index Medicus for the Eastern Mediterranean Region database, Iranian Scientific Information Database, Iraqi Academic Scientific Journals' database, and Pakistan's PakMediNet database), abstract archives of International AIDS Society Conferences [29], as well as published and unpublished country-level and international organizations' reports available through the MENA HIV/AIDS Epidemiology Synthesis Project database [24,25]. Search strings were broad (MeSH/Emtree terms exploded to cover all subheadings and free text terms) with no language or year restrictions (Box S1 in **Online Supplementary Document**).

Duplicate citations were identified using a reference manager, Endnote. Titles and abstracts were then screened for relevance, with relevant/potentially relevant citations undergoing full-text screening. Any document reporting an incidence and/or prevalence measure in FSWs for an STI of interest, based on primary data, was eligible for inclusion. Case reports, case series, editorials, commentaries, and reviews were excluded. Hand searching was further performed on reference lists of all relevant articles.

The term *'study'* is used here to refer to a specific STI incidence or prevalence measure in a specific FSW population. Accordingly, one document/report could contribute multiple studies and one study could be published in different reports. Duplicate study results were included only once using the more detailed/recent report.

Data extraction and synthesis

Extraction was performed by HC, and double extraction by AS (extraction list in Box S2 in **Online Supplementary Document**). Discrepancies were settled by consensus, or by contacting authors. Full-texts in languages other than English were extracted by native speakers. Data were stratified by infection type (current vs ever (seropositivity using antibody testing)), and summarized using medians, ranges, and interquartile ranges (IQR). Definitions of infection types and details of the classification of diagnostic methods' results into current, recent, and ever infection can be found in Table S2 in **Online Supplementary Document**. It was assumed, for *N. gonorrhoeae* and *T. vaginalis* studies, whenever a diagnostic method was not explicitly specified, that the diagnostic method assessed current infection.

All STI studies were extracted and reported. However, studies applying the same assay to different biological specimens from the same person were included only once in analyses, for statistical independence. This was done based on a sequential order that prioritized infection detection in endocervical swabs, followed by vaginal, then urine samples. Studies assessing prevalence using different diagnostic methods, were also included only once in analyses, with studies using polymerase chain reaction prioritized over those using culture or other methods.

Quality assessment

The quality assessment for each STI prevalence study was informed by Cochrane Collaboration guidelines (criteria in Table S3 in **Online Supplementary Document**) [30]. Studies were classified as having "low" vs "high" risk of bias (ROB) on each of three quality domains assessing the 1) rigor of sampling methodology (probability-based; non-probability-based), 2) response rate (≥60% or ≥60% of target sample size reached for studies using respondent-driven or time-location sampling; <60%), and 3) STI ascertainment (biological assay explicitly indicated; otherwise). Studies with missing information for a specific domain were classified as having "unclear" ROB for that domain.

Given reported limitations in HSV-2 diagnostics [31,32], the quality of HSV-2 assays was determined by consulting with an expert advisor, Professor Rhoda Ashley-Morrow, University of Washington, Seattle. Studies where the validity of the diagnostic method could not be confirmed, were excluded from the systematic review.

Quality domains were included in meta-regression analyses (described below) to assess their impact on prevalence.

Meta-analyses

For each STI, the pooled mean prevalence of current and/or ever infection, along with the corresponding 95% confidence intervals (CIs), were estimated using meta-analysis. Overall prevalence measures were replaced by their strata where applicable. For each study, one final stratification was considered based on a pre-defined sequential order that prioritizes country of origin, followed by type of FSW, year, region, and age. Subregional and time-trend analyses were conducted as warranted by data. Variances were stabilized using Freeman-Tukey type arcsine square-root transformation [33,34]. Weights were applied using the inverse-variance method [34,35], before pooling measures using a Dersimonian-Laird random-effects model [36], thereby accounting for sampling variation and for true heterogeneity [37]. Missing sample sizes for measures or their strata (<4% of all studies) were imputed using the median sample size, as calculated from studies with available information.

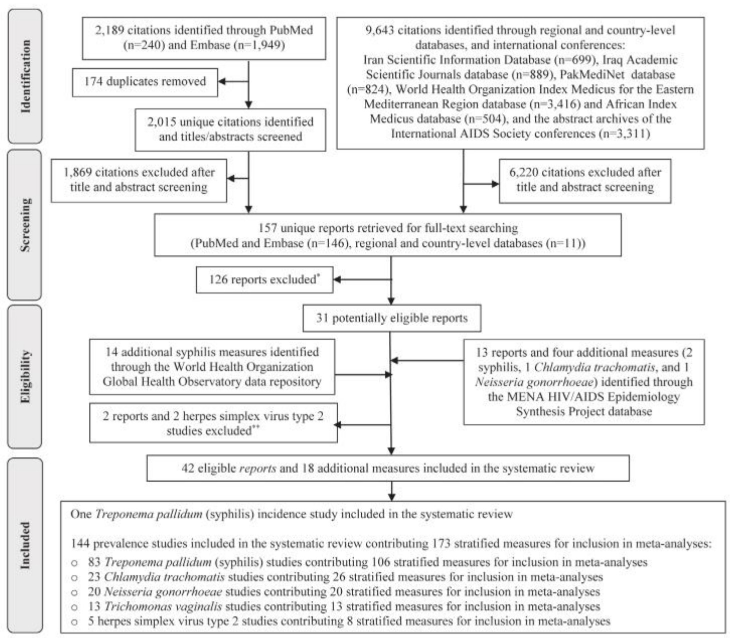
Heterogeneity assessment used Cochran's Q statistic to confirm existence of heterogeneity across studies, I^2 to determine magnitude of between-study variation that is due to true differences in effect size (prevalence) rather than chance, and prediction intervals to estimate the 95% interval of the true effect sizes' distribution [37,38].

Meta-analyses were implemented in R 3.4.2 (R core team, Vienna, Austria) [39].

Meta-regressions

Only syphilis had a considerable number of measures (>100) to warrant conduct of random-effects meta-regression analyses. Independent variables considered *a priori* were: country/subregion, year of data collection, infection type, diagnostic method, STI ascertainment, sample size, sampling methodology, and response rate. Details of subgrouping and justifications are in Table S4 in **Online Supplementary Document**. Meta-regression was conducted using the log-transformed odds of syphilis infection and corresponding variance. Factors associated with higher odds of infection at $P \leq 0.10$ in univariable analyses were included in the multivariable analysis. Factors with $P \leq 0.05$ in the multivariable model were considered as significant predictors of heterogeneity in syphilis prevalence.

Meta-regressions were implemented in Stata/SE 15.1 (StataCorp, College Station, TX, USA) [40].



*Reasons for exclusion:
Eligibility criteria not met (n=17)
Full-text did not include data on relevant indicators (n=95)
Conference abstract did not include data on relevant indicators (n=9)
Conference abstract duplicate of a full-text included in the review (n=2)
Duplicate of another study included in the review (n=3)

**Reasons for exclusion:
Replaced by the full detailed reports identified through the MENA HIV/AIDS Epidemiology Synthesis Project database (n=2)
Validity of the type-specific herpes simplex virus type 2 serology could not be confirmed (n=2)

Figure 1. Flowchart presenting the process of study selection following PRISMA guidelines [27].

RESULTS

Search results and scope of evidence

Figure 1 shows the study selection process based on PRISMA. The search identified a total of 11 832 citations: 240 through PubMed, 1949 through Embase, and 9643 through the rest of the databases. After removing duplicates and screening of titles and abstracts, 157 reports qualified for full-text screening, of which 31 were eligible for inclusion in the systematic review.

Thirteen additional reports, two of which replaced eligible articles, and four additional STI measures, were further identified through the MENA HIV/AIDS Epidemiology Synthesis Project database. Fourteen additional syphilis prevalence measures were identified through the WHO Global Health Observatory data repository. Two studies were excluded based on consultation with Professor Rhoda Ashley-Morrow, an expert advisor in HSV-2 diagnostics, because the validity of the type-specific HSV-2 serology could not be confirmed [41,42].

In sum, 42 eligible reports and 18 additional STI measures were included in the systematic review. These yielded one syphilis incidence study, and 144 prevalence studies assessing the different STIs. The latter contributed 173 stratified measures for inclusion in meta-analyses and meta-regressions.

STI prevalence data were available for 45 812 FSWs from 13 of the 23 MENA countries. Nearly two-thirds (58.9%) of prevalence studies assessed syphilis (in 29 769 FSWs), 16.3% assessed *C. trachomatis* (in 5613 FSWs), 12.8% assessed *N. gonorrhoeae* (in 5230 FSWs), 8.5% assessed *T. vaginalis* (in 4258 FSWs), and 3.6% assessed HSV-2 IgG (in 942 FSWs). Most studies (80.8%) were conducted post-2000. Over half (51.1%) of studies reported on current infection, 30.5% on ever infection (seropositivity using antibody testing), and 1.4% on recent infection. Time of exposure was unclear for the rest of studies (17.0%).

Incidence studies

The only one identified incidence study assessed syphilis incidence in FSWs. The study was conducted in 1988 in Mogadishu, Somalia, and reported cumulative incidence at 12.5% after six months of follow-up [43].

Prevalence studies

Prevalence of current syphilis infection among FSWs ranged, across studies (n=28), from 0%-50.8%, with a median of 9.4% (IQR: 3.0%-23.4%; Table 1). Meanwhile, seropositivity for syphilis (n=33) antibodies ranged from 0%-69.0%, with a median of 4.2% (IQR: 1.9%-15.2%).

Current *C. trachomatis* infection prevalence (n=14) ranged from 0.7%-72.9%, with a median of 7.7% (IQR = 1.7%-22.4%), while seropositivity prevalence using IgG (n=5) ranged from 19.8%-100%, with a median of 85.8% (IQR = 46.8%-97.1%; Table 2). Two studies reported recent *C. trachomatis* infection (assessed using serological biomarkers) at 29.2% [79] and 95.0% [78].

Current *N. gonorrhoeae* infection prevalence (n=18) ranged from 0%-14.5%, with a median of 7.6% (IQR = 1.3%-11.1%; Table 2). Current *T. vaginalis* infection prevalence (n=12) ranged from 0%-19.3%, with a median of 7.0% (IQR = 4.5%-14.2%; Table 2). HSV-2 seropositivity (using IgG; n=5) ranged from 4.7%-55.5%, with a median of 20.0% (IQR = 6.4%-39.1%; Table 3).

Quality assessment

The summarized and study-specific ROB assessments of prevalence measures are in Tables S5 and S6 in **Online Supplementary Document**, respectively. Briefly, nearly half of studies (44.7%) used probability-based sampling. Most studies (78.7%) indicated explicitly the biological assay used for STI ascertainment. Response rate information was missing in over half of studies (51.8%).

Overall, studies were of reasonable quality. Close to 60% of studies had low ROB on at least two quality domains, and none had high ROB on two or more domains.

Pooled mean prevalence estimates

Table 4 shows the results of meta-analyses estimating the pooled mean prevalence of current and/or ever infection for each STI. The mean prevalence of current infection was estimated at 12.7% (95% CI=8.5%-

Table 1. Prevalence of syphilis among FSWs in the Middle East and North Africa*

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Assay type	Tested (n)	Prevalence (%)
CURRENT INFECTION							
Afghanistan:							
Todd, 2010 [44]	2006-08	Jalalabad, Kabul, Mazar-i-Sharif	Conv	NGO	RPR+ & TPHA+	520	0
Egypt:							
MOH, 2000 [45]	1999-00	Greater Cairo	Conv	Community	RPR+ & TPHA+	52	5.8
Iran:							
Kassaian, 2012 [46]	2009-10	Isfahan	Conv	Prison, drop-in center	RPR+	91	0
Navadeh, 2012 [42]	2010	Kerman	RDS	Community	VDRL+	139	7.2
Kazerooni, 2014 [41]	2010-11	Shiraz	RDS	Community	VDRL+ & FTA-ABS+	278	0
Jahanbakhsh, 2017 [47]	2012	Tehran	Conv	Homeless shelters	RPR+	14	0
Morocco:							
MOH, 2008 [48]	2007	Agadir, Rabat-Sale, Tanger	Conv	Clinic	VDRL+ & TPHA+	141	13.5
MOH, 2012 [49]	2011-12	Agadir	RDS	Community	VDRL+ & TPHA+	362	21.4
MOH, 2012 [49]	2011-12	Fes	RDS	Community	VDRL+ & TPHA+	359	18.8
MOH, 2012 [49]	2011-12	Rabat	RDS	Community	VDRL+ & TPHA+	392	13.9
MOH, 2012 [49]	2011-12	Tanger	RDS	Community	VDRL+ & TPHA+	318	13.3
Pakistan:							
Baqi, 1998 [50]	1993-94	Karachi	Conv	Red-light district	VDRL+ & FTA-ABS+	814	5.0
Rehan, 2009 [51] & NACP, 2005 [52]	2004	Karachi	Snowball	Community	RPR+ & TPHA+	421	3.6
Rehan, 2009 [51] & NACP, 2005 [52]	2004	Lahore	SyCS	Red-light district	RPR+ & TPHA+	387	16.0
Shah, 2004 [53]	2004	Hyderabad	Conv	Community	VDRL+ & TPHA+	157	11.5
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	RPR+ & TPHA+	107	2.8
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	RPR+ & TPHA+	426	1.2
Khan, 2011 [55]	2007	Lahore	RDS	Community	RPR+ & TPHA+	730	4.5
Somalia:							
Jama, 1987 [56]	1985-86	Mogadishu	Conv	Community	VDRL+ & TPHA+	85	44.7
Jama Ahmed, 1991 [43]	1988-89	Mogadishu	Conv	Community	VDRL/RPR+ & TPHA+	155	47.7
Scott, 1991 [57]	1989	Kismayu, Merca	Conv	NR	RPR+ & FTA-ABS+	57	50.8
Corwin, 1991 [58]	1990	Chismayu, Merca, Mogadishu	Conv	NR	RPR+ & FTA-ABS+	302	35.4
Watts, 1994 [59]	1990	Chismayu, Merca, Mogadishu	Conv	NR	RPR+ & FTA-ABS+	236	30.9
IOM, 2017 [60]	2014	Hargeisa	RDS	Community	RDT+ & RPR+	96	2.4
Sudan:							
MOH, 2016 [61]	2015-16	Juba, South Sudan	RDS	Community	RDT+ & RPR+	832	7.3
Tunisia:							
Bchir, 1988 [62]	1987	Sousse	Conv	NR	VDRL+ & TPHA+	42	28.6
Ayachi, 1997 [63]	1992-94	Tunis	Conv	NR	VDRL+ & TPHA+	79	24.1
Yemen:							
Stulhofer, 2008 [64]	2008	Aden	RDS	Community	VDRL+	244	4.9

Table 1. Continued

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Assay type	Tested (n)	Prevalence (%)
EVER INFECTION‡							
Afghanistan:							
NACP, 2010 [65]	2009	Kabul	RDS	Community	RDT+	368	5.4
NACP, 2012 [66]	2012	Herat	RDS	Community	RDT+	344	0.9
NACP, 2012 [66]	2012	Kabul	RDS	Community	RDT+	333	0.0
NACP, 2012 [66]	2012	Mazar-i-Sharif	RDS	Community	RDT+	355	2.0
Algeria:							
MOH, 2009 [67]	2004	National	Conv	Sentinel surveillance	TPHA+	185	11.9
MOH, 2009 [67]	2007	National	Conv	Sentinel surveillance	TPHA+	380	18.4
Iran:							
Mirzazadeh, 2016 [68]	2015	National	Conv	Community, clinic	RDT+	1,337	0.4
Pakistan:							
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	TPHA+	107	2.8
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	TPHA+	426	1.6
Bibi, 2010 [69]	2003	Hyderabad	Conv	Red-light district	TPHA+	50	44.0
Raza, 2015 [70]	2014	Rawalpindi	Conv	Clinic	RDT+	NR	20.0
Somalia:							
Jama, 1987 [56]	1985-86	Mogadishu	Conv	Community	TPHA+	85	57.6
Jama Ahmed, 1991 [43]	1988-89	Mogadishu	Conv	Community	TPHA+	155	69.0
Burans, 1990 [71]	NR	Mogadishu	Conv	NR	TPHA+	89	28.1
IOM, 2017 [60]	2008	Hargeisa	RDS	Community	RDT+	237	3.4
Sudan:							
Sudan NACP, 2012 [72]	2011	Alshamalia	RDS	Community	RDT+	305	1.5
Sudan NACP, 2012 [72]	2011	Blue Nile	RDS	Community	RDT+	279	3.4
Sudan NACP, 2012 [72]	2011	Gadarif	RDS	Community	RDT+	282	3.4
Sudan NACP, 2012 [72]	2011	Gezira	RDS	Community	RDT+	296	5.4
Sudan NACP, 2012 [72]	2011	Kassala	RDS	Community	RDT+	288	4.3
Sudan NACP, 2012 [72]	2011	Khartoum	RDS	Community	RDT+	287	1.7
Sudan NACP, 2012 [72]	2011	North Darfur	RDS	Community	RDT+	303	5.2
Sudan NACP, 2012 [72]	2011	North Kodofan	RDS	Community	RDT+	296	4.1
Sudan NACP, 2012 [72]	2011	Red Sea	RDS	Community	RDT+	293	8.9
Sudan NACP, 2012 [72]	2011	River Nile	RDS	Community	RDT+	291	1.9
Sudan NACP, 2012 [72]	2011	Sinnar	RDS	Community	RDT+	303	5.3
Sudan NACP, 2012 [72]	2011	South Darfur	RDS	Community	RDT+	299	1.8
Sudan NACP, 2012 [72]	2011	West Darfur	RDS	Community	RDT+	284	1.8
Sudan NACP, 2012 [72]	2011	White Nile	RDS	Community	RDT+	288	4.2
MOH, 2016 [61]	2015-16	Juba, South Sudan	RDS	Community	RDT+	832	12.0
Tunisia							
Bchir, 1988 [62]	1987	Sousse	Conv	NR	TPHA+	42	38.1
Ayachi, 1997 [63]	1992-94	Tunis	Conv	NR	TPHA+	79	36.7
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	TPHA+	183	2.7

Table 1. Continued

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Assay type	Tested (n)	Prevalence (%)
UNCLEAR							
Afghanistan:							
WHO, 2018 [28]	2010	NR	NR	NR	NR	NR	8.7
MENA HIV ESP, 2013 [74]	2012	Kabul	NR	NR	NR	440	5.7
WHO, 2018 [28]	2017	NR	NR	NR	NR	2,457	1.3
Algeria:							
WHO, 2018 [28]	2013	Oran	NR	NR	NR	27	7.4
WHO, 2018 [28]	2014	Saida	NR	NR	NR	24	29.2
WHO, 2018 [28]	2016	NR	Conv	VCT	NR	183	14.2
WHO, 2018 [28]	2017	NR	Conv	VCT	NR	81	16.0
Djibouti:							
WHO, 2015 [1]	2014	4 urban sites	NR	NR	NR	361	5.0
Iran:							
WHO, 2018 [28]	2008	NR	NR	NR	NR	NR	1.6
Moayedi-Nia, 2016 [75]	2012-13	Tehran	RDS	Community	NR	161	0
Jordan:							
WHO, 2015 [1]	2008	NR	NR	NR	NR	NR	6.7
Morocco:							
Khattabi, 2005 [76]	2004	National	Conv	Prison	NR	332	9.6
Khattabi, 2005 [76]	2004	National	Conv	Clinic	NR	272	12.1
Khattabi, 2005 [76]	2004	Grand Casablanca	Conv	STI clinic	NR	143	9.0
Bennani, 2006 [77]	2005	National	Conv	Prison	NR	102	11.8
Bennani, 2006 [77]	2005	National	Conv	Clinic	NR	143	13.3
WHO, 2018 [28]	2008	NR	NR	NR	NR	NR	16.9
Pakistan:							
MENA HIV ESP, 2010 [24]	2007	NR	NR	NR	NR	NR	23.5
Somalia:							
WHO, 2018 [28]	2017	Bossaso, Hargeisa, Mogadishu	RDS	Community	NR	860	2.7
Sudan:							
WHO, 2018 [28]	2016	National	RDS	Community	NR	4,123	4.1
WHO, 2018 [28]	2017	South Sudan	NR	NR	NR	1,244	14.4
Yemen:							
WHO, 2018 [28]	2010	Hodeida	RDS	Community	NR	301	0

Conv – convenience, FTA-ABS – fluorescent treponemal antibody absorption test, IOM – International Organization for Migration, MENA HIV ESP – MENA HIV/AIDS Epidemiology Synthesis Project database, MOH – Ministry of Health, NACP – National AIDS Control Program, NGO – non-governmental organization, NR – not reported, RDS – respondent-driven sampling, RDT – rapid diagnostic test, RPR – rapid plasma regain, STI – sexually transmitted infection, SyCS – systematic cluster sampling, TPHA – *Treponema pallidum* haemagglutination assay, VCT – voluntary counseling and testing center, VDRL – venereal disease research laboratory

*The table is sorted, for each country, by data collection year(s) then city/province.

†Sample comprised of 77 FSWs and 4 transgender women.

‡Ever infection indicates seropositivity using antibody testing.

Table 2. Prevalence of *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, and *Trichomonas vaginalis* among FSWs in the Middle East and North Africa*

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Specimen	Assay type	Tested (n)	Prevalence (%)
CURRENT INFECTION								
Chlamydia trachomatis								
Algeria:								
Kadi, 1989 [78]	NR	NR	Conv	Clinic	Endocervical	IFAT	44	45.5
Egypt:								
MOH, 2000 [45]	1999-00	Cairo	Conv	Community	Urine	NAAT	52	7.7
Iran:								
Darougar, 1983 [79]	NR	Bandar Abbas, Tehran	Conv	Clinic	Endocervical	Culture	116	6.9
Kazerooni, 2014 [41]	2010-11	Shiraz	RDS	Community	Vaginal	NAAT	278	9.0
Mirzazadeh, 2016 [68]	2015	National	Conv	Clinic, community	Vaginal	NAAT	1337	6.0
Morocco:								
MOH, 2008 [48]	2007	Agadir, Rabat Sale, Tanger	Conv	Clinic	Endocervical & urine	NAAT	141	22.7
MOH, 2012 [49]	2011-12	Agadir	RDS	Community	Endocervical	NAAT	368	22.4
Pakistan:								
Rehan, 2009 [51]	2004	Karachi	Snowball	Community	Vaginal	NAAT	348	5.2
Rehan, 2009 [51]	2004	Lahore	SyCS	Red-light district	Vaginal	NAAT	283	11.0
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	Endocervical	NAAT	107	0.9
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	Endocervical	NAAT	426	1.7
Khan, 2011 [55]	2007	Lahore	RDS	Community	Endocervical	NAAT	730	7.7
Somalia:								
IOM, 2017 [60]	2014	Hargeisa	RDS	Community	Urine	NAAT	90	0.7
Tunisia:								
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	Endocervical	NAAT	188	72.9
Neisseria gonorrhoeae								
Egypt:								
MOH, 2000 [45]	1999-00	Cairo	Conv	Community	Urine	NAAT	52	7.7
Iran:								
Kazerooni, 2014 [41]	2010-11	Shiraz	RDS	Community	Vaginal	Culture	278	1.4
Navadeh, 2012 [42] & WHO, 2011 [80]	2010	Kerman	RDS	Community	NR	NR†	144	0
Nasirian, 2017 [81]	2013-14	Isfahan	Conv	Harm reduction	Endocervical	NAAT	99	9.1
Nasirian, 2017 [81]	2013-14	Isfahan	Conv	Harm reduction	Urine	NAAT	99	0‡
Taghizadeh, 2015 [82]	2014	Sari	Conv	Drop-in center	NR	NR†	117	1.0
Mirzazadeh, 2016 [68]	2015	National	Conv	Clinic, community	Vaginal	NAAT	1337	1.3
Morocco:								
MOH, 2008 [48]	2007	Agadir, Rabat Sale, Tanger	Conv	Clinic	Endocervical & urine	NAAT	141	10.6
MENA HIV ESP, 2010 [24]	NR	NR	NR	NR	NR	NR†	NR	3.5
MOH, 2012 [49]	2011-12	Agadir	RDS	Community	Endocervical	NAAT	368	11.7
Pakistan:								
Rehan, 2009 [51]	2004	Karachi	Snowball	Community	Vaginal	NAAT	348	9.8
Rehan, 2009 [51]	2004	Lahore	SyCS	Red-light district	Vaginal	NAAT	383	12.3

Table 2. Continued

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Specimen	Assay type	Tested (n)	Prevalence (%)
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	Endocervical	NAAT	107	1.9
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	Endocervical	NAAT	426	2.0
Khan, 2011 [55]	2007	Lahore	RDS	Community	Endocervical	NAAT	730	7.5
Somalia:								
Burans, 1990 [71]	NR	Mogadishu	Conv	NR	NR	Culture	89	11.2
IOM, 2017 [60]	2014	Hargeisa	RDS	Community	Urine	NAAT	91	0.4
Tunisia:								
NACP, 2005 [83]	2005	NR	NR	NR	NR	NR†	NR	12.0-17.0§
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	Endocervical	Culture	188	3.7‖
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	Endocervical	NAAT	188	11.2
Trichomonas vaginalis								
Egypt:								
MOH, 2000 [45]	1999-00	Cairo	Conv	Community	Urine	NAAT	52	19.2
Iran:								
Vafaei, 2015 [84]	2009-11	Shiraz	Conv	Clinic, drop-in center	Endocervical	Wet mount	85	8.2
Navadeh, 2012 [42] & WHO, 2011 [80]	2010	Kerman	RDS	Community	NR	NR†	144	1.4
Nasirian, 2017 [81]	2013-14	Isfahan	Conv	Harm reduction	Endocervical	NAAT	99	0.0
Nasirian, 2017 [81]	2013-14	Isfahan	Conv	Harm reduction	Urine	NAAT	99	0.0‡
Mirzazadeh, 2016 [68]	2015	National	Conv	Clinic, community	Vaginal	NAAT	1337	11.9
Morocco:								
MOH, 2008 [48]	2007	Agadir, Rabat Sale, Tanger	Conv	Clinic	Endocervical & vaginal	Culture	141	14.9
MOH, 2012 [49]	2011-12	Agadir	RDS	Community	Vaginal	NAAT	367	11.8
Pakistan:								
Rehan, 2009 [51]	2004	Karachi	Snowball	Community	Vaginal	Culture	386	5.2
Rehan, 2009 [51]	2004	Lahore	SyCS	Red-light district	Vaginal	Culture	384	19.3
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	Vaginal	NAAT	107	5.7
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	Vaginal	NAAT	426	4.3
Khan, 2011 [55]	2007	Lahore	RDS	Community	Vaginal	Culture	730	5.1
RECENT INFECTION								
Chlamydia trachomatis								
Algeria:								
Kadi, 1989 [78]	NR	NR	Conv	Clinic	Serum	MIF>1:64¶	44	95.0
Iran:								
Darougar, 1983 [79]	NR	Bandar Abbas, Tehran	Conv	Clinic	Serum	MIF-IgM	154	29.2
EVER INFECTION**								
Chlamydia trachomatis								
Algeria:								
Kadi, 1989 [78]	NR	NR	Conv	Clinic	Serum	MIF-IgG	44	100

Table 2. Continued

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Specimen	Assay type	Tested (n)	Prevalence (%)
Iran:								
Darougar, 1983 [79]	NR	Bandar Abbas, Tehran	Conv	Clinic	Serum	MIF-IgG	154	94.2
Kassaian, 2012 [46]	2009-10	Isfahan	Conv	Drop-in center	Serum	ELISA-IgG	91	19.8
Tunisia								
Bchir, 1988 [62]	1987	Sousse	Conv	NR	Serum	MIF>1:16	42	73.8
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	Serum	MIF-IgG	183	85.8
UNCLEAR								
Chlamydia trachomatis:								
Iran:								
Navadeh, 2012 [42] & WHO, 2011 [80]	2010	Kerman	RDS	Community	NR	NR	144	2.9
Morocco:								
MENA HIV ESP, 2010 [24]	NR	NR	NR	NR	NR	NR	NR	19.1

Conv – convenience, ELISA – enzyme-linked immunosorbent assay, IFAT – indirect immunofluorescence antibody test, IgG – immuneglobulin G, IgM - immunoglobulin M, IOM – International Organization for Migration, MENA HIV ESP – MENA HIV/AIDS Epidemiology Synthesis Project database, MIF – micro-immunofluorescence, MOH – Ministry of Health, NAAT – Nucleic acid amplification test, NR – not reported, RDS – respondent-driven sampling, SyCS – systematic cluster sampling, WHO – World Health Organization

*The table is sorted for each country by data collection year(s) then city/province.

†For *Neisseria gonorrhoeae* and *Trichomonas vaginalis* studies, whenever the diagnostic method was not explicitly specified, it was assumed that the diagnostic method assessed current infection.

‡Studies reported in the systematic review, but not included in analyses considering the priority order followed for selecting studies applying the same assay to different biological specimens.

§Range reported based on several studies whose abstracts or full-texts could not be retrieved (mid-point: 14.5%).

‖Studies reported in the systematic review, but not included in analyses as prevalence was also assessed using NAAT.

¶Reported in study as recent infection.

**Ever infection indicates seropositivity using antibody testing.

Table 3. Prevalence of *Herpes simplex* virus type 2 (HSV-2) immunoglobulin G (IgG) sero-markers among FSWs in the Middle East and North Africa

Country short citation	Year(s) of data collection	City/province	Sampling	Study site	Specimen	Assay type	Tested (n)	Prevalence (%)
Pakistan:								
Hawkes, 2009 [54]	2007	Abbottabad	RDS	Community	Serum	ELISA-IgG	107	4.7
Hawkes, 2009 [54]	2007	Rawalpindi	RDS	Community	Serum	ELISA-IgG	426	8.0
Syria:								
Ibrahim, 2000 [85]	1995-98	Damascus	Conv	Cheap hotels & prison	Serum	MEIA-IgG	101	22.8
Ibrahim, 2000 [85]	1995-98	Damascus	Conv	Bars	Serum	MEIA-IgG	125	20.0
Tunisia:								
Znazen, 2010 [73]	2007	Gabes, Sousse, Tunis	Conv	Clinic	Serum	ELISA-IgG	183	55.5

Conv – convenience, ELISA – enzyme-linked immunosorbent assay. MEIA – micro-enzyme immunoassay. RDS – respondent-driven sampling

17.7%) for syphilis, 14.4% (95% CI=8.2%-22.0%) for *C. trachomatis*, 5.7% (95% CI=3.5%-8.4%) for *N. gonorrhoeae*, and 7.1% (95% CI = 4.3%-10.5%) for *T. vaginalis*.

The mean prevalence of ever infection was estimated at 12.8% (95% CI=9.4%-16.6%) for syphilis, 80.3% (95% CI=53.2%-97.6%) for *C. trachomatis*, and 23.7% (95% CI=10.2%-40.4%) for HSV-2 IgG.

There was strong evidence for heterogeneity in effect size (here, prevalence). *P* for Cochran's Q statistic was always <0.0001. I^2 was >90% in all meta-analyses, indicating that most variability is due to true differences in effect size across studies, rather than being due to chance. Prediction intervals were also wide affirming high heterogeneity.

Additional meta-analyses at the subregional level indicated the mean prevalence of current syphilis infection at 3.0% (95% CI=0.9%-9.2%) in Eastern MENA, 17.6% (95% CI=14.2%-21.3%) in North Africa, and 27.8% (95% CI=15.2%-42.4%) in the Horn of Africa (Table S7 in **Online Supplementary Document**). There was also a tendency for a decline in current infection prevalence post-2010 (Table S8 and Figure S1A in **Online Supplementary Document**). For the rest of the STIs, the number of studies was small and the CIs were wide and overlapping to warrant conclusive statement about the temporal trend (Table S8 in **Online Supplementary Document**).

Predictors of variability in syphilis infection

Country/subregion, year of data collection, diagnostic method, sample size, sampling methodology, and response rate were associated with higher odds of syphilis infection in the univariable meta-regression analyses. These were, therefore, included in the multivariable model (**Table 5**). About a third of the variability was explained by each of year of data collection and subregion (adjusted R-squared: 34.6% and 31.5%, respectively). Meanwhile, no evidence for an association with infection type (current infection; ever infection), or STI ascertainment (biological assay explicitly indicated; otherwise) was found.

The multivariable analysis showed strong evidence for subregional differences, with Horn of Africa and North Africa showing, respectively, 6-fold (adjusted odds ratio (AOR): 6.4; 95% CI=2.5-16.7) and 5-fold (AOR=5.0; 95% CI=2.5-10.6), higher odds of syphilis infection than Eastern MENA.

There was also strong evidence for a temporal trend of decreasing odds of infection at 7% per year (AOR=0.93; 95% CI=0.88-0.98; linearity dictated by data (Figure S1 in **Online Supplementary Document**) over the last three decades. Although this trend was noted in all subregions, individual subregion meta-regressions were not always powered to detect statistical significance (not shown).

No evidence for an association with diagnostic method, sample size, sampling methodology, and response rate was identified in the multivariable model. The multivariable model explained 48.5% of variation in syphilis prevalence.

DISCUSSION

We provided, to our knowledge, the first detailed assessment of the epidemiology of key STIs in FSWs in MENA, a neglected key population. Our findings indicated substantial STI prevalence, several folds higher than that among the general population [2,13,24,86]. These findings suggest a major role for CHSNs in driving STI transmission in MENA. We further found large heterogeneity in syphilis infection levels by subregion within MENA, as well as a trend of decreasing odds of infection by ~ 7% per year – less than the 17% [86] annual decline needed to achieve the target of 90% reduction in syphilis incidence by 2030 [6].

Despite the significant infection burden, STI surveillance and response in MENA continue to be rudimentary [21], and far below the coverage targets of WHO Global Health Sector Strategy for STIs [6]. Infected individuals are often identified through routine case notifications with surveillance/testing being largely limited to HIV [21,24,87], and sexual health programs, where they exist, cater to general population women rather than women at high risk [24].

Although our expansive search identified considerable evidence at the regional-level, including data that will appear in the scientific literature for the first time, evidence varied by country. Over half of countries had no data on any of the STIs in this key population, less than a third had data on *C. trachomatis*, *N. gonorrhoeae*, or *T. vaginalis*, and only three countries had data on HSV-2 IgG (**Table 1**, **Table 2** and **Table 3**). This outcome is of concern, given the considerable, yet preventable, STI infection burden among FSWs in the region (**Table 4**), and the major "core group" role that CHSNs play in STI transmis-

Table 4. Results of meta-analyses on prevalence studies for *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and *Herpes simplex* virus type 2 (HSV-2) among FSWs in the Middle East and North Africa

Sexually transmitted infection*	Studies	Samples		Reported prevalence		Pooled mean prevalence		Heterogeneity measures		
	N†	Tested	Positive	Median‡ (%)	Range‡ (%)	Estimate (%)	95% CI	Q§ (*P*)	I2‖ (%; 95% CI)	Prediction interval¶ (95%)
Current infection:										
Treponema pallidum (syphilis)	34	7103	842	10.8	0-62.0	12.7	8.5-17.7	1045.3 (*P*<0.0001)	96.8 (96.2-97.4)	0.0-48.8
Chlamydia trachomatis	16	4608	512	8.4	0.7-76.2	14.4	8.2-22.0	611.4 (*P*<0.0001)	97.5 (96.9-98.1)	0.0-53.6
Neisseria gonorrhoeae	20	5230	301	7.9	0-17.5	5.7	3.5-8.4	248.2 (*P*<0.0001)	92.3 (89.6-94.4)	0.0-21.6
Trichomonas vaginalis	13	4258	397	7.1	0-19.3	7.1	4.3-10.5	164.7 (*P*<0.0001)	92.7 (89.3-95.0)	0.0-23.7
Recent infection:										
Chlamydia trachomatis	2**	198	87	62.1	29.2-95.0	–	–	–	–	–
Ever infection:††										
Treponema pallidum (syphilis)	50	9968	710	7.0	0-92.3	12.8	9.4-16.6	1261.0 (*P*<0.0001)	96.1 (95.5-96.7)	0.0-45.2
Chlamydia trachomatis	6	514	395	84.7	19.8-100	80.3	53.2-97.6	213.0 (*P*<0.0001)	97.7 (96.4-98.5)	0.0-100.0
Herpes simplex virus type 2 IgG	8	942	188	20.3	4.7-59.7	23.7	10.2-40.4	185.0 (*P*<0.0001)	96.2 (94.3-97.5)	0.0-84.9
Unclear										
Treponema pallidum (syphilis)	22	12698	771	8.9	0-29.2	7.7	5.1-10.7	591.3 (*P*<0.0001)	96.4 (95.5-97.2)	0.0-25.7
Chlamydia trachomatis	2**	293	32	11.0	2.9-19.1	–	–	–	–	–

CI – confidence interval, FSWs – female sex workers, IgG – immunoglobulin G, P – *P*-value

*The same population may have contributed different measures for both current infection and ever (seropositivity using antibody testing) infection.

†Missing sample sizes for measures (or their strata) were imputed using the median sample size calculated from studies with available information (only two stratified measures for *Neisseria gonorrhoeae*, one stratified measure for *Chlamydia trachomatis*, one stratified measure for current syphilis infection, 5 stratified measures of unclear syphilis infection, had their sample size imputed, that is 5% of all data).

‡Medians and ranges were calculated based on the stratified prevalence measures.

§Q – the Cochran's Q statistic is a measure assessing the existence of heterogeneity in effect size (here, prevalence) across studies.

‖I2 – a measure assessing the magnitude of between-study variation that is due to differences in effect size (here, prevalence) across studies rather than chance.

¶Prediction interval: a measure estimating the 95% interval of the distribution of true effect sizes (here, prevalence measures).

**Meta-analyses were performed if at least three studies were available.

††Ever infection indicates seropositivity using antibody testing.

sion in any population [10]. Indeed, while the population proportion of FSWs (proportion of FSWs out of the total women population) varies across countries and may seem relatively small [18,88], the size of CHSNs is large suggesting a considerable number of women and men at risk of STI-related morbidity, either through engagement in high sexual risk behavior, or through onward infection transmission [89].

Availability of STI data stands in contrast to HIV data, for which the volume of evidence among FSWs was several fold higher and encompassed most countries [18]. Attending to WHO Global Health Sector Strategy on STIs [6] necessitates a major expansion of STI research and surveillance, as has been done for HIV [17,87,90]. Regrettably, integrated bio-behavioural surveillance surveys (IBBSS) among key populations continue to be focused on HIV, rarely incorporating STIs [91,92]. This presents an important, yet lost, opportunity for monitoring STI levels and trends in key populations, informing programming efforts, gaining an in-depth understanding of sexual networks' structure, and advancing STI research in this region [13,91,93].

Subregion and time explained most variation in syphilis prevalence—each explained over a third of the variation, and both (remarkably) explained ~50% of the variation (**Table 5**). The strong subregional differences, with Horn of Africa showing the highest prevalence, followed by North Africa, and then Eastern MENA (**Table 5** and Table S7 in **Online Supplementary Document**), appear to reflect variability in the risk environment, such as differences in structure of sexual networks [24], condom use [18], and access to care [24]. The same pattern has been seen in HIV epidemiology among FSWs [18].

There was strong evidence for a time trend of decreasing odds of infection at ~7% per year (**Table 5**, and Table S8 and Figure S1 in the OSD), consistent with, but smaller than, the decline reported for the general population in MENA in a recent global analysis [86], and the declines reported for the general populations in other regions [86]. Different factors may have contributed to this trend including safer sex following the HIV epidemic [94], increased condom use to prevent unwanted pregnancy [18], and HIV-related mortality which may have disproportionally affected populations at higher risk of STIs [95]. This may have been also a consequence of a shorter

Table 5. Results of meta-regression analyses to identify associations and sources of between-study heterogeneity in syphilis prevalence in the Middle East and North Africa (MENA)

Factors		Studies	Samples	Univariable analyses				Multivariable analysis*		
		Total N	Total n	OR† (95% CI)	P	P‡ of LR test	Variance explained R2 (%)	AOR† (95% CI)	P	P§ of LR test
Country/subregion:‖										
Eastern MENA	Afghanistan, Iran, Pakistan	28	10865	1.00		<0.001	31.52	1.00		<0.001
Egypt, Jordan, Yemen	Egypt, Jordan, Yemen	4	881	0.89 (0.15-5.10)	0.893			0.66 (0.13-3.28)	0.609	
North Africa	Algeria, Morocco, Sudan, Tunisia	48	12394	5.34 (2.45-11.61)	<0.001			5.01 (2.37-10.61)	<0.001	
Horn of Africa	Djibouti, Somalia, South Sudan	26	5629	21.63 (8.89-52.69)	<0.001			6.40 (2.45-16.69)	<0.001	
Year of data collection¶		106	29769	0.88 (0.85-0.91)	<0.001	<0.001	34.61	0.93 (0.88-0.98)	0.005	0.005
Infection type	Current	34	7103	1.00		0.515	0.00	–	–	–
	Ever**	50	9968	1.25 (0.52-3.00)	0.622			–	–	–
	Unclear	22	12698	0.69 (0.23-2.04)	0.501			–	–	–
Diagnostic method	RPR/VDRL & TPHA/FTA-ABS/RDT	29	6095	1.00		<0.001	22.44	1.00		0.444
	RPR/VDRL	4	488	0.09 (0.01-0.61)	0.013			0.76 (0.15-4.00)	0.746	
	TPHA	28	1781	2.17 (0.86-5.45)	0.099			1.29 (0.54-3.07)	0.558	
	RDT	23	8707	0.17 (0.06-0.45)	<0.001			0.46 (0.18-1.18)	0.104	
	Not specified	22	12698	0.43 (0.16-1.16)	0.094			0.75 (0.24-2.33)	0.614	
STI ascertainment	Biological assay not reported	23	13066	1.00		0.284	0.15	–	–	–
	Biological assay explicitly indicated	83	16703	1.66 (0.65-4.20)	0.284			–	–	–
Sample size	<100 participants	42	1960	1.00		<0.001	20.02††	1.00		
	≥100 participants	64	27809	0.16 (0.08-0.32)	<0.001			1.60 (0.62-4.15)	0.329	0.329
Sampling methodology	Non-probability/unclear sampling	66	12555	1.00		<0.001	18.73‡‡	1.00		
	Probability-based sampling	40	17214	0.16 (0.08-0.34)	<0.001			0.63 (0.25-1.63)	0.339	0.339
Response rate	<60%/unclear	69	18400	1.00		<0.001	10.23§§	1.00		
	≥60%	37	11369	0.25 (0.12-0.54)	0.001			0.73 (0.29-1.84)	0.495	0.495

AOR – adjusted odds ratio, CI – confidence interval, FTA-ABS – fluorescent treponemal antibody absorption test, LR – likelihood ratio, OR – odds ratio, P – *P*-value, RDT – rapid diagnostic test, RPR – rapid plasma regain, STI – sexually transmitted infection TPHA – *Treponema pallidum* haemagglutination assay. VDRL – venereal disease research laboratory

*Adjusted R^2 in the multivariable model: 48.46%.

†An increment of 0.1 was added to number of events when generating log odds of syphilis infection. This is because 8 stratified measures had zero events.

‡Factors with $P \leq 0.1$ were eligible for inclusion in the multivariable analysis.

§Factors with $P<0.05$ in the multivariable model were considered as significant predictors.

‖Countries were grouped based on geography and similarity in prevalence levels.

¶Missing values for year of data collection (only one stratified measure) were imputed using data for year of publication adjusted by the median difference between year of publication and median year of data collection for studies with complete information.

**Ever infection indicates seropositivity using antibody testing.

††The high R^2 was investigated and found to be due to confounding with year of data collection. Most studies with sample size ≥100 were conducted in recent years.

‡‡The high R^2 was investigated and found to be due to confounding with country and year of data collection. Studies with non-probability sampling were mostly from the Horn of Africa. These studies tended also to be conducted in earlier years.

§§The high R^2 was investigated and found to be due to confounding with year of data collection. Most studies with response rate ≥60% were conducted in recent years.

duration of active syphilis infection in FSWs or their sex partners [96,97], possibly because of improvements in syphilis diagnostics and treatment, or because of widespread use of antibiotics (including for non-STI infections, which sometimes may cure concurrent syphilis) [86].

This being said, recent surveillance data seems also to suggest an increase in syphilis incidence and/or prevalence in other sexual networks or in specific settings, such as among MSM [98-100], and even among reproductive-age women in few countries where congenital syphilis appears to be rising [101,102]. Contributors to these trends may include behavioral factors, such as more sexual partners and unprotected sex among MSM, as well as contextual factors, and possibly even biological factors [99,100,102-104].

Prevalence measures for syphilis and for *C. trachomatis* in FSWs in MENA were comparable to global levels [22,23], but prevalence measures for *N. gonorrhoeae* and *T. vaginalis* leaned towards the lower end of the global range [22,23]. Even though the risk environment among FSWs in MENA seems less conducive to STI transmission, as compared to other regions [18], STI prevalence levels are substantial, perhaps affected by poor access to health care and prevention interventions [21,24,105], as well as absence of enabling environments for this vulnerable population, in a context of criminality [106,107] and stigma [108-110].

While interventions aiming at promoting safer sex, such as condom use, and STI etiological diagnosis and treatment, in high risk populations are widely accepted and advocated for [6,111-114], STI syndromic case management and presumptive treatment have been increasingly subject to criticism amid growing concerns about their role in promoting pathogens' antimicrobial resistance (AMR) [111,115-119]. Indeed, substantial AMR prevalence and multiple drug resistant strains have been found in gonococcal isolates from FSWs in sub-Saharan Africa [120,121] and elsewhere [122]. This suggests that despite the effectiveness of targeted STI treatment services in reducing STI incidence and prevalence, their appropriateness and sustainable implementation will need to be informed by surveillance and monitoring, notably for AMR, and thus may vary across settings [111,122]. This further supports WHO efforts towards building a global business case for accelerating development of STI vaccines as a fundamental solution to STI drug resistance [123-125].

This study is limited by the quantity and quality of available data. STI prevalence among FSWs remains unknown in over half of countries. While there was considerable evidence for syphilis, less evidence was found for *C. trachomatis*, *N. gonorrhoeae*, *T. vaginalis*, and HSV-2, limiting our ability to conduct advanced meta-analytics—meta-regressions were carried out only for syphilis. Though, for syphilis prevalence, the differences between current vs ever (seropositivity using antibody testing) infection, as well as the differences between diagnostics, were consistent with the findings of a large global analysis for the general population [86], the confidence intervals were wide owing to the smaller number of studies (**Table 5**). Several measures were based on routine data reporting, and did not include sufficient documentation of study methodology. There was also a wide array of diagnostics used for STI ascertainment, which may have affected observed prevalence.

Available studies may not be representative of the wider population of FSWs, or could be subject to biases, such as selection bias or detection bias. Of note, however, that there was no evidence that any of the assessed study-specific quality domains (Tables S5-S6 in **Online Supplementary Document**), including sampling methodology, response rate, and explicit indication of the assay used for infection ascertainment, had an effect on prevalence in the multivariable meta-regression (**Table 5**). Despite limitations, our study provided a detailed synthesis of STI epidemiology in FSWs in MENA, in a background of lack of evidence for this region [22,23]. A significant volume of published and unpublished data was identified and analyzed, and for the first time.

In conclusion, STI levels among FSWs are considerable, supporting a key role for CHSNs in STI transmission dynamics in MENA, and highlighting the public health needs of this neglected and vulnerable population. Despite the progress in our epidemiological understanding, major gaps persist, with no evidence being available for over half of MENA countries. With the limited STI surveillance [24,126], and the focus of programmatic response on case management and syndromic approach, rather than being evidence-informed and grounded on etiological studies [24,126], there is a critical need to expand STI surveillance and the broader STI research agenda. STI testing should be part of IBBSS studies, as well as part of voluntary counseling and testing services for HIV [91,93]. Interventions should factor research findings to ensure adequate and efficient resource allocation. Without such expansion of STI efforts, it will not be possible to monitor infection trends, or to inform a public health response that attends to the WHO Global Health Sector Strategy on STIs [6].

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Additional material

Online Supplementary Document

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2. Summary of findings

The study identified 145 STI studies including data on over 45,000 FSWs in 13 of the 23 MENA countries. Findings indicated substantial STI prevalence among FSWs, several-fold higher than that among the general population. These findings suggest a key role for HSWNs in driving STI transmission in this region. In-depth quantitative assessments of geographic and temporal trends of syphilis prevalence demonstrated strong regionalisation within MENA, as well as a trend of decreasing syphilis prevalence by approximately 7% per year. The decline was, however, less than the 17% [5] annual decline needed to achieve the target of 90% reduction in syphilis by 2030, as stipulated by the World Health Organization's Global Health Sector Strategy for STIs [6].

Research paper 1 findings of emerging HIV epidemics in HSWNs in a number of countries yet still limited HIV circulation in others, motivated an interest in using STIs, mainly HSV-2 given the long-lasting and reliably measured antibodies associated with this infection, as a potential predictor of sexual risk behaviour levels and of HIV epidemic potential in HSWNs. However, only three HSV-2 measures among FSWs could be identified through research paper 2, and therefore an analysis of paired HSV-2-HIV data focused on FSWs in MENA was not possible. Accordingly, a global analysis of the HSV-2-HIV association was undertaken in research paper 3.

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CHAPTER 5. RESEARCH PAPER 3-HSV-2 AS A BIOMARKER OF HIV EPIDEMIC POTENTIAL AMONG FSWS

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First Name(s)	Hiam		
Surname/Family Name	Chemaitelly		
Thesis Title	Characterizing HIV epidemiology among female sex workers and their clients in the Middle East and North Africa		
Primary Supervisor	Professor Helen Weiss		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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1. Preamble

This chapter provides a demonstration of the utility of HSV-2 seroprevalence as a predictor of HIV epidemic potential in HSWNs globally, particularly in countries, or settings within countries, where HIV epidemic potential in these networks remains unknown and where high-risk populations are hidden and stigmatized, through a global systematic analysis of empirical paired prevalence measures for HSV-2 and HIV among FSWs (**addresses objective 3 of thesis**). The study was motivated by findings of research paper 1 that showed recent emergence and steady growth of HIV epidemics in HSWNs in several countries or settings, yet limited HIV circulation in other countries or settings where HIV epidemic potential in HSWNs remains unknown.

The objectives of this study were addressed through a global systematic review of paired HSV-2 and HIV prevalence measures focused on FSWs, that updated and expanded an earlier systematic review of these measures in different populations. The resulting database of paired HSV-2-HIV prevalence measures among FSWs in the different world regions was subsequently used to conduct meta-analyses that pooled HIV prevalence measures at different HSV-2 prevalence levels, and meta-regression analyses that quantified the magnitude of the association between HSV-2 prevalence and HIV prevalence adjusting for regional, temporal, and behavioural differences among FSWs.

Further published details on study methodology and results can be found in Appendix VII.

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HSV-2 as a biomarker of HIV epidemic potential in female sex workers: meta-analysis, global epidemiology and implications

Hiam Chemaitelly[1,2,3]✉, Helen A. Weiss[4] & Laith J. Abu-Raddad[1,2,5]

This study investigated herpes simplex virus type 2 (HSV-2) seroprevalence utility as a predictor of HIV epidemic potential among female sex workers (FSWs) globally. We updated and analyzed a systematically-assembled database for paired HSV-2 and HIV seroprevalence measures among FSWs. The study identified 231 paired HSV-2/HIV prevalence measures from 40 countries. The pooled mean HIV prevalence using meta-analysis increased from 3.7% (95% CI 0.3–9.9%) among populations of FSWs with HSV-2 prevalence < 25% to 18.7% (95% CI 14.1–23.8%) among those with HSV-2 prevalence 75–100%. HIV prevalence was negligible in FSWs with HSV-2 prevalence ≤ 20% suggesting a threshold effect. Multivariable meta-regressions explained > 65% of HIV prevalence variation, and identified a strong positive HSV-2/HIV association. Compared to populations of FSWs with HSV-2 prevalence < 25%, adjusted odds ratios (AORs) of HIV infection increased from 2.8 (95% CI 1.2–6.3) in those with HSV-2 prevalence 25–49%, to 13.4 (95% CI 6.1–29.9) in those with HSV-2 prevalence 75–100%. HSV-2 is a strong predictor of HIV epidemic potential among FSWs. HSV-2 prevalence of 25–49% indicates potential for intermediate-intensity HIV epidemics, with higher levels indicative of large epidemics. HSV-2 surveillance could inform HIV preparedness in countries where HIV prevalence among FSWs is still limited or at zero-level.

Female sex workers (FSWs) continue to be a vulnerable and stigmatized population that is disproportionately affected by HIV[1–3]. Although FSWs generally constitute a small proportion of the total adult female population, typically less than 1%, this translates to millions of women globally that are at high risk of HIV infection and in need of prevention or treatment services[4,5].

In resource-limited settings, HIV prevalence among FSWs is estimated at an average of 12%, with odds of infection being 14-fold higher than among women in the general population[2]. Despite their increased risk, access to testing and linkage to treatment is often suboptimal, and could be even lower than that of women in the general population[6]. Until recently, HIV prevalence among FSWs in the World Health Organization (WHO) Eastern Mediterranean Region (EMRO) has been persistently very low[2], with the exception of Djibouti and South Sudan where the epidemic is established at ~ 20%[5,7]. Over the last decade, however, epidemics emerged in this population in a number of EMRO countries[5]. While HIV prevalence remains low, it has been growing rapidly, by as much as ~ 15% per year[5], with the potential for further growth being unknown. Epidemic potential is also unknown for half of EMRO countries where studies have consistently assessed HIV prevalence among FSWs at zero or negligible levels, but where documented overlap with other at-risk populations may create opportunities for seeding epidemics[5].

Predicting HIV epidemic potential, that is the level that HIV prevalence can reach in a population, is essential for informing program development and resource allocation[8]. One approach is to use self-reported sexual risk behavior data. The latter, however, is limited by reporting bias, recall bias, limitations in value of ego-centric data

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to map level of risk in the sexual network, poor representability due to insufficient integrated bio-behavioral surveillance surveys (IBBSS), and lack of standardization across studies[5,9–12]. Since herpes simplex virus type 2 (HSV-2) is almost exclusively sexually transmitted, is more transmissible than HIV, and produces long-lasting antibodies, it has been used as a biological marker of sexual risk and objective indicator of the risk of exposure to HIV[8,9,13–15]. It is also believed, based on observational evidence, that there is an epidemiologic synergy between HSV-2 and HIV infection[16–18], though recent evidence has casted doubt about this synergy[19]. Earlier analyses using empirical data as well as mathematical modeling also supported the utility of HSV-2 in predicting HIV epidemic potential[8,9,20].

Limited HIV prevalence is often observed among FSWs in various settings suggesting that the virus may not yet have been introduced in commercial heterosexual sex networks, or may not have had sustainable transmission upon introduction[2,5]. In situations where HIV prevalence has been repeatedly assessed at zero or negligible levels, such as for several EMRO countries, periodic IBBSS for HIV surveillance, though desirable, is often (incorrectly) perceived as unnecessary[21–23]. Testing for other sexually transmitted infections (STIs) such as HSV-2 are also typically not incorporated in HIV surveillance activities[21,22,24]. However, the recent emergence and steady growth of HIV epidemics among FSWs in different EMRO countries, after years of limited or no prevalence, advocate for the relevance and urgency of collecting such data to enable assessment of HIV epidemic potential in these settings[5].

This study systematically reviews paired HSV-2 and HIV (antibody) prevalence data among FSWs, globally, and analyzes these data to investigate use and utility of HSV-2 as a predictor of HIV prevalence and epidemic potential among FSWs by (1) estimating the pooled mean HIV prevalence at various HSV-2 prevalence levels, and (2) determining the magnitude of the HSV-2/HIV ecological association in light of regional, temporal, and condom use differences among FSWs.

Results

Search results and scope. The systematic search identified a total of 3386 citations, which after removing duplicates and screening, yielded 78 eligible reports (Fig. 1). Hand searching of the reference lists of eligible reports and reviews yielded three additional articles, and one comprehensive country-level public health report from India[25] that replaced three other full-texts[26–28]. Two reports were further excluded after consulting with Professor Rhoda Ashley-Morrow, an expert advisor in HSV-2 diagnostics, because the reliability of HSV-2 serologic testing could not be confirmed[29,30]. In total, 77 reports comprising 231 paired HSV-2 and HIV prevalence measures among FSWs, from 40 countries, were eligible for inclusion. These contributed to the database generated through our earlier systematic review[20] a total of 63 additional paired HSV-2 and HIV prevalence measures from 17 recent reports. Identified measures dated from 1988–2018 and are tabulated in Table S1 of Supplementary Information (SI) based on WHO regional classification [Region of the Americas (AMRO), African Region (AFRO), EMRO, European Region (EURO), South-East Asia Region (SEARO), and Western Pacific Region (WPRO)].

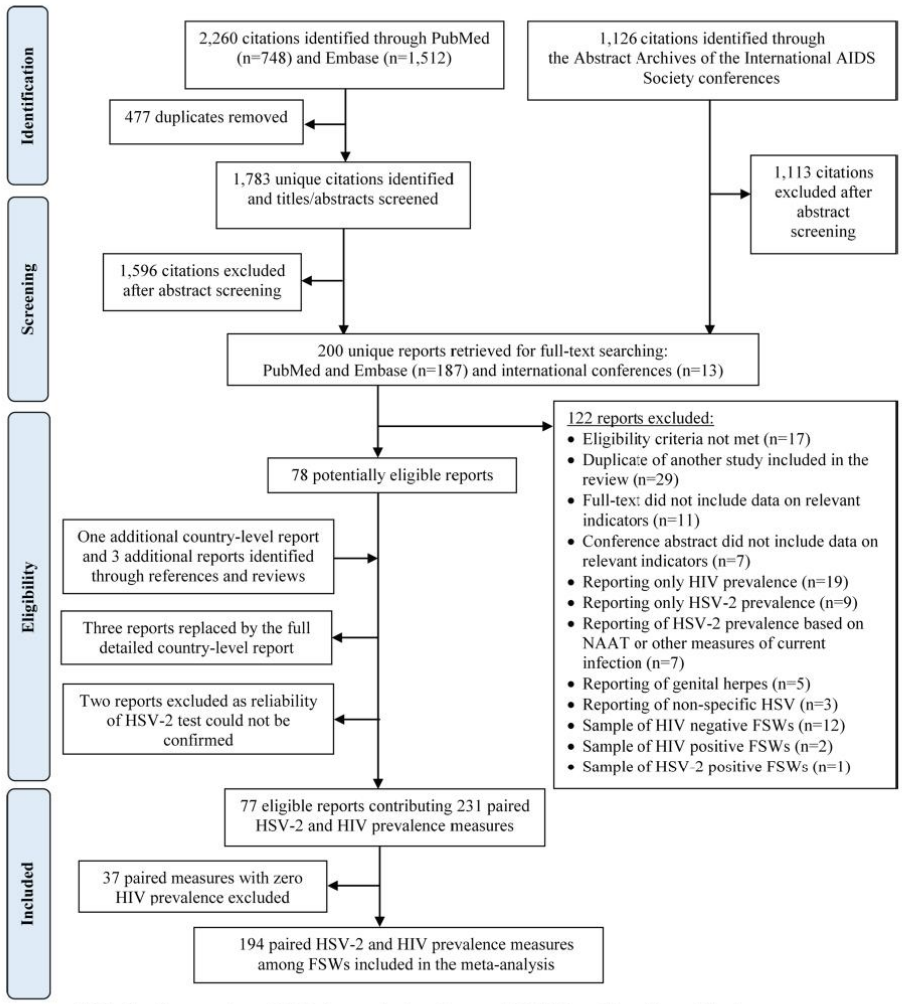
As the focus of this work is on examining the association between the two infections, it was pre-decided to restrict the analysis to settings where HIV has been introduced; we therefore excluded 37 paired measures with zero HIV prevalence from further analysis. After excluding measures with zero HIV prevalence, analysis was performed on a total of 194 paired measures from 33 countries (Fig. S1 of SI). India contributed the largest number of measures (n = 58; 29.9%), followed by China (n = 37, 19.1%), then Peru (n = 19; 9.8%). The distribution of measures across world regions is illustrated in Fig. 2A,B. The highest data contribution was for SEARO (n = 71; 36.6%), followed by AFRO and AMRO (each with n = 41; 21.1%), WPRO (n = 38; 19.6%), and lastly EURO (n = 3; 1.6%). There were only four studies from EMRO, all of which reported zero HIV prevalence, and thus were excluded from analysis.

Overview of the distribution of HIV prevalence by HSV-2 prevalence. Table 1 summarizes HIV prevalence data among FSWs, stratified by HSV-2 prevalence. Globally, among FSWs with HSV-2 prevalence < 25%, the median HIV prevalence was 2.0% (n = 8; range = 0.1–32.7%), increased slightly to 2.5% (n = 23; range = 0.2–33.3%) with HSV-2 prevalence 25–49%, then increased sharply to 10.8% (n = 92; range = 0.2–39.7%) with HSV-2 prevalence 50–74%, and to 14.9% (n = 71; range = 0.2–76.8%) with HSV-2 prevalence 75–100%. The scatterplots illustrating the distribution of the paired HSV-2 and HIV prevalence measures further suggested a threshold effect with limited HIV prevalence at HSV-2 prevalence ≤ 20% (Fig. 2A; n = 13; median = 0.0; range = 0.0–2.0).

In AFRO, HSV-2 prevalence among FSWs was > 50% in almost all studies. The median HIV prevalence was 20.0% (n = 21; range = 6.6–39.7%) with HSV-2 prevalence 50–74%, and 50.0% (n = 18; range = 11.8–76.8%) with HSV-2 prevalence 75–100%. In the other regions, the median HIV prevalence was 2.0% (n = 7; range = 0.1–5.3%) with HSV-2 prevalence < 25%, 2.5% (n = 22; range = 0.2–27.4%) with HSV-2 prevalence 25–49%, 7.7% (n = 71; range = 0.2–27.4%) with HSV-2 prevalence 50–74%, and 9.5% (n = 53; range = 0.2–47.1%) with HSV-2 prevalence 75–100%.

The median proportion of FSWs who inject drugs was 3.3% (n = 33; range = 0.0–81.9; Table S1 of SI). It was 1.2% (n = 11; range = 0.5–51.6%) in AMRO, 3.5% (n = 10; range = 0.0–3.9%) in SEARO, and 7.4% (n = 9; range = 1.3–81.9%) in WPRO. Meanwhile, there were no studies from AFRO, only one study from EURO reporting this proportion at 0%, and two studies from EMRO each reporting this proportion at 3.0%.

The median HSV-2 prevalence across these studies was assessed at 33.3% (range = 4.7–95.7) while the median HIV prevalence was assessed at 3.2% (range = 0.0–39.1%). In studies where the proportion of FSWs who inject drugs was < 5%, the median HSV-2 prevalence was 30.0% (range = 4.7–95.7%) while the median HIV prevalence was 2.0% (n = 19; 95% CI 0.0–9.6%). In studies where the proportion of FSWs who inject drugs was ≥ 5%



FSWs, female sex workers; HSV-2, herpes simplex virus type 2; NAAT, nucleic acid amplification test.

Figure 1. Flow chart presenting the process of study selection following PRISMA guidelines[47].

but < 10%, the median HSV-2 prevalence was 70.8% (n = 7; range = 29.7–86.6%) while the median HIV prevalence was 5.2% (95% CI 0.0–39.1%). In studies where the proportion of FSWs who inject drugs was ≥ 10%, the median HSV-2 prevalence was 82.0% (n = 3; range = 72.9–92.6%) while the median HIV prevalence was 4.1% (95% CI 0.3–38.3%).

Pooled mean HIV prevalence stratified by HSV-2 prevalence. The results of meta-analyses estimating the pooled mean HIV prevalence stratified by HSV-2 prevalence are presented in Table 1. Forest plots are shown in Fig. S2 of SI.

Across world regions, the pooled mean HIV prevalence was estimated at 3.7% (95% confidence interval (CI) = 0.3–9.9%) with HSV-2 prevalence < 25%, 4.5% (95% CI 2.0–7.9%) with HSV-2 prevalence 25–49%, 10.1% (95% CI 8.2–12.3%) with HSV-2 prevalence 50–74%, and 18.7% (95% CI 14.1–23.8%) with HSV-2 prevalence 75–100%.

Estimates in AFRO were higher at 22.2% (95% CI 17.6–27.1%) with HSV-2 prevalence 50–74%, and 47.7% (95% CI 39.4–55.9%) with HSV-2 prevalence 75–100%. In the rest of world regions, the pooled mean HIV prevalence was 1.7% (95% CI 0.3–3.8%) with HSV-2 prevalence < 25%, 3.9% (95% CI 1.6–7.1%) with HSV-2

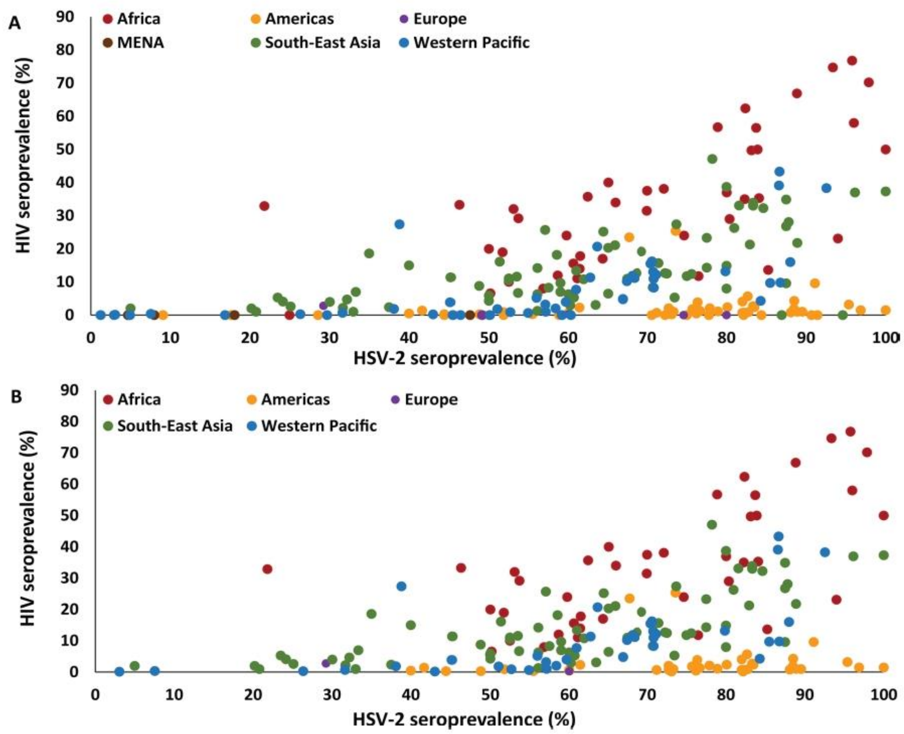


Figure 2. Scatterplot showing the global distribution of the paired herpes simplex type 2 (HSV-2) and HIV prevalence measures among female sex workers. (**A**) Distribution of *all* measures identified through the systematic review and (**B**) distribution of measures included in the analysis after excluding measures with zero HIV prevalence.

prevalence 25–49%, 7.5% (95% CI 5.9–9.2%) with HSV-2 prevalence 50–74%, and 11.3% (95% CI 8.0–15.2%) with HSV-2 prevalence 75–100%.

There was evidence for heterogeneity in HIV prevalence in all meta-analyses: Cochran's Q statistic p values were <0.01, I^2 was mostly $>90\%$ indicating that most variability is due to true differences in HIV prevalence rather than chance, and prediction intervals were generally wide affirming heterogeneity.

Association of HSV-2 with HIV prevalence. Table 2 shows the results of meta-regression analyses examining the association between HIV prevalence and HSV-2 prevalence among FSWs globally. In the univariable analyses, HSV-2 prevalence, WHO region, year of data collection, and proportion of FSWs reporting consistent condom use were associated with HIV prevalence at p value ≤ 0.2, and hence were included in the multivariable analysis.

The multivariable models, whether considering HSV-2 prevalence as a categorical variable (Model 1) or as a linear variable (Model 2), both showed strong evidence for an association with HSV-2 and WHO region (p value ≤ 0.05). Some evidence for an association, that is a p value between 0.05 and 0.1, was found for consistent condom use, but no evidence (p value >0.1) was found for year of data collection. Models 1 and 2 explained, respectively, 65.3% and 70.6% of the variation in HIV prevalence.

Model 1 showed that, relative to FSWs with HSV-2 prevalence $<25\%$, odds of HIV infection were three-fold higher (95% CI 1.2–6.3) among those with HSV-2 prevalence 25–49%, five-fold higher (95% CI 2.4–11.3) among those with HSV-2 prevalence 50–74%, and 13-fold higher (95% CI 6.1–29.9) among those with HSV-2 prevalence 75–100%. Regional differences were identified, where compared to AMRO, odds were four-fold higher for EURO (95% CI 1.0–12.1), six-fold higher for WPRO (95% CI 3.4–9.9), 11-fold higher for SEARO (95% CI 7.0–17.8), and thirty-seven-fold higher for AFRO (95% CI 23.2–59.4). FSWs reporting 25–49% consistent condom use had twice higher odds of HIV infection compared to those reporting 75–100% consistent condom use (95% CI 1.0–3.2).

Similar results were found using Model 2. Here, however, a 1% increase in HSV-2 prevalence among FSWs, beyond the 20% threshold, was associated with a 4% increase in the odds of HIV infection (adjusted odds ratio (AOR) = 1.04, 95% CI 1.03–1.05).

	Studies	Samples		HIV prevalence		Pooled mean HIV prevalence		Heterogeneity measures		
HSV-2 prevalence[a]	N	Tested	HIV positive	Median (%)	Range (%)	(%)	95% CI	Q (*p* value)[c]	I^{2d} (%; 95% CI)	Prediction interval[e] (95%)
African region										
<25%	1[b]	220	72	32.7	–	–	–	–	–	–
25–49%	1[b]	54	18	33.3	–	–	–	–	–	–
50–74%	21	6895	1711	20.0	6.6–39.7	22.2	17.6–27.1	418.7 ($p<0.01$)	95.2 (93.8–96.3)	4.5–47.6
75–100%	18	5829	2670	50.0	11.8–76.8	47.7	39.4–55.9	614.1 ($p<0.01$)	97.2 (96.5–97.8)	14.1–82.5
Total	41	12,998	4471	32.7	6.6–76.8	33.1	27.8–38.7	1696.8 ($p<0.01$)	97.6 (97.3–98.0)	5.2–70.0
Other WHO regions										
<25%	7	2190	35	2.0	0.1–5.3	1.7	0.3–3.8	47.9 ($p<0.01$)	87.5 (76.5–93.3)	0.0–12.0
25–49%	22	8280	580	2.5	0.2–27.4	3.9	1.6–7.1	877.1 ($p<0.01$)	97.6 (97.1–98.1)	0.0–27.8
50–74%	71	28,935	2521	7.7	0.2–27.4	7.5	5.9–9.2	1954.2 ($p<0.01$)	96.4 (95.9–96.9)	0.0–26.3
75–100%	53	15,243	2222	9.5	0.2–47.1	11.3	8.0–15.2	2607.0 ($p<0.01$)	98.0 (97.7–98.2)	0.0–48.1
Total	153	54,648	5358	5.9	0.1–47.1	7.8	6.4–9.3	6130.8 ($p<0.01$)	97.5 (97.3–97.7)	0.0–33.2
Global										
<25%	8	2410	107	2.0	0.1–32.7	3.7	0.3–9.9	247.7 ($p<0.01$)	97.2 (95.9–98.1)	0.0–37.2
25–49%	23	8334	598	2.5	0.2–33.3	4.5	2.0–7.9	911.0 ($p<0.01$)	97.6 (97.0–98.0)	0.0–29.6
50–74%	92	35,830	4232	10.8	0.2–39.7	10.1	8.2–12.3	3633.0 ($p<0.01$)	97.5 (97.2–97.7)	0.0–36.0
75–100%	71	21,072	4892	14.9	0.2–76.8	18.7	14.1–23.8	5844.9 ($p<0.01$)	98.8 (98.7–98.9)	0.0–69.2
Total	194	67,646	9829	10.1	0.1–76.8	11.8	9.9–13.9	12,598.5 ($p<0.01$)	98.5 (98.4–98.6)	0.0–49.3

Table 1. Results of meta-analyses on studies reporting HIV prevalence among female sex workers stratified by HSV-2 prevalence levels. CI, confidence interval; HSV-2, herpes simplex virus type 2. [a]Excluding 37 studies with zero HIV prevalence. [b]Meta-analysis not possible for a single study. [c]Q: the Cochran's Q statistic is a measure assessing the existence of heterogeneity in effect size (here, HIV prevalence) across studies. [d]I^2: a measure assessing the magnitude of between-study variation that is due to differences in effect size (here, HIV prevalence) across studies rather than chance. [e]Prediction interval: a measure estimating the 95% interval of the distribution of true effect sizes (here, HIV prevalence).

Table 3 shows the results of meta-regression analyses excluding AFRO. Results were consistent with those for all regions (Table 2). In Model 1, relative to FSWs with HSV-2 prevalence < 25%, AORs were 4.0 (95% CI 1.7–9.8), 7.8 (95% CI 3.3–18.2), 19.1 (95% CI 7.9–46.1) among those with HSV-2 prevalence 25–49%, 50–74%, and 75–100%, respectively. The AOR in the linear association (Model 2) was 1.04 (95% CI 1.03–1.05).

Discussion

Motivated by the concept of using current HSV-2 prevalence in a population as a proxy biomarker of future HIV prevalence in that population[8,9,20] and its relevance to HIV preparedness, this study assessed the utility of HSV-2 as a predictor of HIV epidemic potential among FSWs through a global systematic analysis of empirical paired HSV-2 and HIV prevalence measures. We found strong evidence for an association between HIV and HSV-2 prevalence, even after accounting for potential confounders such as region, temporal trend, and condom use (Tables 2 and 3). HIV prevalence was negligible at HSV-2 prevalence ≤ 20% (Fig. 2), but increased steadily with higher HSV-2 prevalence suggesting a threshold effect—the odds of HIV infection doubled with a 25% increase in HSV-2 prevalence (Tables 1 and 2). These findings demonstrate that in populations where HIV prevalence is still limited, but has potential to grow, HSV-2 prevalence can be used to provide a prediction of future HIV prevalence.

The hierarchy of HIV prevalence among FSWs was evident even in the context of Africa's general population HIV epidemics (Table 1). Outside the African Region, HSV-2 prevalence among FSWs of 25–49% was indicative of the potential for intermediate-intensity HIV epidemics with an HIV prevalence of ~ 5% or less. For FSW populations with HSV-2 prevalence ≥ 50%, HIV prevalence was higher and often exceeded 10%. Our findings based on analysis of empirical data substantiate mathematical modeling analyses predicting quantitatively such an association[8,9], which also appears to exist for other populations[20]. The modeling analyses simulating HSV-2 and HIV propagation along diverse sexual networks demonstrated that HSV-2 prevalence ≥ 50% is indicative of substantial sexual risk behavior, sufficient to sustain large HIV epidemics in a sexual network[9]. In contrast, HSV-2 prevalence < 20% in a sexual network is indicative of low sexual risk behavior that is not likely to sustain an epidemic (a "threshold effect")[8]. Both of these modeling predictions were confirmed in the present study through analysis of actual empirical data (Table 1).

After decades of virtually zero HIV prevalence[2], EMRO has recently seen emergence of HIV epidemics among FSWs in several countries[5]. However, and despite an apparently rapid epidemic growth, HIV prevalence in FSWs remains overall at low levels[5]. It is unfortunate that there were too few HSV-2 prevalence measures among FSWs in this region to predict HIV epidemic potential (Table S1 of SI)[24]. Available measures indicated also relatively low HSV-2 prevalence, often below 20% (Table S1 of SI)[24], the apparent threshold for a significant

	Studies	Samples	Univariable analyses				Multivariable analysis-model 1			Multivariable analysis-model 2		
Factors	**Total n**	**Total n**	**OR (95% CI)**	***p* value**	**F *p* value[a]**	**Adj. R^2 (%)**	**AOR (95% CI)**	***p* value**	**F *p* value[b]**	**AOR[c] (95% CI)**	***p* value**	**F *p* value[b]**
HSV-2 prevalence												
<25%	8	2410	1.0		<0.01	10.8	1.0		<0.01	–	–	–
25–49%	23	8334	1.4 (0.4–5.0)	0.60			2.8 (1.2–6.3)	0.01		–	–	–
50–74%	92	35,830	4.0 (1.3–12.6)	0.02			5.2 (2.4–11.3)	<0.01		–	–	–
75–100%	71	21,072	7.2 (2.3–22.7)	<0.01			13.4 (6.1–29.9)	<0.01		–	–	–
HSV-2 prevalence[c]												
	191	66,239	1.03 (1.02–1.04)	<0.01	<0.01	10.8	–	–	–	1.04 (1.03–1.05)	<0.01	<0.01
WHO region												
AMRO	41	12,037	1.0		<0.01	48.5	1.0		<0.01	1.0		<0.01
AFRO	41	12,998	31.7 (19.0–53.0)	<0.01			37.1 (23.2–59.4)	<0.01		36.2 (23.6–55.7)	<0.01	
EURO	3	718	1.3 (0.3–5.2)	0.70			3.5 (1.0–12.1)	0.05		5.5 (1.7–17.5)	<0.01	
SEARO	71	24,047	8.5 (5.4–13.4)	<0.01			11.2 (7.0–17.8)	<0.01		12.5 (8.1–19.1)	<0.01	
WPRO	38	17,846	3.8 (2.3–6.4)	<0.01			5.8 (3.4–9.9)	<0.01		6.2 (3.8–10.0)	<0.01	
Publication year												
<2000	15	5049	1.0		0.83	0.0	–	–	–	–	–	–
2000–2004	7	2368	1.2 (0.3–5.5)	0.80			–	–	–	–	–	–
2005–2009	56	13,855	1.7 (0.6–4.3)	0.30			–	–	–	–	–	–
2010–2014	99	40,760	1.4 (0.6–3.6)	0.44			–	–	–	–	–	–
2015–2019	17	5614	1.2 (0.4–3.7)	0.81			–	–	–	–	–	–
Data collection year[d]												
<1995	18	6478	1.0		0.11	1.8	1.0		0.15	1.0		0.17
1995–1999	14	2462	1.0 (0.3–3.1)	0.97			0.7 (0.3–1.5)	0.31		0.7 (0.3–1.3)	0.26	
2000–2004	61	15,736	1.0 (0.4–2.5)	0.93			1.0 (0.6–1.7)	0.98		1.0 (0.6–1.6)	0.85	
2005–2009	88	37,770	2.0 (0.9–4.6)	0.10			1.4 (0.8–2.5)	0.30		1.3 (0.8–2.3)	0.34	
2010–2014	13	5200	1.4 (0.4–4.6)	0.56			0.6 (0.3–1.3)	0.19		0.6 (0.3–1.3)	0.22	
Sample size												
<200	52	5507	1.0		0.76	0.0	–	–	–	–	–	–
≥200	142	62,139	0.92 (0.54–1.56)	0.76			–	–	–	–	–	–
Proportion of FSWs reporting consistent condom use												
75–100%	77	31,462	1.0		0.09	2.1	1.0		0.09	1.0		0.08
50–74%	19	8129	0.4 (0.2–1.0)	0.04			1.1 (0.6–1.9)	0.79		1.2 (0.7–2.0)	0.55	
25–49%	31	6367	1.4 (0.7–2.7)	0.38			1.8 (1.0–3.2)	0.05		1.9 (1.1–3.2)	0.02	
<25%	9	3715	1.1 (0.3–3.3)	0.91			0.7 (0.3–1.5)	0.31		0.8 (0.4–1.6)	0.51	
Unclear	58	17,973	0.7 (0.4–1.2)	0.19			1.3 (0.8–2.1)	0.30		1.2 (0.8–1.8)	0.47	

Table 2. Results of meta-regression analyses assessing the association between HIV prevalence and HSV-2 prevalence among female sex workers globally. Adj, Adjusted; AFRO, African Region; AMRO, Region of the Americas; AOR, adjusted odds ratio; CI, confidence interval; EURO, European Region; FSWs, female sex workers; HSV-2, herpes simplex virus type 2; OR, odds ratio; SEARO, South-East Asia Region; WHO, World Health Organization; WPRO, Western Pacific Region. Adjusted R^2 is 65.3% in the multivariable model 1, and 70.6% in the multivariable model 2. [a]Factors with *p* value ≤ 0.2 were eligible for inclusion in the multivariable analysis. [b]Factors with *p* value ≤ 0.05 and those with 0.05 < *p* value ≤ 0.1 in the multivariable model were considered as showing, respectively, "strong" and "some" evidence for an association with HIV prevalence. [c]Analysis of the association with HSV-2 prevalence as a linear term excluded three measures with HSV-2 prevalence ≤ 20% in light of the observed threshold effect. [d]Missing values for year of data collection were imputed using data for year of publication adjusted by the median difference between year of publication and median year of data collection for studies with complete information.

HIV epidemic (Fig. 2). HSV-2 prevalence in the general population in EMRO also appears to be low, and overall lower than that in other regions[8,31]. Indeed, a recent global assessment[32] estimated HSV-2 prevalence among women in the general population at 7.6% in EMRO, 9.6% in SEARO, 10.7% in EURO, 14.6% in WPRO, 24.0% in AMRO, and 43.9% in AFRO, whereas median HSV-2 prevalence among FSWs in our study was > 50% in all regions aside from EMRO. This suggests that HIV prevalence may not grow to reach considerable levels in many FSW populations in EMRO, and possibly will persist at levels close to zero HIV prevalence. Having said so, this region could largely benefit from integrating testing for HSV-2 in HIV surveillance activities. However, much more data on HSV-2 prevalence are needed before we can assess HIV epidemic potential among FSWs in this region with meaningful confidence.

	Studies	Samples	Univariable analyses				Multivariable analysis-model 1			Multivariable analysis-model 2		
Factors	**Total n**	**Total n**	**OR (95% CI)**	***p* value**	**F *p* value[a]**	**Adj. R^2 (%)**	**AOR (95% CI)**	***p* value**	**F *p* value[b]**	**AOR[c] (95% CI)**	***p* value**	**F *p* value[b]**
HSV-2 prevalence												
<25%	7	2190	1.0		<0.01	8.6	1.0		<0.01	–	–	–
25–49%	22	8280	1.9 (0.6–6.7)	0.29			4.0 (1.7–9.8)	<0.01		–	–	–
50–74%	71	28,935	4.5 (1.5–14.0)	<0.01			7.8 (3.3–18.2)	<0.01		–	–	–
75–100%	53	15,243	6.2 (2.0–19.4)	<0.01			19.1 (7.9–46.1)	<0.01		–	–	–
HSV-2 prevalence[c]												
	150	53,241	1.02 (1.01–1.04)	<0.01	<0.01	7.1	–	–	–	1.04 (1.03–1.05)	<0.01	<0.01
WHO region												
AMRO	41	12,037	1.0		<0.01	34.0	1.0		<0.01	1.0		<0.01
EURO	3	718	1.3 (0.3–5.6)	0.71			4.1 (1.2–14.6)	0.03		6.5 (2.0–21.2)	<0.01	
SEARO	71	24,047	8.5 (5.3–13.6)	<0.01			10.3 (6.3–16.9)	<0.01		11.3 (7.1–17.8)	<0.01	
WPRO	38	17,846	3.8 (2.2–6.6)	<0.01			5.3 (3.0–9.5)	<0.01		5.5 (3.2–9.4)	<0.01	
Publication year												
<2000	10	2920	1.0		0.02	5.4	–	–	–	–	–	–
2000–2004	4	734	0.7 (0.1–3.6)	0.63			–	–	–	–	–	–
2005–2009	36	10,101	1.3 (0.4–3.5)	0.67			–	–	–	–	–	–
2010–2014	93	37,170	2.4 (0.9–6.2)	0.08			–	–	–	–	–	–
2015–2019	10	3723	0.7 (0.2–2.7)	0.63			–	–	–	–	–	–
Data collection year[d]												
<1995	12	3384	1.0		<0.01	23.4	1.0		<0.01	1.0		<0.01
1995–1999	12	2059	1.2 (0.4–3.4)	0.76			0.5 (0.2–1.3)	0.15		0.5 (0.2–1.2)	0.12	
2000–2004	42	11,247	0.7 (0.3–1.7)	0.44			0.8 (0.4–1.6)	0.59		0.8 (0.4–1.5)	0.42	
2005–2009	81	34,649	3.6 (1.6–8.0)	<0.01			1.7 (0.8–3.4)	0.17		1.6 (0.8–3.0)	0.18	
2010–2014	6	3309	0.6 (0.2–2.1)	0.39			0.3 (0.1–1.0)	0.04		0.4 (0.2–1.0)	0.06	
Sample size												
<200	36	4422	1.0		0.38	0.0	–	–	–	–	–	–
≥200	117	50,226	1.3 (0.7–2.3)	0.38			–	–	–	–	–	–
Proportion of FSWs reporting consistent condom use												
75–100%	73	30,137	1.0		<0.01	11.6	1.0		0.07	1.0		0.04
50–74%	16	5537	0.3 (0.1–0.6)	<0.01			1.6 (0.8–3.1)	0.17		1.6 (0.9–2.9)	0.14	
25–49%	19	3967	0.9 (0.4–1.8)	0.69			2.7 (1.4–5.3)	<0.01		2.7 (1.5–5.1)	<0.01	
<25%	3	988	0.3 (0.1–1.5)	0.15			1.1 (0.3–3.8)	0.88		1.3 (0.4–4.2)	0.62	
Unclear	42	14,019	0.3 (0.2–0.5)	<0.01			1.6 (0.9–2.7)	0.11		1.4 (0.9–2.4)	0.16	

Table 3. Results of meta-regression analyses assessing the association between HIV prevalence and HSV-2 prevalence among female sex workers globally but excluding the African Region. Adj, Adjusted; AMRO, Region of the Americas; AOR, adjusted odds ratio; CI, confidence interval; EURO, European Region; FSWs, female sex workers; HSV-2, herpes simplex virus type 2; OR, odds ratio; SEARO, South-East Asia Region; WHO, World Health Organization; WPRO, Western Pacific Region. Adjusted R^2 is 58.2% in the multivariable model 1, and 64.1% in the multivariable model 2. [a]Factors with p value ≤ 0.2 were eligible for inclusion in the multivariable analysis. [b]Factors with p value ≤ 0.05 and those with 0.05 < p value ≤ 0.1 in the multivariable model were considered as showing, respectively, "strong" and "some" evidence for an association with HIV prevalence. [c]Analysis of the association with HSV-2 prevalence as a linear term excluded three measures with HSV-2 prevalence ≤ 20% in light of the observed threshold effect. [d]Missing values for year of data collection were imputed using data for year of publication adjusted by the median difference between year of publication and median year of data collection for studies with complete information.

Several other findings emerged from this study. There was regional variation in HIV prevalence that could not be captured by HSV-2 prevalence, especially so for the African Region (Table 2), but also outside Africa (Table 3). This finding suggests that other factors may differentially impact each of HSV-2 and HIV prevalence, and that these should be accounted for to better describe the HIV/HSV-2 association. This is also supported by modeling analyses that demonstrated that, while some sexual network statistics affect HSV-2 and HIV transmission similarly, others can affect them differentially[9]. A plausible explanation relates to HIV having lower infectiousness and shorter acute infection duration, therefore facing more difficulty in propagating within sexual networks compared to HSV-2[9]. For instance, while concurrency (mean number of current sexual partners) is a strong predictor of both HSV-2 and HIV prevalence, clustering within a sexual network (or high exposure within specific circles), provides a higher chance for HIV to spread, but limits HSV-2 from reaching farther nodes in the wider sexual network[9]. Meanwhile, higher degree correlation, that is broad connectivity between sexual partnerships, appears to favor HSV-2 spread, but not HIV[9]. This suggests that, despite the strength of the association, HSV-2 cannot be used as the sole predictor of HIV epidemic potential.

Our findings indicated only a small role for self-reported condom use in predicting HIV prevalence (Tables 2 and 3), suggesting that such self-reported behavioral measures may not carry meaningful explanatory power, and affirming documented issues in self-reported measures[11,12,33].

Our study has limitations. There was variability in the number of paired HSV-2/HIV prevalence measures among FSWs across regions, thus limiting our ability to perform further stratified, region-specific, analyses. For instance, there was an insufficient number of studies from EURO to warrant meaningful analysis and interpretation, and no studies from EMRO. Our regional estimates may have also been biased by some countries having larger data contributions (that is more or larger sample size studies) than others, but meta-regression analyses did not identify an association with study sample size. There was also heterogeneity in HIV prevalence, as commonly seen in observational studies assessing prevalence[5,34]. The latter, however, was (mostly) explained through the meta-regression analyses, which affirmed HSV-2 prevalence as an independent contributor to this heterogeneity (Tables 2 and 3). Only a handful of studies reported age-related data, and these varied immensely in the type of reported measure, thus constraining age inclusion in the analysis.

A number of studies did not report data on condom use among FSWs, and very few reported coverage for other interventions to warrant their inclusion in the analyses. For example, only one study reported antiretroviral therapy (ART) coverage (Table S1 of SI), which presumably could affect the association between HIV and HSV-2 prevalence. This being said, most studies were conducted before the mass scale up of ART (Table 2), and thus ART is unlikely to have affected the observed association in the current analysis but may impact future analyses on future data examining this association. Few studies also reported data on current injecting drug use, a non-sexual mode of HIV transmission, with overall no major differences across regions. The latter however is unlikely to have affected the observed HSV-2/HIV association given that the median fraction of FSWs currently injecting drugs is < 5% (Table S1 of SI). Our findings also showed that even in studies where the proportion of FSWs who inject drugs was ≥ 5%, HSV-2 prevalence was substantial with a median of 72%, likely given the nature of the study population and/or the likelihood of exchanging sex for drugs.

The association between HIV prevalence and HSV-2 prevalence is likely non-linear, although the distribution of measures (Fig. 2) and an earlier mathematical modeling analysis[8] suggested that this association may not be far from linearity (above the threshold effect). This implies that our AOR for the HIV/HSV-2 (linear term) association should be interpreted with caution as an estimate for the average increase in odds of HIV prevalence per 1% increase in HSV-2 prevalence beyond the 20% threshold. While HSV-2 prevalence was probably at endemic equilibrium given infection circulation in human populations for centuries, HIV prevalence may not have been at equilibrium, but we were unable to account for the HIV epidemic phase in the analysis[17]. Despite these limitations, the parsimonious multivariable meta-regression models explained > 65% of the variation in HIV prevalence supporting the inferences drawn in this study.

In conclusion, we demonstrated an association between HSV-2 prevalence and HIV prevalence among FSWs that can be utilized in assessing HIV epidemic potential in this at-risk population. We also demonstrated the relevance of integrating testing for HSV-2 in HIV surveillance activities targeting this population, especially in settings where HIV prevalence among them is still at negligible or low level. Our findings stress the need for HSV-2 testing in future surveillance efforts, notably in IBBSS surveys, as a tool to inform HIV preparedness and resource allocation, particularly in countries where HIV epidemic potential among key populations remains unknown. Such data is essential to avoid the costly implications of emerging HIV epidemics and to ensure that countries are still "on track" towards ending AIDS[35].

Methods

Data sources and selection methods. We updated a database of paired HSV-2 and HIV prevalence measures, retrieved through an earlier systematic review[20], by conducting a new search focused on FSWs, on September 3rd, 2019, using broad MeSH/Emtree and free text terms for "sex work", "women", "HSV-2", and "HIV" (search criteria in Box S1 of SI). Paired measures eligible for inclusion were identified through a systematic review process following Cochrane Collaboration guidelines[36]. Briefly, PubMed, Embase, and the abstract archives of International AIDS Society conferences were surveyed. Citations were screened for duplication, and then for relevance using Endnote (Thomson Reuters, USA). Full-texts of articles deemed relevant or potentially relevant underwent further screening, and paired measures for HSV-2 and HIV antibody prevalence (seroprevalence), based on primary data, were identified and extracted along with key information on study population characteristics, year(s) of data collection, year of publication, country of origin/survey, number tested and number positive for HSV-2 and HIV infections, diagnostic tests used for infections' ascertainment, proportion of FSWs who inject drugs, proportion of infected FSWs on ART, and proportion of FSWs reporting consistent condom use. The latter was assessed primarily using self-reported condom use at last sex with client, or alternatively using self-reported "consistent/regular" condom use or condom use "all the time" during commercials sex acts (extraction list in Box S2 of SI).

Plan of analysis. *Descriptive analysis.* Scatterplots were generated to illustrate the distribution of paired HSV-2 and HIV prevalence measures among FSWs across world regions. Countries' regional classification was based on the WHO regional definition (WHO classification in Box S3 of SI)[37]. Maps showing countries' data contribution were generated using Tableau Desktop v.10.1[38]. Studies were classified into four categories based on HSV-2 prevalence level among FSWs (< 25%, 25–49%, 50–74%, and 75–100%). Descriptive statistics of the reported HIV prevalence measures were then calculated stratified by HSV-2 prevalence category.

Meta-analysis. Forest plots were used to visualise estimates of HIV prevalence and 95% CIs for each HSV-2 stratum. The pooled mean HIV prevalence and associated 95% CIs were estimated, for different HSV-2 strata, using random-effects meta-analysis. Here, variances of HIV prevalence measures were first stabilized using a Freeman-Tukey type arcsine square-root transformation[39,40]. Prevalence measures were then weighted using the inverse-variance method[40,41], and subsequently pooled using a DerSimonian-Laird random-effects model[42] to account for sampling variation and true between-study heterogeneity[43].

Heterogeneity across HIV prevalence measures was assessed, with and without considering HSV-2 stratification, using: Cochran's Q statistic to confirm existence of heterogeneity across prevalence measures, I^2 to quantify magnitude of variation that is due to true differences in prevalence across studies rather than chance, and prediction interval to estimate the 95% interval of the distribution of true prevalence measures[43,44]. Additional meta-analyses contrasting the African Region to the rest of world regions were performed, for relevance, as almost all HSV-2 prevalence measures in this region were > 50% (in contrast to the other regions), and considering the unique HIV epidemic history in this part of the world[1].

Meta-analyses were implemented in R v.3.4.2[45].

Meta-regression. Random-effects meta-regression analyses were conducted to assess whether HSV-2 prevalence can be used as a predictor of HIV prevalence among FSWs. Covariates, considered a priori, included: WHO region (AMRO, AFRO, EMRO, EURO, SEARO, and WPRO), publication year (< 2000, 2000–2004, 2005–2009, 2010–2014, 2015–2019), data collection year (< 1995, 1995–1996, 2000–2004, 2005–2009, 2010–2014), study sample size (< 200, ≥ 200), and proportion of FSWs reporting consistent condom use (< 25%, 25–49%, 50–74%, 75–100%, unclear). Proportion of FSWs who inject drugs could not be factored in our analysis given the low number of studies and heterogeneity across measures (Table S1 of SI). The proportion of infected FSWs on ART also could not be factored in our analysis as only a single measure was identified (Table S1 of SI). Missing values for year of data collection were imputed using data for year of publication adjusted by the median difference between year of publication and year of data collection (for studies with complete information). Meta-regression analyses were performed using two scenarios including and excluding AFRO. Meta-regressions estimated the *odds ratios* of HIV infection assuming that the probability of HIV infection for a given population is equal to that of HIV prevalence in this population.

Factors associated with HIV prevalence at p value ≤ 0.20 in univariable analysis were eligible for inclusion in the multivariable analysis. Two multivariable models were considered using HSV-2 prevalence as a categorical variable, or as a linear term after excluding HSV-2 prevalence ≤ 20% given observed threshold effect. In the multivariable model, a p value of ≤ 0.05 for any factor indicated strong evidence for an association with HIV prevalence, while $0.05 < p$ value ≤ 0.1 indicated some evidence for an association with prevalence.

Meta-regressions were implemented in Stata/SE v.16[46].

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Author contributions

H.C. designed the study, conducted the systematic review of the literature, performed the data analyses, and wrote the first draft of the article. H.A.W. contributed to study design, data analyses, and drafting of the article. L.J.A. conceived the study and contributed to study design, data analyses, and drafting of the article. All authors contributed to discussion and interpretation of the results and writing of the manuscript. All authors have read and approved the final manuscript.

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Competing interests

The authors declare no competing interests.

Additional information

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2. Summary of findings

The study identified 231 paired HSV-2-HIV prevalence measures from 40 countries. Findings indicated evidence for a strong positive association between population-level HSV-2 and HIV prevalence measures, even after accounting for potential confounders such as region, temporal trend, and condom use. There was also a threshold effect where HIV prevalence was negligible at HSV-2 prevalence ≤20%, and increased steadily with higher HSV-2 prevalence. In fact, the odds of HIV infection doubled with each 25% increase in HSV-2 prevalence. The study further showed that, outside the African Region where HIV epidemics among FSWs are hyper-endemic, HSV-2 prevalence of 25-49% among FSWs was indicative of the potential for intermediate-intensity HIV epidemics with an HIV prevalence in HSWNs of ~5% or less. Meanwhile, for FSW populations with HSV-2 prevalence ≥50%, HIV prevalence was higher and often exceeded 10%. These findings demonstrate that in FSW populations where HIV prevalence is still at zero level or has not yet reached its full potential, HSV-2 prevalence can be used to predict future HIV prevalence, even before virus introduction in the population. HSV-2 testing among FSWs in future surveillance efforts can therefore be used as a tool to inform HIV preparedness and resource allocation, particularly in countries where the HIV epidemic potential among FSWs remains unknown.

Research paper 1 provided a comprehensive mapping of HIV prevalence among FSWs and clients in the region and yielded a large database that comprised measures for population size estimates, HIV prevalence, sexual and injecting risk behaviour, and coverage of prevention and treatment interventions in these populations, in addition to only six HIV seroconversion measures all dating to before the year 2000. Against this lack of knowledge about HIV incidence among FSWs, the assembled database in research paper 1 motivated and made feasible the design of a mathematical modelling study (research paper 4) to estimate HIV incidence arising in the context of HSWNs and its contribution to total HIV incidence in the adult population in MENA.

CHAPTER 6. RESEARCH PAPER 4-HIV INCIDENCE AND IMPACT OF INTERVENTIONS AMONG FSWS AND CLIENTS IN MENA

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Student ID Number	LSH395506	**Title**	Mrs
First Name(s)	Hiam		
Surname/Family Name	Chemaitelly		
Thesis Title	Characterizing HIV epidemiology among female sex workers and their clients in the Middle East and North Africa		
Primary Supervisor	Professor Helen Weiss		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?			
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Please list the paper's authors in the intended authorship order:	Hiam Chemaitelly, Houssein H. Ayoub, Ryosuke Omori, Shereen El Feki, Joumana G. Hermez, Helen A. Weiss, and Laith J. Abu-Raddad
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I am the first and corresponding author on this paper. I co-conceived the study, designed the study and model, coded the mathematical model, conducted the model parameterization, generated simulations, and wrote the first draft of the article and revised it based on feedback from co-authors. The included co-authors either provided technical programming assistance given the complexity of coding the structural networks (Houssein Ayoub and Ryosuke Omori) or facilitated access to data and provided insights on policy implications of research findings (from UNAIDS: Shereen El Feki and from WHO-EMRO: Joumana G. Hermez)

SECTION E

Student Signature	[redacted]
Date	02 October 2021

Supervisor Signature	[redacted]
Date	04 October 2021

1. Preamble

This chapter provides the first detailed epidemiological investigation of HIV incidence occurring in HSWNs in MENA, of the contribution of these networks to total incidence in the population, and of the impact of expanding FSWs' access to prevention interventions on averting new infections in these networks (**addresses objective 4 of thesis**). The study was motivated by research paper 1's main finding of emerging HIV epidemics among FSWs and their clients in several MENA countries. Research paper 1 also made this study feasible by providing a comprehensive database of HIV prevalence, sexual and injecting risk behaviours, risk group size estimates, and coverage of prevention interventions among FSWs and clients at country-level across MENA. The latter database served as data input to the mathematical model that was used to address the gap in our knowledge of HIV incidence in MENA. The study provides essential statistics that can be used to inform HIV programming and progress monitoring towards achieving UNAIDS 2030 targets [1-3].

The objectives of this study were addressed by constructing a novel individual-based mathematical model built to describe HIV transmission dynamics in HSWNs. Statistical methods were applied to generate, using 500 simulation runs, mean estimates for 1) HIV incidence and incidence rates for each of FSWs, clients, and client spouses, 2) the relative contribution of sexual versus injecting HIV acquisitions to HIV incidence among FSWs, 3) the contribution of HSWNs to total HIV incidence in the adult population, and 4) the number of infections averted in each of FSWs, clients, and client spouses by expanding coverage of select prevention interventions among FSWs.

Further details on study methodology and results can be found in the attached manuscript and associated Appendix VIII.

HIV incidence and impact of interventions among female sex workers and their clients in the Middle East and North Africa: Mathematical modelling analysis

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Abstract

Background: HIV incidence among female sex workers (FSWs) and clients in the Middle East and North Africa (MENA) is unknown. Incidence, contribution of heterosexual sex work networks (HSWNs) to the epidemic, and impact of interventions were assessed in MENA countries using mathematical modeling.

Methods: A novel individual-based model to simulate HIV epidemic dynamics in HSWNs was developed and applied to 12 MENA countries with sufficient data. Model input parameters were provided through a systematic review of HIV prevalence, sexual and injecting behaviors, and risk group size estimates of FSWs and clients.

Findings: The estimated number of new infections in 2020 in the 12 countries was 3,471 (range: 1,295-10,308) among FSWs, 6,416 (range: 3,144-14,223) among clients, and 4,717 (range: 3,490-7,288) among client spouses. These infections accounted for 25.1% of total HIV incidence in the MENA region. Contribution of incidence in HSWNs to total incidence ranged from 3.3% in Pakistan to 71.8% in South Sudan and 72.7% in Djibouti. Incidence in HSWNs was distributed equally among FSWs, clients, and client spouses. Estimated incidence rates among FSWs, per 1,000 person-years, ranged from 0.4 (95% CI: 0.0-7.1) in Yemen to 34.3 (95% CI: 17.2-59.6) in South Sudan. Among FSWs who inject drugs, estimated incidence rates, per 1,000 person-years, ranged from 5.1 (95% CI: 0.0-35.1) in Iran to 45.8 (95% CI: 0.0-428.6) in Pakistan. All interventions substantially reduced incidence among FSWs, clients, and client spouses. Even when a subpopulation did not benefit directly from an intervention, it still benefited indirectly through reduction in onward transmission. The indirect impact was often half as large as the direct impact.

Interpretation: Substantial HIV incidence occurs in HSWNs across MENA with client spouses being heavily affected, in addition to FSWs and clients. Rapidly scaling up comprehensive treatment and prevention services for FSWs can sizably reduce incidence arising in HSWNs.

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Keywords: HIV; sex work; incidence; mathematical model; interventions; Middle East and North Africa.

Research in context

Evidence before this study

The HIV epidemic is steadily growing in the Middle East and North Africa (MENA). Despite evidence for emerging epidemics among female sex workers (FSWs) in MENA, HIV incidence among them and their clients is unknown. The large size of heterosexual sex work networks (HSWNs), relative to those of men who have sex with men and people who inject drugs, suggests that these networks could be driving much of HIV incidence. Searches of PubMed and Embase, to September 9, 2021, using broad terms for sex work, HIV, and MENA identified no regional estimates for HIV incidence among FSWs and their clients.

Added value of this study

A novel individual-based mathematical model was developed to describe HIV transmission dynamics in HSWNs for any country or region. Benefiting from a comprehensive and current systematic database of HIV prevalence, sexual and injecting behaviors, and risk group size estimates of FSWs and clients in MENA, the model was used to estimate HIV incidence and other epidemiological measures among FSWs, clients, and client spouses, as well as impact of HIV interventions. HIV incidence in HSWNs was estimated to contribute at least 25% of all HIV incidence in MENA. However, there were large differences across countries, reflecting differences in epidemic phase. Yet, even in countries where HIV prevalence among FSWs is relatively low, substantial incidence is occurring in HSWNs due to their large size. While incidence of HIV is more likely to be detected among FSWs, it constitutes less than a third of the incidence in HSWNs—the other two-thirds are split among clients and their spouses, who rarely access any HIV programmes. HSWNs appear to constitute a major driver of incidence among women in the general population through unprotected sex with HIV-positive clients. The study demonstrates that clients and their spouses can substantially benefit from expanding coverage of interventions, even if these interventions are delivered only to FSWs. These estimates inform HIV programming and monitoring of progress toward achieving UNAIDS targets for 2030.

Implications of all available evidence

With the emergence of HIV epidemics in FSWs in MENA, HIV incidence in HSWNs is likely to increase. Scale-up of HIV interventions among FSWs should be a priority, and such interventions will have a substantial impact on reducing infection burden among FSWs and their clients. A significant proportion of incidence among general population women will also be averted by HIV interventions among FSWs. Yet, FSWs in this region continue to suffer from poor coverage of all interventions and MENA is far from achieving UNAIDS and WHO targets. The situation may have been exacerbated by the COVID-19 pandemic. Strengthening non-governmental entities working with FSWs to deliver services and programs may assist, as demonstrated in several countries. Surveillance systems for HIV need to be enhanced among FSWs, through regular, national, integrated bio-behavioral surveillance surveys, to monitor the HIV epidemic and progress toward global targets, and to enhance our understanding of HIV epidemiology in HSWNs.

Introduction

To accelerate ending the HIV/AIDS epidemic as a public health threat by 2030,[1] the Joint United Nations Programme on HIV/AIDS (UNAIDS) formulated the 'UNAIDS 2016-2021 Strategy",[2] and more recently the 'UNAIDS 2021-2026 Strategy",[3] a call for scaling-up HIV response among people living with HIV (PLHIV) to achieve 90% coverage for HIV testing, treatment, and sustained viral suppression by 2020,[2] and 95% coverage by 2030.[2-4] The strategy emphasized enhancing access to combination prevention interventions among key populations as a cornerstone to achieve the goal.[2] Targets were set to reduce the global number of persons newly acquiring HIV and of AIDS-related deaths to fewer than 500,000 by 2020, and fewer than 200,000 by 2030.[2,4]

Despite progress, the global community has not met the 2020 targets, with 1.5 million new HIV infections and 680,000 AIDS-related deaths estimated in 2020.[5] Over half of newly-acquired infections occurred among key populations and their sexual partners,[6] indicating persistent gaps in reaching populations most at risk.[7,8]

The Middle East and North Africa (MENA), a region including approximately 10% of the world's population,[9] continues to lag behind in HIV prevention and treatment.[7] ART coverage in MENA, as defined by UNAIDS, is only 43%, the lowest across all world regions,[8] and HIV incidence appears to be increasing since 2010.[7,8] HIV epidemics have emerged in the last two decades among female sex workers (FSWs),[10] men who have sex with men (MSM),[11] and people who inject drugs (PWID).[12] Yet, HIV surveillance remains limited in scale and scope,[10-16] with scarce data on incidence among marginalized and hard-to-reach populations.[10-12,17,18] Although heterosexual sex work networks (HSWNs) may be driving a large proportion of HIV incidence in MENA owing to their large size[10,19,20] relative to those of PWID[12] and MSM,[11] levels of incidence among FSWs and their clients remains unknown.[10] This evidence gap is hampering HIV programming and monitoring of progress toward UNAIDS targets.

To address this evidence gap, we developed a novel individual-based mathematical model to simulate HIV transmission dynamics in HSWNs, and applied it to estimate for each MENA country: 1) current HIV incidence and incidence rate among FSWs, their clients, and client stable sexual partners/spouses; 2) relative contribution of heterosexual sex intercourse versus injecting drug use to incidence among FSWs; 3) contribution of HSWNs to incidence in the total adult population; and 4) impact of various targets for interventions on incidence in HSWNs.

Methods

Overview of mathematical model

An individual-based Monte Carlo simulation model was developed to simulate sexual networks of FSWs and clients and HIV transmission dynamics in these networks, and to estimate current and future HIV incidence, factoring in both current intervention coverage and potential future scale-up. Model structure was informed by earlier individual-based models for sexually transmitted infections (STIs).[21-23] The model simulates cohorts of FSWs and clients (regular and non-regular/one-time) in each country over time as they engage in sexual (and injecting for FSWs) behaviors and acquire or transmit HIV.

Parameterization of the model with current data was primarily based on a recently completed comprehensive systematic review of HIV prevalence and sexual and injecting behaviors among FSWs and clients in MENA, and size estimates of these populations.[10] The review identified 485 HIV prevalence measures on 287,719 FSWs and 69 measures on 29,531 clients/proxy populations, along with detailed sexual and injecting behavior data, in addition to >300 population-size estimates in these populations.[10]

Heterosexual sex work network

In the model, each FSW or client in the network enters/exits the sexual network, forms/dissolves sexual partnerships, or acquires HIV through sex or by injecting drugs at event-specific probabilities at each time step in each simulation run. The sexual network is constructed assuming that the number of sexual partnerships formed by each regular or non-regular client with FSWs follows a gamma distribution, reflecting sexual network and behavior studies.[10,21,24-27] The mean and variance of these distributions were informed by country-level data on sexual behavior in HSWNs—the variance was set at 25% of the mean.[10] Each month, every regular or non-regular client may form a new partnership with one or more FSWs, based on a random probability drawn from these distributions. Existing partnerships may also dissolve stochastically assuming an exponential distribution at a rate of inverse of duration of partnerships, which varies based on whether they involve a regular or non-regular client. Accordingly, in such sexual networks, each client randomly selects FSW partners, but clients may have different propensities to form partnerships, a situation known as proportionate mixing.[21,28]

FSWs exit the HSWN if they cease to practice sex work, and for clients if they cease seeking sex with FSWs, or through natural and AIDS-related mortality (Table 1). Lower HIV transmission, slower AIDS disease progression, and higher life expectancy were assumed for individuals on antiretroviral therapy (ART; Table 1). Those who exit the HSWN are replaced by susceptible persons, thus maintaining a fixed cohort size for FSWs and clients.

While the model assumes that HIV acquisition among FSWs can occur through sex with a client or through injecting drug use with an injecting partner, HIV acquisition among clients was assumed to occur only through sex with an HIV-positive FSW. Other sources of infection, such as the client's spouse, other heterosexual partners, male same-sex partners, and injecting drug use were not considered. Evidence suggests that the risk of HIV infection through these modes of exposure among clients is probably substantially smaller than the risk of infection through sex with a FSW in most MENA countries.[10,18-20]

HIV sexual transmission in FSW-client partnerships

Probability of HIV sexual transmission in an HIV sero-discordant partnership, that includes an HIV-positive FSW/client and a susceptible counterpart, was determined from the probability of transmission per coital act per HIV stage of infection, number of coital acts per partnership, which varied based on whether partnerships were with regular or non-regular clients, and interventions that affect HIV transmission.

These interventions included ART in the FSW or client, condom use in the partnership, male circumcision in the client, and pre-exposure prophylaxis (PrEP) in the FSW. Coverage of these interventions for FSWs and clients was based on data for each country and was implemented in the model by random assignment.

HIV transmission through drug injection

Proportions of FSWs who inject drugs were based on data for each country. HIV acquisition through injecting drug use was modeled through an external hazard rate (force of infection) that depended on whether the FSW was on PrEP and whether her injecting partner was on ART. Otherwise, a constant hazard rate was assumed and was derived by fitting model output to country-level data on HIV prevalence among FSWs who inject drugs,[10] or alternatively if such data were not available, to HIV prevalence among PWID.[12] FSWs who inject were assumed to inject for a specific duration, set at 10 years,[12] which differed from the duration of sex work set at 35 years.[10]

HIV sexual transmission from clients to their spouses

HIV sexual transmission from clients to their spouses was modeled using a separate deterministic model, but using the individual-based model output as input (Supplementary Material). Numbers of HIV transmissions from clients to spouses were estimated using the proportion of clients in spousal partnerships, HIV prevalence among clients, numbers of susceptible spouses, and probability of HIV transmission per partnership. The latter was estimated using the probability of transmission per coital act per HIV stage of infection, numbers of coital acts per partnership, condom use, and ART coverage among clients. It was assumed that all HIV incidence among spouses occurs through transmission from the HIV-positive client to the susceptible spouse, as other sources of exposure are likely limited in the MENA context.[10,18-20]

HIV natural history

HIV natural history was based on established empirical epidemiological measures (Table 1). Progression through each of HIV infection stages was modeled assuming an exponential distribution through rates derived as the inverse of duration of each HIV stage and implemented through a stochastic process.

Data sources and model parameters

The primary data source for this modeling study was the recently completed systematic review of HIV, sexual and injecting behavior, and population size estimates in FSWs and clients in MENA.[10] Countries were included in the present study if they had sufficient input data to simulate the HIV epidemic in the HSWN *and* HIV prevalence among FSWs was ≥0.5%. Otherwise, it was not feasible to conduct the simulations. Twelve of the 23 MENA countries were included: Algeria, Bahrain, Djibouti, Iran, Libya, Morocco, Pakistan, Somalia, South Sudan, Sudan, Tunisia, and Yemen. Injecting drug use among FSWs was modelled in countries in which evidence suggested a significant role for injecting drug use in the HIV epidemic.[10] These included Bahrain, Iran, Libya, and Pakistan.

Country-specific parameter values were selected based on the most recent representative studies identified through the aforementioned systematic review.[10] Priority was given to studies with rigorous sampling methodologies, such as integrated bio-behavioral surveillance surveys (IBBSS). Where several nationally representative estimates based on IBBSS were available,[10] the mean of these estimates was considered. Otherwise, data collected after the year 2000 were pooled using random-effects meta-analysis. This methodology used Freeman-Tukey type arcsine square-root transformation to stabilize variances[29,30] before weighting measures using the inverse-variance method,[30,31] followed by pooling using DerSimonian-Laird random-effects models to account for sampling variation and true heterogeneity.[32,33] Data for coverage of interventions were primarily based on findings of the systematic review,[10] or alternatively, on UNAIDS compilations,[34] or imputed using the regional median for these parameters.[10]

Demographic and Health Survey data on men in the general population were used to derive, for each country, the proportion of clients in spousal partnerships (defined as a marital/cohabiting partnership for ≥1 year) and the proportion of sexual acts protected by condom use in these partnerships.[35] For countries with missing information, measures were imputed by pooling regional data using random-effects meta-analysis.

The population size of FSWs and clients in each country was based on country-level data.[10] Other model parameters, such as for HIV transmission and efficacy of interventions, were based on current evidence in the literature (Tables 1-3).

Model simulations

The model-generated sexual network was established with a "burn-in" of 50 years to ensure equilibrium of network structure prior to HIV introduction. Subsequently, HIV infection was seeded and the model was run for an additional "burn-in" of 300 years to ensure epidemic equilibrium in each country by 2020. Since epidemiological measures of interest, such as HIV incidence, were estimated over a short time horizon of one year, and in absence of quality country-level trend data for HIV prevalence in FSWs and clients in nearly all MENA countries,[10] analyses were implemented starting from this epidemic equilibrium.

Model predictions for each country were based on the mean and 95% uncertainty intervals (UIs) of distributions of outcome measures generated by 500 simulation runs. UIs were generated after excluding runs with HIV stochastic extinction. For computational efficiency, simulations were performed using a cohort of 600 FSWs and 6,000 clients (one-third of which are regular and two-thirds are non-regular/one-time clients), as informed by MENA data,[10] with outcome measures subsequently scaled-up to reflect the actual population sizes in each country.[10]

Model fitting

Model fitting to HIV prevalence data among FSWs and HIV prevalence among FSWs who inject drugs was performed to estimate the overall rate of sexual partnership formation and the baseline hazard rate of acquiring HIV through injecting drug use in each included country. Nonlinear least-square fitting using the Nelder-Mead simplex algorithm[36] was implemented iteratively to generate a set of 50 best model fits. A best model fit was defined as a relative error of <5% between model predictions and empirical data. The final best model fit was the most probable value for the sexual partnership rate and injecting hazard rate among the 50 best model fits.

Outcome measures

HIV epidemiological measures

HIV incidence was defined as the number of new infections per year and was calculated by summing new infections occurring among FSWs (or clients) at each time-step (1 month) during the year. HIV incidence rate was defined as the number of new infections per susceptible person per 1,000 person-years and was calculated by dividing the number of incident infections among FSWs, clients, and client spouses by the respective numbers of susceptible individuals in these populations at the start of that year. The relative contribution of sexual versus injecting HIV acquisitions to total incidence among FSWs was estimated by dividing the number of incident infections resulting from each of sexual and injecting transmission during one year by all incident infections during that year. The relative contribution of HSWNs to HIV incidence in the total adult population was estimated by dividing the sum of incident infections arising among FSWs, clients, and client spouses over the duration of a year, by the total HIV incidence in the population (15-49 years) during that year, as estimated by UNAIDS.[34]

Impact of interventions

The impact of expanding HIV interventions among FSWs on HIV incidence arising in HSWNs was assessed by estimating, using 500 simulation runs, the mean number of infections that would be averted over a 10-year duration after implementing the interventions, and the proportional decrease in incidence during this time (Table 4).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the article. The corresponding author had full access to all the data in the study and had the final responsibility for the decision to submit for publication.

Results

Estimated HIV incidence (number of new infections) in 2020 in the 12 countries combined was 3,471 (range: 1,295-10,308) among FSWs, 6,416 (range: 3,144-14,223) among clients, and 4,717 (range: 3,490-7,288) among client spouses (total: 14,604; Tables 2 and 3). The total incidence among FSWs, clients, and spouses constituted 28.1% of overall incidence among adults estimated by UNAIDS[34] in these 12 countries combined (total: 51,995) , and 25.1% of incidence estimated for all 23 countries of MENA (total: 58,189).[34]

In countries in which HIV acquisition through injecting drug use among FSWs is negligible, estimated numbers of new infections among FSWs in 2020 ranged between 21 in Djibouti and 2,345 in South Sudan (Table 2). Meanwhile, estimated numbers of new infections in clients ranged from 25 in Tunisia to 5,167 in South Sudan, whereas that among spouses ranged from 18 in Tunisia to 3,978 in South Sudan.

While the estimated number of incident infections by country varied owing to HSWN size differences, in each of these countries, total incidence in HSWNs was distributed roughly equally among FSWs, clients, and spouses (Table 2). The only exception was South Sudan, the only country in this region with low male circumcision coverage (23.6%),[37] where incidence in clients and their spouses was twice as large as that among FSWs. Also, apart from South Sudan, HIV prevalence among clients was approximately 25% of that among FSWs. HSWN contributions to total incidence in the population ranged from 6.4% in Tunisia to 71.8% in South Sudan and 72.7% in Djibouti. Incidence rate among FSWs ranged from 0.4 (95% CI: 0.0-7.1) per 1,000 person-years in Yemen to 34.3 (95% CI: 17.2-59.6) per 1,000 person-years in South Sudan.

In countries where HIV acquisition through injecting drug use creates significant exposure for FSWs, estimated numbers of new infections among FSWs in 2020 ranged from 1 in Bahrain to 339 in Pakistan (Table 3). Meanwhile, numbers of new infections among clients and their spouses ranged from <1 in Bahrain to 301 and 114, respectively, in Pakistan. Incidence among FSWs out of total incidence in HSWNs was higher in these countries (Table 3) compared to countries with limited drug injection transmission (Table 2), as many FSWs were infected through drug injection in addition to those being infected through sex. Still, sexual transmission contributed most HIV incidence among FSWs; 67.6% in Pakistan, 68.0% in Iran, and 75.0% in Libya. Also, as a consequence of the role of injecting, incidence among clients out of total incidence in HSWN, and especially incidence among spouses, was relatively smaller.

In these countries, HIV prevalence among clients was only ~10% of that among FSWs (Table 3). The contribution of HSWNs to total incidence in the population was also relatively low in these countries, ranging from 3.3% in Pakistan to 14.4% in Libya. Incidence rate per 1,000 person-years among all FSWs (including those who inject drugs) ranged from 0.5 (95% CI: 0.0-3.4) in Bahrain to 2.6 (95% CI: 0.0-8.8) in Libya. However, FSWs who inject drugs were disproportionately affected with higher incidence rates per 1,000 person-years ranging from 5.1 (95% CI: 0.0-35.1) in Iran to 45.8 (95% CI: 0.0-428.6) in Pakistan.

Models showed that all considered interventions, whether individually or in combination, substantially reduced incidence among FSWs, clients, and client spouses (Tables 5 and 6). However, the interventions affected the three subpopulations differently. Increasing ART coverage and improving adherence to treatment among FSWs resulted in major reductions in incidence with clients benefiting the most, as they benefited directly from viral suppression in HIV-positive FSWs. Meanwhile, FSWs and client spouses benefited only indirectly through reduction in the pool of HIV-positive clients. Still, the number of averted infections among FSWs and spouses was substantial, and as much as half of that among clients in countries where HIV transmission through injecting drug use is negligible (Table 5). In countries where HIV transmission through injecting drug use is a significant mode of HIV exposure, FSWs additionally benefited directly from this intervention, as it increased viral suppression among their injecting partners (Table 6).

Increased condom use considerably reduced incidence for both FSWs and clients, as both benefited directly from this intervention (Tables 5 and 6). Though client spouses did not benefit directly from this intervention, still the estimated number of averted infections among them was about half of that among clients (Tables 5 and 6), as a consequence of the reduction in the pool of HIV-positive clients.

Expanding coverage of PrEP among FSWs, which remains very limited in MENA,[6] considerably reduced incidence, with FSWs benefiting most, as they directly experienced diminished risk of HIV acquisition (Tables 5 and 6). Meanwhile, clients benefited only indirectly by reducing the pool of HIV-positive FSWs. Still, the number of averted infections among clients was substantial and as much as half of that among FSWs. Even client spouses had significantly reduced incidence, although they benefited from the already indirect benefits among clients that resulted from increasing PrEP coverage among FSWs. Numbers of averted infections among spouses were often close to half that among clients (Table 5).

Expanding voluntary medical male circumcision (VMMC) coverage in South Sudan, the only country in MENA where this intervention is needed, led to major reductions in HIV incidence among clients, spouses, and FSWs (Table 5). The number of averted infections was particularly high for clients and their spouses (about half that among clients).

Packages of combined interventions also considerably reduced incidence. A moderately optimistic combination of interventions led to ≤60% reduction in incidence among FSWs and clients, and half this reduction in client spouses (Tables 5 and 6). The most optimistic scenario for combined interventions led to ≤90% reduction in incidence among FSWs and clients, and half as much among spouses (Tables 5 and 6).

Discussion

HIV transmission in HSWNs is a major source of incident cases in MENA and contributes at least 25% of the annual number of HIV infections in this region. The contribution of HSWNs to incidence varied among countries from 3% in Pakistan to over 70% in South Sudan and Djibouti. This variation reflected large differences in epidemic phase (recent or established epidemic) and HIV prevalence among FSWs. It is remarkable that even in countries where HIV prevalence among FSWs is relatively low, substantial incidence occurs in HSWNs due to their relatively large size compared to networks of MSM and PWID. For example, HIV prevalence among FSWs in Morocco is only 2%, but HSWNs represent 24% of all incident cases in this country.

HIV incidence is more likely to be detected among FSWs than among clients and their spouses due to some HIV testing and prevention programs,[10,18,38] and our findings highlight that this is less than a third of the actual incidence that occurs in HSWNs. The other two-thirds are split among clients and their spouses, who rarely access HIV response programming. It is striking that one-third of incidence in HSWNs occurs among spouses of clients, although they do not engage in sexual risk behavior and do not normally benefit from any HIV intervention, but are exposed to infection by their husbands. This finding and vulnerability is consistent with evidence in MENA indicating that for the vast majority of HIV infections among women, the source of the infection is an HIV-positive spouse.[17-20,39-41]

Although HIV incidence in HSWNs in MENA is substantial, it presently contributes only about 1% of total incidence worldwide. Relatively nascent HIV epidemics in MENA FSWs, with only a few national epidemics reaching a concentrated level, have limited the extent of HIV incidence. Indeed, the recent systematic review of HIV prevalence in MENA found that of all 485 prevalence measures among FSWs, 46.8% were at zero prevalence,[10] demonstrating the limited extent of the epidemic thus far in most countries, and perhaps the window of opportunity to prevent the epidemic from expanding. This window of opportunity may close with time, as the same review found that HIV prevalence in FSWs is increasing at ~15% per year.[10] Any major increase in HIV prevalence in FSWs would entail a major increase in HIV incidence in HSWNs, as these results demonstrate for countries such as Djibouti and South Sudan, where HIV prevalence is already at a concentrated level.

These results indicate that structural factors have curtailed HIV incidence in HSWNs. While condom use is still far from universal, roughly half of sexual acts in MENA between FSWs and clients are condom-protected,[10] thereby preventing a proportion of HIV transmissions. The importance of condom use in reducing transmission can be seen in the impact of increasing condom use coverage on incidence (Tables 5 and 6). Since this intervention *directly* protects both FSWs and clients at the same time, it has a major impact. Increasing access to and coverage of condom use in HSWNs should be a priority for HIV programming in MENA.

Another factor that reduced incidence is male circumcision, which is essentially universal in MENA.[37] This is best demonstrated in South Sudan, the only country in this region with low male circumcision coverage (Table 2). Unlike other countries, HIV incidence there in clients and their spouses was twice that among FSWs. For all other countries, it was similar to that among FSWs. The role of male circumcision can also be seen in the impact of increasing VMMC coverage on HIV incidence in this country (Table 5). VMMC has particularly reduced HIV incidence among clients and their spouses, thus, onward transmission of HIV to the wider population. This is also supported by numerous modelling studies of the impact of VMMC in settings with similar HIV epidemiology to that of South Sudan, such as Zambia[42] and Zimbabwe.[43] Given that most of HIV incidence in South Sudan occurs among clients and their spouses, expanding coverage of VMMC should become a priority for this country.

Against a background of expanding epidemics in HSWNs, the results indicate that interventions can significantly reduce incidence and prevent expansion of epidemics. A modest package of interventions reduced incidence by as much as 60% among both FSWs and clients (Tables 5 and 6). However, the results highlighted that with the low coverage of interventions at present, achieving the UNAIDS elimination target will require scale-up not only of single interventions, but of combination of interventions.

The type of intervention determines whether its impact is most beneficial to FSWs, clients, or spouses. Nonetheless, even when a subpopulation does not benefit directly from an intervention, it still benefits indirectly by reducing the pool of infected persons in the HSWN. Increasing condom use reduces incidence equally among both FSWs and clients. Meanwhile, increasing ART coverage for FSWs living with HIV, aside from benefiting them for their own health and well-being, also benefits primarily the clients, as it reduces onward transmission from FSWs.

Expanding PrEP coverage among FSWs benefits primarily FSWs as it reduces their acquisition of the infection, and hence the possibility of transmission within the HSWN. Notably, indirect effects on onward transmission were large and often about half as large as the direct effects. This is best seen for the impact of the interventions on incidence among client spouses. None of the interventions targeted spouses. However, the reduction in incidence among them was often as large as half the reduction seen in clients or FSWs.

Despite substantial incidence arising in HSWNs, the HIV response in MENA remains limited in scope and scale.[38] Our systematic review of HIV among FSWs showed that only 18% of FSWs in the region report ever being tested for HIV,[10] lower than that found in other regions[44] and far below the 90% target of the 'UNAIDS 2016-2021 Strategy'.[2] ART coverage among PLHIV in MENA is the lowest of all world regions,[6,8] and far behind the WHO regional target of 50% coverage by 2015.[45] No data on viral suppression among FSWs affected by HIV in MENA can be located, but only a minority of PLHIV are virally suppressed.[6,8] The situation may have worsened with the advent of COVID-19 due to interruptions in the provision of prevention and treatment services.[46] The results also demonstrate an additional vulnerability for FSWs who inject drugs, where as much as a third of HIV incidence among FSWs was due to drug injection in countries such as Iran and Pakistan. Gender-sensitive harm reduction services for FSWs who inject drugs need to be available wherever a significant proportion of FSWs inject drugs.

Reaching FSWs and their clients in MENA continues to be a challenge given punitive laws[7,38,47] and stigma[48-50] associated with sex work. Diverse typologies and increased mobility of FSWs[47,51,52] are additional barriers. Programs and services, where they exist, are exclusively the realm of non-governmental organizations, which are often inadequately resourced or under legal restrictions preventing provision of comprehensive intervention packages to FSWs.[18,38]

This study has limitations. Analyses were possible for only 12 of 23 MENA countries with sufficient HIV prevalence, behavioral, and risk group size estimate data to apply the model. However, these 12 countries constituted 65% of the total population of MENA and included all countries where current evidence suggests significant epidemics in HSWNs.[10] Some of the input data, such as for HIV prevalence, originated from IBBSS surveys conducted in specific settings or cities, and may not represent the total FSW population in a given country, thereby possibly affecting the estimates. Some model input data were global rather than MENA-specific such as the real-world effectiveness in achieving viral suppression among FSWs.[53]

The model did not simulate further onward HIV transmission beyond FSWs, clients, and client spouses; thus, this study may underestimate the contribution of HSWNs to total HIV incidence in the population. In the absence of country-level trend data for HIV prevalence,[10] estimates were generated assuming endemic equilibrium. This may not have had an appreciable effect on estimated epidemiological measures such as incidence, as they were generated over only one year, but may have underestimated the impact of interventions if HIV prevalence is increasing, as suggested for the MENA region.[10]

HSWNs are large and it is not feasible computationally to simulate the entire HSWN in each country using such a fine-grained, individual-based modelling approach. For computational feasibility and efficiency, simulations were performed using sub-cohorts of FSWs and clients that are representative of the full cohorts of FSWs and clients. Results were subsequently scaled-up to reflect actual population sizes of FSWs and clients. This reduction in simulated cohort sizes made it difficult to simulate HSWNs and sustain HIV epidemics in countries where HIV prevalence among FSWs is ≤0.5%. These countries were thus excluded from analysis (n=6). This may also have underestimated HIV incidence in included countries due to finite-network effects and higher likelihood of stochastic extinction. This further resulted in higher stochasticity in simulations assessing the impact of interventions up to 2030. The impact was thus assessed after 30 years “burn-in” to reduce stochasticity, and then scaled back to a 10-year duration, which may have overestimated the indirect impact of interventions on onward transmission of infection. The indirect impact of interventions on incidence is slower to materialize than the direct impact. The latter, such as for condom use, is immediate the moment a condom is used in a simulated sexual partnership.

Conclusions

HIV incidence in HSWNs is a major source of incidence in MENA and contributes at least 25% of the annual number of HIV infections in this region. With the nascency of HIV epidemics among FSWs, and evidence suggesting a trend of increasing HIV prevalence,[10] incidence in HSWNs is likely to grow. Scale-up of interventions among FSWs should be a priority, and this study forecasts a substantial impact for these interventions in controlling the epidemic. However, the region is still far from achieving UNAIDS targets,[2,8] and the situation may have worsened with the advent of COVID-19.[46] There is a need to rapidly scale up ART coverage among FSWs and for programs that improve their retention in the treatment cascade and their access to comprehensive prevention services. Strengthening the role of non-governmental entities working with FSWs to lead the delivery of services and programs, supported by the governments, may prove successful, as demonstrated in Morocco.[10,38] Expansion of surveillance systems, including conduct of regular national IBBSS surveys, is warranted to monitor the epidemic and to track progress toward UNAIDS goals.

Contributors

HC co-conceived the study, designed the study and model, coded the mathematical model, conducted the model parameterization, generated the simulations, and wrote the first draft of the article. HHA contributed to coding of the model and generation of simulations. RO contributed to model development. HAW contributed to study design and drafting of the article. LJA co-conceived the study and contributed to study design, simulations, and drafting of the article. All authors contributed to discussion and interpretation of the results and to writing of the manuscript. All authors have read and approved the final manuscript.

Declaration of interests

The authors have no competing interests to declare.

Table 1: Values of model parameters.

Parameter	Value	Justification/Source
HIV transmission and natural history		
Transmission probability per coital act		
Acute stage of HIV infection	0.0360	Observational cohorts and subsequent analyses.[54,55]
Latent stage of HIV infection	0.0008	Observational cohorts and subsequent analyses.[54,55]
Advanced stage of HIV infection	0.0042	Observational cohorts and subsequent analyses.[54,56-59]
From clients to stable sexual partners (spouses)	0.0018	Weighted average derived using transmission probability per coital act for each HIV infection stage and time spent in that stage.
Duration of HIV infection stages in absence of ART		
Acute stage of HIV infection	49 days	Observational cohorts and subsequent analyses.[54,55,60-65]
Latent stage of HIV infection	9 years	Observational cohorts and subsequent analyses.[54,55,60-65]
Advanced stage of HIV infection	2 years	Observational cohorts and subsequent analyses.[54,55,59-65]
HIV prevalence		
FSWs	See Table 2	Based on findings of FSWs in MENA systematic review.[10]
FSWs who inject drugs	See Table 2	Based on findings of FSWs in MENA systematic review, in countries where evidence suggests a significant role for injecting drug use in the HIV epidemic.[10] For countries with missing information, findings were based on PWID in MENA systematic review,[12] or UNAIDS data.[34]
Clients of FSWs	See Table 2	Model prediction.
Client spouses	See Table 2	Assumed to be 1/3 of HIV prevalence in clients of FSWs.[19,20,66]
Population size		
FSWs	See Table 2	Based on findings of FSWs in MENA systematic review.[10] For countries with missing information, findings were based on median proportion of reproductive-age women reporting current/recent sex work across MENA countries (0.6%, median out of 111 studies) in FSWs in MENA systematic review,[10] and estimates for the size of the population of adult women aged 15-49.[9]
Clients of FSWs	See Table 2	Assumed to be ten times larger than the size of the FSWs population based on FSWs in MENA systematic review[10] and modeling studies.[19,20]
Sexual risk behavior		
Number of coital acts with a FSW		
Regular clients	3 acts per month	Based on findings of FSWs in MENA systematic review.[10]
One-time clients	1 act per month	Based on findings of FSWs in MENA systematic review.[10]
Partnership duration with a FSW		
Regular clients	3 months	Reasonable value informed by findings of FSWs in MENA systematic review.[10]
One-time clients	1 month	Reasonable value informed by findings of FSWs in MENA systematic review.[10]
Proportion of clients in stable partnerships		
Morocco	52.3%*	Demographic and Health Survey (2003).[35]
Yemen	61.2%*	Demographic and Health Survey (2003).[35]
Pooled estimate-MENA countries with data†	56.4%	Demographic and Health Surveys.[35]
Number of coital acts with spouses for regular and one-time clients	25 acts per year	Reasonable value considering that over 80% of women seeking antenatal or family planning services had sexual relations at least once per week[67] and accounting for the fact that clients of FSWs have reduced number of acts with spouses.
Injecting risk behavior		

Proportion of FSWs who inject drugs	See Table 2	Median of country-specific estimates based on findings of FSWs in MENA systematic review.[10] For countries with missing information, findings were based on most representative estimates based on findings of a systematic review of HIV among PWID in MENA and recent unpublished updates.[12]
Time spent in injecting drug use	10 years	Based on findings of systematic reviews.[12,68]
HIV prevention interventions		
ART		
Efficacy in preventing HIV transmission to partners	96%	Based on findings of a randomized clinical trial.[69]
Real-world effectiveness in achieving viral suppression in FSWs	57%	Based on findings of a systematic review.[53]
Effectiveness in slowing disease progression from the latent to the advanced stage of HIV infection	1/3	Based on findings of cohort and modeling studies.[70-72]
Effectiveness in slowing disease progression to AIDS death for those in the advanced stage of HIV infection	1/3	Based on findings of cohort and modeling studies.[70-72]
Coverage in clients/PLHIV	See Table 2	UNAIDS[34] and World Bank[73] data.
Coverage in FSWs	See Table 2	UNAIDS[34] and World Bank[73] data. Coverage was assumed to be equal to that estimated for all PLHIV as no recent data on coverage among FSWs was available (except for South Sudan[10]).
Condoms		
Effectiveness in reducing HIV transmission	80%	Based on findings of observational studies.[74-76]
Coverage in commercial sex	See Table 2	Median of country-specific estimates based on findings of FSWs in MENA systematic review.[10] For countries with missing information, findings were based on median proportion of FSWs reporting condom use at last sex (44.0%, median out of 97 studies) in FSWs in MENA systematic review.[10]
Coverage in spousal partnerships†		
Morocco	1.5%	Demographic and Health Survey (2003).[35]
Pakistan	10.6%	Demographic and Health Survey (2017).[35]
Yemen	0.5%	Demographic and Health Survey (2003).[35]
Pooled estimate-MENA countries with data‡	2.9%	Demographic and Health Surveys.[35]
VMMC		
Efficacy in reducing HIV transmission	58%	Based on findings of clinical trials and systematic review.[77-80]
Coverage	See Table 2	Global VMMC prevalence data.[37]
PrEP		
Effectiveness in reducing HIV transmission	51%	Based on findings of a systematic review.[81]
Coverage in clients	See Table 2	UNAIDS data.[34]
Coverage in FSWs	See Table 2	UNAIDS data.[34]

Abbreviations: ART: anti-retroviral therapy, FSW: female sex workers, MENA: Middle East and North Africa, NA: not applicable, PLHIV: people living with HIV, PrEP: pre-exposure prophylaxis, PWID: people who inject drugs, UNAIDS: The Joint United Nations Programme on HIV/AIDS, VMMC: voluntary male circumcision; WHO-EMRO: World Health Organization's Regional Office for the Eastern Mediterranean.

*Data only available for women, the fraction of men in spousal partnerships was assumed to be equal to that of women.

†Proportion of women reporting condoms as current contraceptive method.

‡Includes all MENA countries with data regardless of whether these countries qualified for inclusion in this study.

Table 2: HIV epidemiological measures for FSWs, clients, and client spouses in MENA and the contribution of sex work to total HIV incidence in the population in 2020, in countries with no significant HIV transmission through injecting drug use among FSWs. The table includes measures based on empirical data for model input, as well as measures estimated using the model.

Epidemiological measures	Algeria	Djibouti	Morocco	Somalia	South Sudan	Sudan	Tunisia	Yemen
Model input								
Population								
FSWs (n)	65,969	4,481	72,000	36,174	110,968	212,500	25,500	58,934
FSWs (population proportion; %)*	0.6%	1.7%	0.8%	1.0%	4.1%	2.0%	0.9%	1.6%
Clients of FSWs (n)	659,690	44,810	720,000	361,740	1,109,680	2,125,000	255,000	589,340
HIV prevalence (%)								
Empirical data								
All FSWs	4.9%	9.3%	2.2%	4.5%	37.9%	1.5%	1.2%	0.8%
HIV incidence in the total adult population per year as estimated by UNAIDS† (n)	2,000	<100	<1,000	<500	16,000	2,900	<1,000	1,000
Current HIV interventions' coverage (%)								
Condom use (empirical data)	65.3%	59.6%	52.3%	31.5%	72.4%	26.0%	58.3%	46.0%
Male circumcision (empirical data)	97.9%	96.5%	99.9%	93.5%	23.6%	90.7%	99.8%	99.0%
ART (empirical data)								
FSWs	32.0%	30.0%	57.0%	28.0%	9.4%	15.0%	31.0%	21.0%
Clients/People living with HIV	32.0%	30.0%	57.0%	28.0%	16.0%	15.0%	31.0%	21.0%
PrEP (empirical data)								
FSWs	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Clients	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Model estimates for 2020								
HIV prevalence								
All FSWs (%)	4.9%	9.2%	2.2%	4.6%	38.2%	1.5%	1.4%	0.7%
95% uncertainty interval (%)	0.8-12.8%	3.3-16.0%	0.5-8.0%	0.8-13.1%	32.2-43.5%	0.3-9.7%	0.2-8.3%	0.2-6.0%
Clients of FSWs (%)	1.3%	2.4%	0.5%	1.1%	16.9%	0.3%	0.4%	0.2%
95% uncertainty interval (%)	0.2-3.3%	0.8-4.3%	0.1-1.9%	0.2-3.0%	14.0-19.2%	0.07-2.3%	0.07-2.1%	0.1-1.7%
Client spouses	0.4%	0.8%	0.2%	0.4%	5.6%	0.1%	0.1%	0.06%
95% uncertainty interval (%)	0.1-1.1%	0.3-1.4%	0.03-0.6%	0.1-1.0%	4.7-6.4%	0.02-0.8%	0.02-0.7%	0.0-0.6%
HIV incidence in HSWNs per year								
All FSWs (n)	179	21	83	93	2,345	163	21	26
95% uncertainty interval (n)	0-770	0-60	0-600	0-422	1,295-3,884	0-1,771	0-170	0-393
Clients of FSWs (n)	234	29	100	113	5,167	213	25	30
95% uncertainty interval (n)	0-770	0-67	0-600	0-422	3,144-7,398	0-2,125	0-213	0-393
Client spouses (n)	173	22	61	84	3,978	166	18	26
95% uncertainty interval (n)	31-431	7-39	11-217	15-266	3,330-4,484	32-1,082	4-108	10-235
HIV incidence rate‡ (per 1,000 person-years)								
All FSWs	2.9	5.1	1.2	2.8	34.3	0.8	0.9	0.4
95% uncertainty interval	0.0-13.2	0.0-14.8	0.0-8.7	0.0-12.5	17.2-59.6	0.0-8.8	0.0-7.3	0.0-7.1
Clients of FSWs	0.2	0.3	0.07	0.2	2.5	0.05	0.05	0.03

Epidemiological measures	Algeria	Djibouti	Morocco	Somalia	South Sudan	Sudan	Tunisia	Yemen
95% uncertainty interval	0.0-0.6	0.0-0.8	0.0-0.4	0.0-0.6	1.5-3.6	0.0-0.5	0.0-0.4	0.0-0.3
Client spouses	0.5	0.9	0.2	0.4	6.7	0.1	0.1	0.07
95% uncertainty interval	0.08-1.2	0.3-1.6	0.03-0.6	0.07-1.1	5.6-7.7	0.03-0.9	0.02-0.8	0.03-0.7
Contribution to total HIV incidence in the population (%)								
All FSWs	9.0%	21.2%	8.3%	18.6%	14.7%	5.6%	2.1%	2.6%
Clients of FSWs	11.7%	29.3%	10.0%	22.6%	32.3%	7.3%	2.5%	3.0%
Client spouses	8.7%	22.2%	6.1%	16.8%	24.9%	5.7%	1.8%	2.6%
Heterosexual sex work networks	29.3%	72.7%	24.4%	58.1%	71.8%	18.7%	6.4%	8.2%

Abbreviations: ART: antiretroviral therapy; FSWs: female sex workers; HSWNs: heterosexual sex work networks; PrEP: pre-exposure prophylaxis: UNAIDS: The Joint United Nations Programme on HIV/AIDS.

*Proportion of FSWs out of total reproductive-age women aged 15-49 years.

†Estimates for the number of new infections occurring in the population per year were provided by UNAIDS.[34] Assumed to be 99 where incidence is reported as "<100", 499 where incidence is reported as "<500", and 999 where incidence is reported as "<1,000".

‡Numbers of new HIV infections per susceptible person per 1,000 person-years. Numbers are rounded to the first decimal unless the number was <0.1%.

Table 3: HIV epidemiological measures among FSWs, clients, and client spouses in MENA and the contribution of sex work to total HIV incidence in the population in 2020, in countries with significant HIV transmission through injecting drug use among FSWs. The table includes measures based on empirical data for model input, as well as measures estimated using the model.

Epidemiological measures	Bahrain	Iran	Libya	Pakistan
Model input				
Population				
FSWs (n)	2,143	91,500	11,459	228,800
FSWs (population proportion; %)*	0.6%	1.4%	0.6%	0.4%
Clients of FSWs (n)	21,430	915,000	114,590	2,288,000
Proportion of FSWs who inject drugs (%)	3.9%	13.6%	2.9%	2.0%
HIV prevalence (%)				
Empirical				
All FSWs	0.8%	3.3%	4.9%	2.3%
FSWs who inject drugs	21.0%	9.9%	44.0%	38.4%
HIV incidence in the total adult population per year as estimated by UNAIDS† (n)	Unknown	4,000	<500	23,000
Current HIV interventions' coverage (%)				
Condom use (empirical data)	44.0%	57.1%	80.0%	50.5%
Male circumcision (empirical data)	81.2%	99.7%	96.6%	96.4%
ART (empirical data)				
FSWs	45.0%	20.0%	44.0%	8.0%
Clients/People living with HIV	45.0%	20.0%	44.0%	8.0%
PrEP (empirical data)				
FSWs	0.0%	0.0%	0.0%	0.0%
Clients	0.0%	0.0%	0.0%	0.0%
Model estimates for 2020				
HIV prevalence				
All FSWs	0.9%	3.3%	4.6%	2.4%
95% uncertainty interval (%)	0.3-1.8%	1.3-6.3%	1.8-8.3%	0.7-5.0%
FSWs who inject drugs	20.2%	9.9%	44.8%	37.8%
95% uncertainty interval (%)	8.0-37.0%	3.4-17.8%	21.1-68.8%	11.1-66.7%
Clients of FSWs (%)	0.03%	0.3%	0.5%	0.2%
95% uncertainty interval (%)	0.0-0.08%	0.1-0.6%	0.2-1.0%	0.05-0.6%
Client spouses	0.01%	0.1%	0.2%	0.08%
95% uncertainty interval (%)	0.0-0.03%	0.03-0.2%	0.07-0.3%	0.02-0.2%
HIV incidence in HSWNs per year				
All FSWs (n)	1	172	28	339
95% uncertainty interval (n)	0-7	0-610	0-96	0-1,525
FSWs who inject drugs (n)	1	55	7	110
95% uncertainty interval (n)	0-7	0-305	0-38	0-763
Clients of FSWs (n)	<1	171	33	301
95% uncertainty interval (n)	0-4	0-610	0-96	0-1,525
Client spouses (n)	<1	64	11	114
95% uncertainty interval (n)	0-1	20-127	5-20	25-278
HIV incidence rate‡ (per 1,000 person-years)				
All FSWs	0.5	2.0	2.6	1.5
95% uncertainty interval	0.0-3.4	0.0-7.1	0.0-8.8	0.0-6.9
FSWs who inject drugs	15.2	5.1	43.4	45.8
95% uncertainty interval	0.0-117.6	0.0-35.1	0.0-300.0	0.0-428.6
Clients of FSWs	0.02	0.2	0.3	0.1
95% uncertainty interval	0.0-0.2	0.0-0.7	0.0-0.8	0.0-0.7
Client spouses	0.01	0.1	0.2	0.09
95% uncertainty interval	0.0-0.03	0.04-0.3	0.07-0.3	0.02-0.2
Contribution to HIV incidence in FSWs (%)‡‡				
Sexual transmission	14.5%	68.0%	75.0%	67.6%
Injecting drug use	85.5%	32.0%	25.0%	32.4%
Contribution to total HIV incidence in the population (%)				

Epidemiological measures	Bahrain	Iran	Libya	Pakistan
All FSWs[§]	--	4.3%	5.6%	1.5%
Injecting drug use in FSWs	--	1.4%	1.4%	0.5%
Clients of FSWs	--	4.3%	6.6%	1.3%
Client spouses	--	1.6%	2.2%	0.5%
Heterosexual sex work networks	--	10.2%	14.4%	3.3%

Abbreviations: ART: antiretroviral therapy; FSWs: female sex workers; HSWNs: heterosexual sex work networks; PrEP: pre-exposure prophylaxis: UNAIDS: The Joint United Nations Programme on HIV/AIDS.
[*]Proportion of FSWs out of total reproductive-age women aged 15-49 years.
[†]Estimates for the number of new infections occurring in the population per year were provided by UNAIDS.[34] Assumed to be 499 where incidence is reported as "<500".
[‡]Numbers of new HIV infections per susceptible person per 1,000 person-years. Numbers are rounded to the first decimal unless the number was <0.1%.
[§]Including FSWs who inject drugs.

Table 4: Select modelled HIV prevention intervention packages to control the HIV epidemic among FSWs and clients in MENA. Baseline coverage was used whenever it was higher than that set in the investigated scenario.

Intervention	Coverage level
1. Expanding ART coverage in FSWs assuming real-world ART effectiveness in achieving viral suppression of 57% (real-world adherence to ART)[53]	1. Increase to 25% 2. Increase to 50% 3. Increase to 81% (global target)[7]
2. Expanding ART coverage in FSWs assuming ART efficacy in preventing HIV transmission to partners of 96% (optimal adherence to ART)[69]	1. Increase to 25% 2. Increase to 50% 3. Increase to 81% (global target)[7]
3. Increasing condom use coverage	1. Increase to 50% 2. Increase to 80%
4. Expanding VMMC coverage in clients (only applicable to South Sudan)[37]	1. Increase to 50% 2. Increase to 80%
5. Expanding PrEP coverage in FSWs	1. Increase to 25% 2. Increase to 50%
6. Moderately optimistic scenario	
a) Expanding ART coverage in FSWs assuming ART efficacy in preventing HIV transmission to partners of 96%	1. Increase to 50%
b) Increasing condom use coverage	2. Increase to 50%
c) Expanding VMMC coverage in clients (only applicable to South Sudan)	3. Increase to 50%
d) Expanding PrEP coverage in FSWs	4. Increase to 25%
7. Most optimistic scenario	
a) Expanding ART coverage in FSWs assuming ART efficacy in preventing HIV transmission to partners of 96%	1. Increase to 81%
b) Increasing condom use coverage	2. Increase to 80%
c) Expanding VMMC in clients (only applicable to South Sudan)	3. Increase to 80%
d) Expanding PrEP coverage in FSWs	4. Increase to 50%

Abbreviations: ART: antiretroviral therapy; FSWs: female sex workers; PrEP: pre-exposure prophylaxis; VMMC: voluntary medical male circumcision.

Table 5: Estimates of the number and proportion of HIV infections averted over 10 years by increasing the coverage of select interventions among FSWs in MENA. This table includes results for countries with no significant injecting drug use among FSWs. Baseline coverage was used whenever it was higher than that set in the investigated scenario.

Countries	**Algeria**			**Djibouti**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**1,905**	**2,504**	**1,809**	**234**	**308**	**229**
Infections averted[*] by prevention intervention scenario- N (%)						
ART in FSWs (eART: 0.57)						
Increasing coverage to 25%	NA	NA	NA	NA	NA	NA
Increasing coverage to 50%	118 (6.2)	338 (13.5)	110 (6.1)	20 (8.4)	47 (15.4)	17 (7.4)
Increasing coverage to 81%	429 (22.5)	1,017 (40.6)	403 (22.3)	49 (21.1)	121 (39.4)	46 (20.1)
ART in FSWs (eART: 0.96)						
Increasing coverage to 25%	NA	NA	NA	NA	NA	NA
Increasing coverage to 50%	731 (38.4)	1,193 (47.6)	489 (27.0)	82 (35.1)	144 (46.8)	56 (24.5)
Increasing coverage to 81%	1,050 (55.1)	2,010 (80.3)	826 (45.7)	121 (51.9)	244 (79.2)	98 (42.8)
Condom use (eCondom: 0.80)						
Increasing use to 50%	NA	NA	NA	NA	NA	NA
Increasing use to 80%	732 (38.4)	963 (38.5)	348 (19.2)	113 (48.3)	148 (47.9)	59 (25.8)
VMMC (eVMMC: 0.58)						
Increasing coverage to 50%	NA	NA	NA	NA	NA	NA
Increasing coverage to 80%	NA	NA	NA	NA	NA	NA
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	348 (18.3)	251 (10.0)	107 (5.9)	25 (10.5)	6 (2.0)	-3 (-1.3)
Increasing coverage to 50%	556 (29.2)	330 (13.2)	89 (4.9)	68 (29.0)	42 (13.7)	12 (5.2)
Intervention packages						
Moderately optimistic scenario[†]	948 (49.8)	1,338 (53.4)	569 (31.5)	99 (42.3)	146 (47.5)	52 (22.7)
Most optimistic scenario[‡]	1,457 (76.5)	2,188 (87.4)	912 (50.4)	180 (77.2)	273 (88.4)	110 (48.0)
Countries	**Morocco**			**Somalia**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**853**	**1,062**	**617**	**953**	**1,161**	**866**
Infections averted[*] by prevention intervention scenario- N (%)						
ART in FSWs (eART: 0.57)						
Increasing coverage to 25%	NA	NA	NA	NA	NA	NA
Increasing coverage to 50%	NA	NA	NA	93 (9.8)	207 (17.8)	76 (8.8)
Increasing coverage to 81%	136 (15.9)	265 (24.9)	83 (13.5)	200 (21.0)	474 (40.8)	180 (20.8)
ART in FSWs (eART: 0.96)						
Increasing coverage to 25%	NA	NA	NA	NA	NA	NA
Increasing coverage to 50%	NA	NA	NA	345 (36.2)	557 (48.0)	218 (25.2)
Increasing coverage to 81%	538 (63.1)	824 (77.6)	267 (43.3)	519 (54.5)	935 (80.6)	405 (46.8)
Condom use (eCondom: 0.80)						
Increasing use to 50%	NA	NA	NA	278 (29.1)	334 (28.8)	105 (12.1)
Increasing use to 80%	489 (57.3)	590 (55.6)	193 (31.3)	649 (68.2)	777 (66.9)	287 (33.1)
VMMC (eVMMC: 0.58)						
Increasing coverage to 50%	NA	NA	NA	NA	NA	NA
Increasing coverage to 80%	NA	NA	NA	NA	NA	NA
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	138 (16.2)	57 (5.4)	2 (0.3)	121 (12.6)	44 (3.8)	-1 (-0.1)
Increasing coverage to 50%	325 (38.1)	235 (22.1)	80 (13.0)	235 (24.7)	102 (8.8)	9 (1.0)
Intervention packages						
Moderately optimistic scenario[†]	520 (61.0)	599 (56.4)	217 (35.2)	577 (60.5)	759 (65.3)	303 (35.0)
Most optimistic scenario[‡]	719 (84.3)	934 (88.0)	293 (47.5)	808 (84.8)	1,075 (92.5)	434 (50.1)
Countries	**South Sudan**			**Sudan**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**24,020**	**53,445**	**41,112**	**1,824**	**2,062**	**1,690**

Infections averted* by prevention intervention scenario- N (%)						
ART in FSWs (eART: 0.57)						
Increasing coverage to 25%	964 (4.0)	5,188 (9.7)	2,073 (5.0)	1 (0.04)	51 (2.5)	-16 (-1.0)
Increasing coverage to 50%	2,714 (11.3)	14,151 (26.5)	5,799 (14.1)	339 (18.6)	583 (28.3)	248 (14.7)
Increasing coverage to 81%	5,006 (20.8)	24,367 (45.6)	9,936 (24.2)	453 (24.8)	928 (45.0)	351 (20.8)
ART in FSWs (eART: 0.96)						
Increasing coverage to 25%	3,491 (14.5)	12,418 (23.2)	4,985 (12.1)	474 (26.0)	615 (29.8)	311 (18.4)
Increasing coverage to 50%	6,401 (26.6)	26,315 (49.2)	10,797 (26.3)	891 (48.8)	1,257 (61.0)	698 (41.3)
Increasing coverage to 81%	10,476 (43.6)	42,507 (79.5)	17,745 (43.2)	919 (50.4)	1,673 (81.1)	757 (44.8)
Condom use (eCondom: 0.80)						
Increasing use to 50%	NA	NA	NA	747 (40.9)	809 (39.2)	331 (19.6)
Increasing use to 80%	4,600 (19.2)	11,178 (20.9)	4,372 (10.6)	1,359 (74.5)	1,501 (72.8)	710 (42.0)
VMMC (eVMMC: 0.58)						
Increasing coverage to 50%	1,959 (8.2)	10,331 (19.3)	4,235 (10.3)	NA	NA	NA
Increasing coverage to 80%	4,422 (18.4)	21,626 (40.5)	8,904 (21.7)	NA	NA	NA
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	2,796 (11.6)	3,038 (5.7)	1,042 (2.5)	294 (16.1)	172 (8.3)	54 (3.2)
Increasing coverage to 50%	5,715 (23.8)	6,238 (11.7)	2,134 (5.2)	557 (30.5)	290 (14.1)	118 (7.0)
Intervention packages						
Moderately optimistic scenario†	9,604 (40.0)	32,672 (61.1)	13,302 (32.4)	1,131 (62.0)	1,428 (69.2)	625 (37.0)
Most optimistic scenario‡	16,084 (67.0)	48,583 (90.9)	20,591 (50.1)	1,556 (85.3)	1,924 (93.3)	867 (51.3)
Countries	**Tunisia**			**Yemen**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**210**	**261**	**189**	**257**	**302**	**265**
Infections averted* by prevention intervention scenario- N (%)						
ART in FSWs (eART: 0.57)						
Increasing coverage to 25%	NA	NA	NA	48 (18.7)	54 (17.8)	43 (16.2)
Increasing coverage to 50%	4 (2.0)	27 (10.3)	1 (0.5)	45 (17.6)	81 (26.7)	37 (14.0)
Increasing coverage to 81%	6 (2.9)	67 (25.8)	3 (1.6)	62 (24.1)	126 (41.8)	63 (23.8)
ART in FSWs (eART: 0.96)						
Increasing coverage to 25%	NA	NA	NA	69 (26.7)	82 (27.3)	55 (20.8)
Increasing coverage to 50%	77 (36.8)	120 (46.1)	40 (21.2)	85 (33.1)	151 (49.9)	76 (28.7)
Increasing coverage to 81%	106 (50.3)	205 (78.4)	77 (40.7)	128 (49.7)	240 (79.5)	110 (41.5)
Condom use (eCondom: 0.80)						
Increasing use to 50%	NA	NA	NA	68 (26.5)	77 (25.6)	49 (18.5)
Increasing use to 80%	98 (46.4)	119 (45.4)	37 (19.6)	178 (69.4)	208 (69.1)	120 (45.3)
VMMC (eVMMC: 0.58)						
Increasing coverage to 50%	NA	NA	NA	NA	NA	NA
Increasing coverage to 80%	NA	NA	NA	NA	NA	NA
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	24 (11.2)	-2 (-0.8)	-14 (-7.4)	57 (22.0)	50 (16.6)	25 (9.4)
Increasing coverage to 50%	57 (27.0)	24 (9.0)	-3 (-1.6)	133 (51.8)	122 (40.4)	86 (32.5)
Intervention packages						
Moderately optimistic scenario†	92 (43.8)	129 (49.5)	44 (23.3)	139 (53.9)	180 (59.5)	92 (34.7)
Most optimistic scenario‡	164 (78.0)	232 (88.8)	91 (48.1)	214 (83.3)	276 (91.6)	140 (52.8)

Abbreviations: ART: antiretroviral therapy; FSWs: female sex workers; e: effectiveness; NA: not applicable; PrEP: pre-exposure prophylaxis; VMMC: voluntary medical male circumcision.

*Estimates for the number of averted infections have been rounded to the nearest digit and may not exactly match the corresponding proportion of averted infections.

†Includes expanding ART coverage to 50% with efficacy in preventing HIV transmission to partners of 96%, increasing condom use to 50%, and increasing PrEP to 25%. Baseline coverage was used whenever it was higher than that set in the investigated scenario. For South Sudan only, this package also included increasing VMMC to 50%.

‡Includes expanding interventions to the highest modelled coverage levels including expanding ART coverage to 81% with efficacy of 96%, increasing condom use to 80%, and increasing PrEP to 50%. For South Sudan only, this package also included increasing VMMC to 80%.

Table 6: Estimates of numbers and proportions of HIV infections averted over 10 years by increasing the coverage of select interventions among FSWs in MENA. This table includes results for countries with significant injecting drug use among FSWs. Baseline coverage was used whenever it was higher than that set in the investigated scenario.

Countries	**Bahrain**			**Iran**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**11**	**4**	**2**	**1,748**	**1,710**	**669**
Infections averted[*] by prevention intervention scenario- N (%)						
ART in FSWs & PWID partners (eART: 0.57)						
Increasing coverage to 25%	NA	NA	NA	19 (1.1)	36 (2.1)	1 (0.1)
Increasing coverage to 50%	<1 (4.5)	<1 (6.9)	<1 (4.4)	261 (14.9)	408 (23.9)	74 (11.1)
Increasing coverage to 81%	3 (25.4)	2 (39.3)	<1 (20.7)	556 (31.8)	838 (49.0)	180 (26.9)
ART in FSWs & PWID partners (eART: 0.96)						
Increasing coverage to 25%	NA	NA	NA	273 (15.6)	304 (17.8)	49 (7.3)
Increasing coverage to 50%	3 (29.3)	2 (42.8)	<1 (24.3)	664 (38.0)	879 (51.4)	181 (27.1)
Increasing coverage to 81%	7 (66.6)	3 (81.6)	1 (50.0)	989 (56.6)	1,403 (82.1)	287 (42.9)
Condom use (eCondom: 0.80)						
Increasing use to 50%	<1 (3.9)	<1 (7.4)	<1 (2.6)	NA	NA	NA
Increasing use to 80%	1 (9.8)	2 (47.9)	1 (27.8)	532 (30.5)	711 (41.6)	133 (19.9)
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	1 (11.4)	<1 (6.7)	<1 (1.7)	206 (11.8)	48 (2.8)	-13 (-1.9)
Increasing coverage to 50%	3 (24.4)	<1 (11.1)	<1 (5.3)	496 (28.4)	258 (15.1)	35 (5.2)
Intervention packages						
Moderately optimistic scenario[†]	4 (38.1)	2 (46.7)	<1 (23.7)	820 (46.9)	946 (55.3)	201 (30.0)
Most optimistic scenario[‡]	9 (76.6)	4 (91.1)	1 (52.2)	1,368 (78.2)	1,545 (90.4)	325 (48.6)
Countries	**Libya**			**Pakistan**		
	In FSWs	**In clients**	**In client spouses**	**In FSWs**	**In clients**	**In client spouses**
Cumulative incidence 2020-2030	**295**	**340**	**115**	**3,162**	**3,055**	**1,183**
Infections averted[*] by prevention intervention scenario- N (%)						
ART in FSWs & PWID partners (eART: 0.57)						
Increasing coverage to 25%	NA	NA	NA	204 (6.5)	392 (12.8)	53 (4.5)
Increasing coverage to 50%	11 (3.6)	15 (4.5)	2 (1.7)	634 (20.1)	1,019 (33.4)	232 (19.6)
Increasing coverage to 81%	52 (17.6)	112 (32.9)	20 (17.4)	961 (30.4)	1,579 (51.7)	318 (26.9)
ART in FSWs & PWID partners (eART: 0.96)						
Increasing coverage to 25%	NA	NA	NA	492 (15.6)	792 (25.9)	160 (13.5)
Increasing coverage to 50%	100 (34.0)	140 (41.3)	23 (20.0)	1,066 (33.7)	1,609 (52.7)	303 (25.6)
Increasing coverage to 81%	172 (58.3)	268 (78.9)	49 (42.6)	1,820 (57.6)	2,538 (83.1)	568 (48.0)
Condom use (eCondom: 0.80)						
Increasing use to 50%	NA	NA	NA	NA	NA	NA
Increasing use to 80%	NA	NA	NA	1,257 (39.8)	1,541 (50.4)	326 (27.6)
PrEP in FSWs (ePrEP: 0.51)						
Increasing coverage to 25%	36 (12.1)	14 (4.1)	1 (0.9)	501 (15.8)	306 (10.0)	76 (6.4)
Increasing coverage to 50%	75 (25.3)	35 (10.2)	4 (3.5)	908 (28.7)	525 (17.2)	110 (9.3)
Intervention packages						
Moderately optimistic scenario[†]	128 (43.3)	153 (44.9)	26 (22.6)	1,457 (46.1)	1,804 (59.0)	393 (33.2)
Most optimistic scenario[‡]	202 (68.6)	274 (80.5)	51 (44.3)	2,514 (79.5)	2,820 (92.3)	628 (53.1)

Abbreviations: ART: antiretroviral therapy; FSWs: female sex workers; e: effectiveness; NA: not applicable; PrEP: pre-exposure prophylaxis; PWID: people who inject drugs.

[*]Estimates for the number of averted infections have been rounded to the nearest digit and may not exactly match the corresponding proportion of averted infections.

[†]Includes expanding ART coverage to 50% with efficacy in preventing HIV transmission to partners of 96%, increasing condom use to 50%, and increasing PrEP to 25%. Baseline coverage was used whenever it was higher than that set in the investigated scenario.

[‡]Includes expanding interventions to the highest modelled coverage levels including expanding, ART coverage to 81% with efficacy of 96%, increasing condom use to 80%, and increasing PrEP to 50%.

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2. Summary of findings

The study estimated HIV incidence and related epidemiological measures in HSWNs of 12 of the 23 MENA countries that had sufficient input data to feasibly simulate the HIV epidemic in HSWNs. HSWNs were identified as a major source of incidence, contributing at least 25% of all HIV incidence in MENA. Although HSWNs' contribution to incidence varied across countries depending on the HIV epidemic phase, the large size of these networks resulted in substantial incidence even in countries with low HIV prevalence among FSWs. Two-thirds of this incidence was equally divided between clients and their spouses suggesting that HSWNs are an important driver of HIV incidence among general population women in this region. The study further demonstrated that expanding coverage of treatment and prevention interventions among FSWs alone can substantially reduce HIV incidence among clients and client spouses, and that even a moderate package of combination prevention interventions targeting only FSWs could avert ~60% of new HIV infections among them and their clients. The study findings provide a basis to empower advocacy for strengthening HIV programming targeting FSWs, in line with UNAIDS recently endorsed strategy for achieving the HIV elimination goal [3, 4]. Findings also stress the need for expanding HIV surveillance among FSWs to monitor the HIV epidemic and progress towards global targets.

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CHAPTER 7. DISCUSSION

In this chapter, I discuss the key findings from the thesis which have extended our understanding of the epidemiology of HIV among FSWs, their clients, and client spouses in the MENA region. This discussion aims to integrate the different findings of each of the studies completed in this thesis to build a coherent and broad understanding of the epidemiology of HIV infection in HSWNs in MENA.

1. A pattern of emerging HIV epidemics among FSWs and clients but still limited transmission in half of HSWNs

A key finding is identifying patterns of emerging HIV epidemics among FSWs and clients in several MENA countries, some of which are still at low to intermediate intensity while others are already established at high incidence (research paper 1; [1]). A related finding is the trend of growing HIV prevalence among FSWs over the last two decades with increasing prevalence odds of infection of about 15% per year (research paper 1; [1]). The emerging epidemics among FSWs and clients in MENA have often been preceded by large epidemics among PWID [2] and MSM [3], suggesting recent bridging of the infection from these key populations to HSWNs.

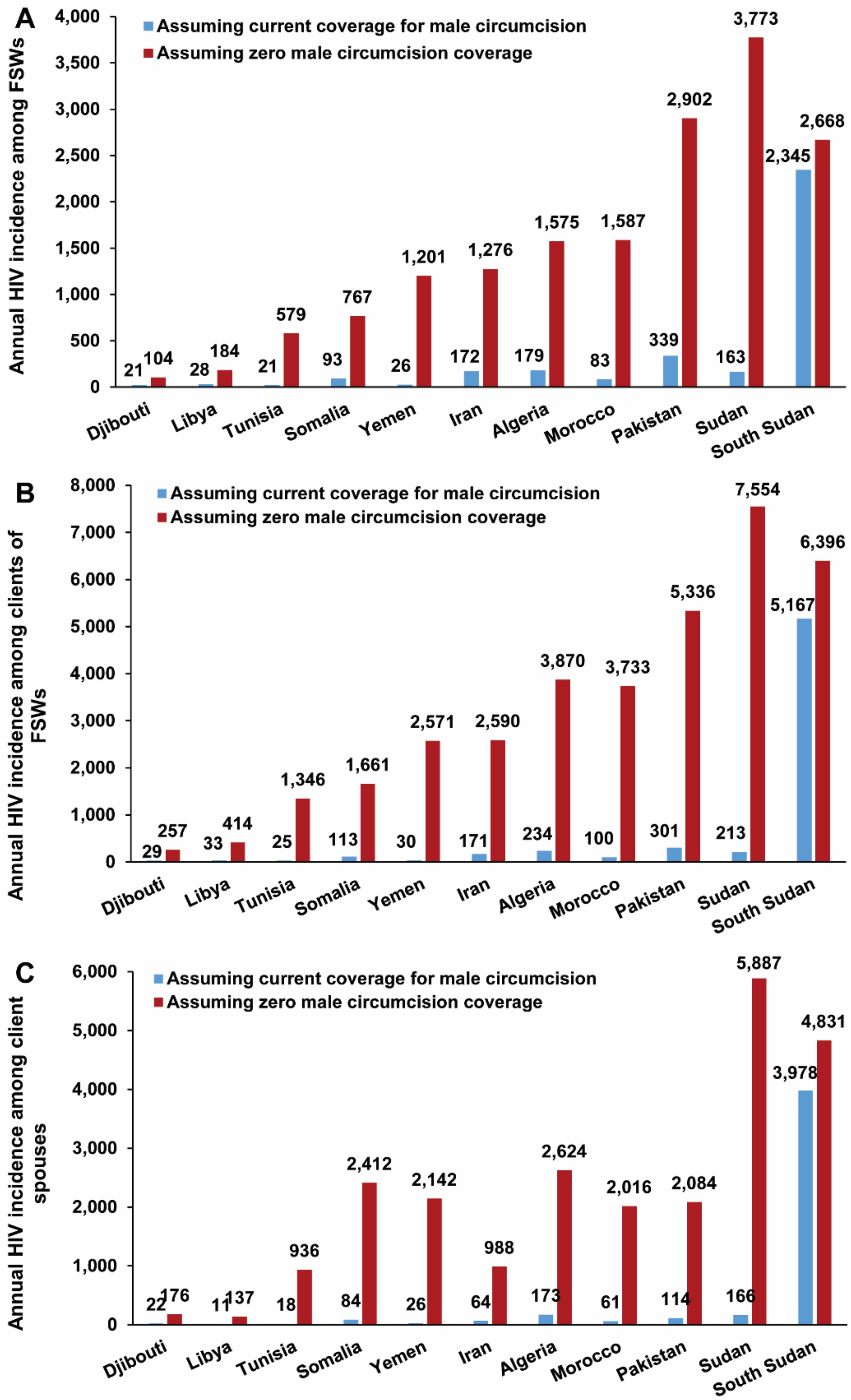
This being said, and although HIV has been circulating in the region for few decades, the infection is still not established in many HSWNs. Nearly half of the studies (46.8%) among FSWs reported zero HIV prevalence, and seven out of 18 countries with data had zero or nearly zero pooled mean HIV prevalence among FSWs (research paper 1; [1]). Possible explanations for this are that i) HIV has not yet been effectively introduced or bridged to many of these networks, ii) networks' structure is characterized by low connectivity and thus not conducive for sustainable HIV transmission, iii) the risk environment, in terms of number of partners, lack of condom use, sex with PWID, and injecting drug use, is not conducive enough for sustainable HIV transmission (research paper 1; [1]), and/or iv) male circumcision had an important impact in reducing HIV heterosexual transmission.

2. A critical role for male circumcision in limiting HIV transmission in MENA

With an RCT-demonstrated effectiveness of ~60% [4-7] and long-term observed effectiveness of ~70% [8, 9] against heterosexual HIV acquisition, male circumcision, which is at universal coverage in nearly all MENA countries, has been a critical factor in limiting HIV transmission in HSWNs. An illustration of the effect of male circumcision can be seen in Figure 1. This figure compares HIV incidence as estimated in research paper 4 [10], that is at current universal coverage for male circumcision in all countries except in South Sudan where the coverage is low at 23.6% [11], to HIV incidence estimated by the model of research paper 4, but applying an extreme counter-factual scenario that assumes zero male circumcision in all countries.

The reduction in incidence due to male circumcision exceeded the 60-70% reduction expected assuming the direct reduction in HIV acquisition among clients of FSWs. In addition to the direct protection among male clients, FSWs and client spouses also benefited indirectly from the reduced onward transmission, in line with findings of other observational [12-14] and mathematical modelling studies [15, 16]. The combined direct and indirect effects of male circumcision indicate an important role for this biological cofactor in curtailing the sustainability of HIV transmission chains in HSWNs in MENA. This is further demonstrated in the singular nature of the epidemiology of HIV in the HSWNs of South Sudan, the only MENA country at low male circumcision coverage (23.6% [11]; research paper 4; [10]).

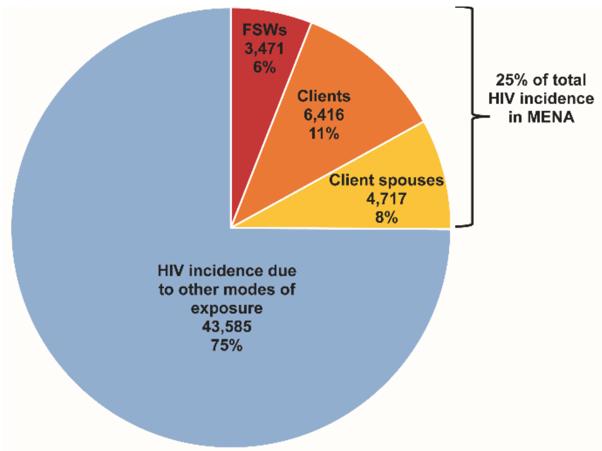
Figure 1. Estimates of annual HIV incidence in A) FSWs, B) clients, and C) client spouses at current coverage of male circumcision versus corresponding estimated HIV incidence in a counter-factual scenario of zero coverage of male circumcision. Estimates represent the mean across 500 simulation runs of the individual-based model.



3. A sizable contribution of HSWNs to total HIV incidence

The results in the thesis indicate that HIV incidence in HSWNs contributes a quarter of the annual HIV incidence occurring in MENA (Figure 2). This is a conservative estimate considering that incidence in HSWNs could be estimated for only 12 of the 23 MENA countries (research paper 4; [10]) and that zero incidence was assumed for the remaining countries with no data or with HIV prevalence in FSWs of <0.5%. In the 12 assessed countries combined, HSWNs account for a third of total HIV incidence (research paper 4; [10]).

Figure 2. Distribution of HIV incidence across MENA

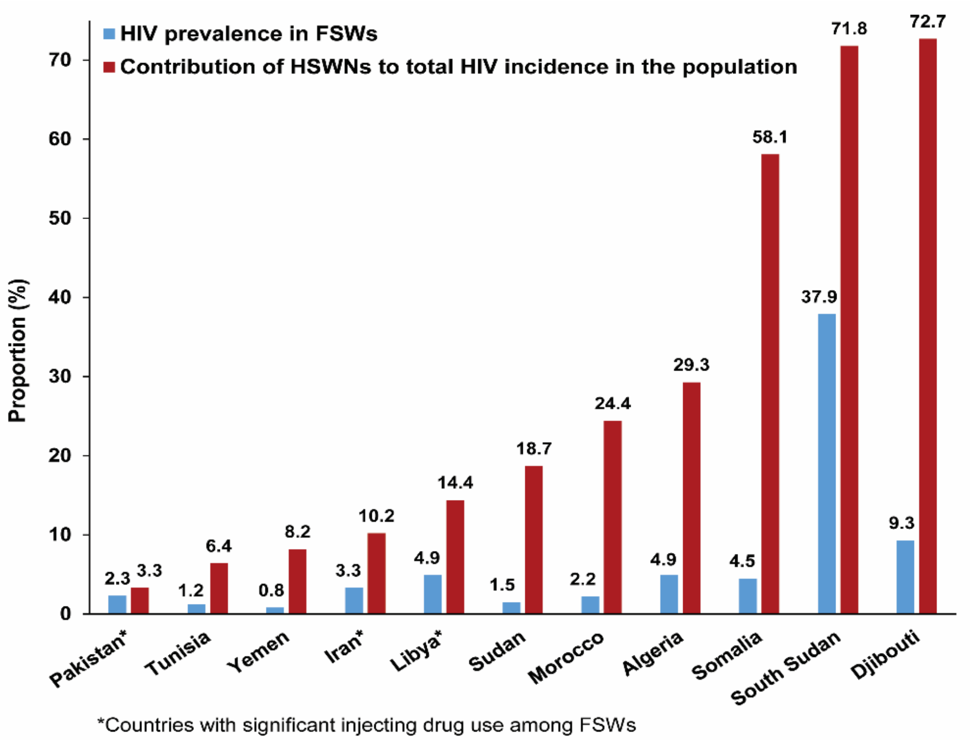


In several of these countries, such as Morocco, Sudan, and Yemen, the large size of these networks translated into substantial HIV incidence, and thus a sizable contribution to total incidence in the population ranging from 8.2% to 24.4%, even when HIV prevalence among FSWs was low in the range of 0.8% to 2.2% (Figure 3; research paper 4; [10]).

However, with an estimated 14,600 incident infections annually, HSWNs in MENA still contribute only about 1% to total HIV incidence worldwide (research paper 4; [10]). This is mainly because, except for Djibouti and South Sudan where the epidemic is established at a high level, many of the epidemics among FSWs in the region have only emerged within the last two decades and are mostly of low to intermediate intensity (prevalence among FSWs <5%)

(research paper 1; [1]). Growth in HIV incidence remains slow as HIV prevalence among FSWs and clients remains low (research paper 1; [1])

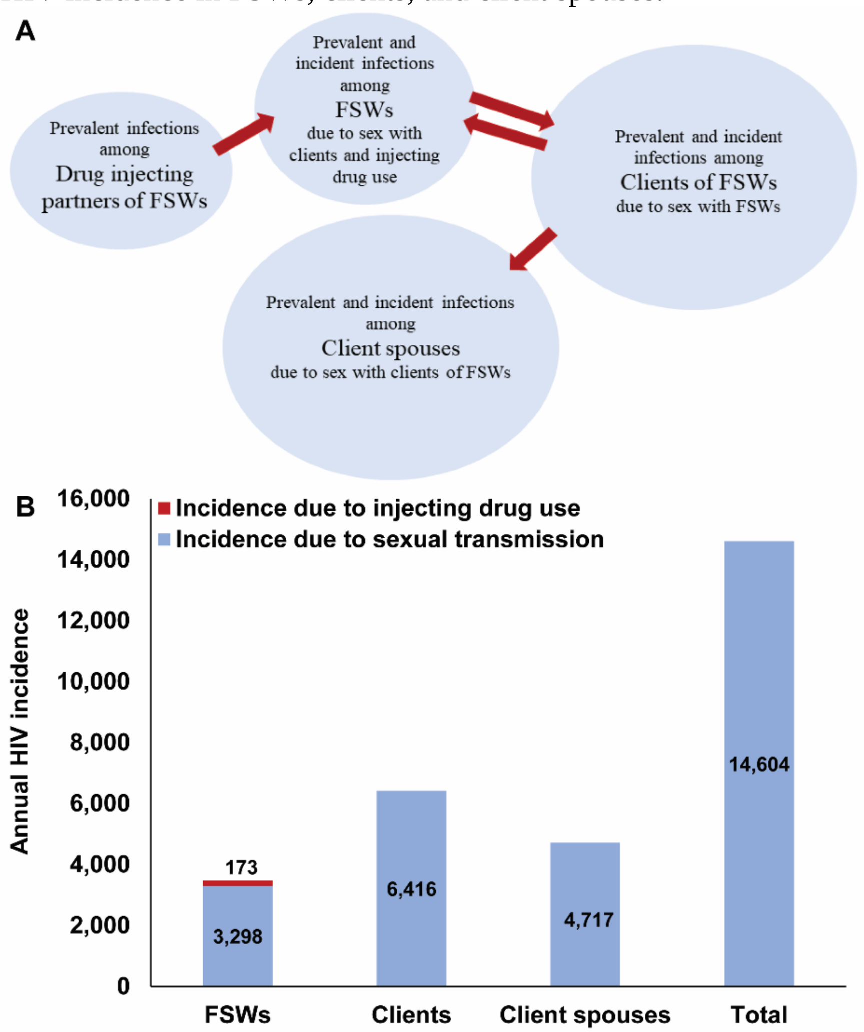
Figure 3. Contribution of heterosexual sex work networks (HSWNs) to total HIV incidence in MENA countries for which HIV transmission dynamics in HSWNs could be modelled and simulated [10].



4. **Most of HIV incidence in HSWNs does not occur among FSWs, but among clients and client spouses**

Figure 4 illustrates HIV transmission dynamics in HSWNs in MENA. FSWs mostly acquire HIV through sexual transmission rather than injecting drug use; the latter contributes only 5% of new HIV infections among FSWs (research paper 4; [10]). Meanwhile, with the large size of the client population and most of them being susceptible to the infection (HIV prevalence among clients is only 25% of that among FSWs (research papers 1 & 4; [1, 10])), prevalent infections among FSWs result in substantial incidence among clients, which in turn translates into substantial incidence among client spouses who are also largely susceptible. Indeed, two-thirds of HIV incidence in HSWNs occur among clients and their spouses, both being roughly equally affected (research paper 4; [10]). Consequently, a large proportion of incidence identified among general population women in MENA is perhaps a spill-over of HIV circulation in HSWNs. This finding is in line with evidence indicating that having an HIV positive spouse is the main source of infection in the vast majority of diagnosed HIV infections among general population women in MENA [17-23].

Figure 4. Dynamics of HIV transmission in HSWNs in MENA described using A) a conceptual diagram illustrating the flow of HIV transmission in these networks and B) the estimated annual HIV incidence in FSWs, clients, and client spouses.



Despite the substantial HIV incidence among clients and their spouses, this incidence is less likely to be detected compared to incidence among FSWs, as FSWs are more likely to be targeted by HIV testing and prevention programs than clients or their spouses [1, 17, 24].

5. HIV epidemic potential in HSWNs remains uncertain

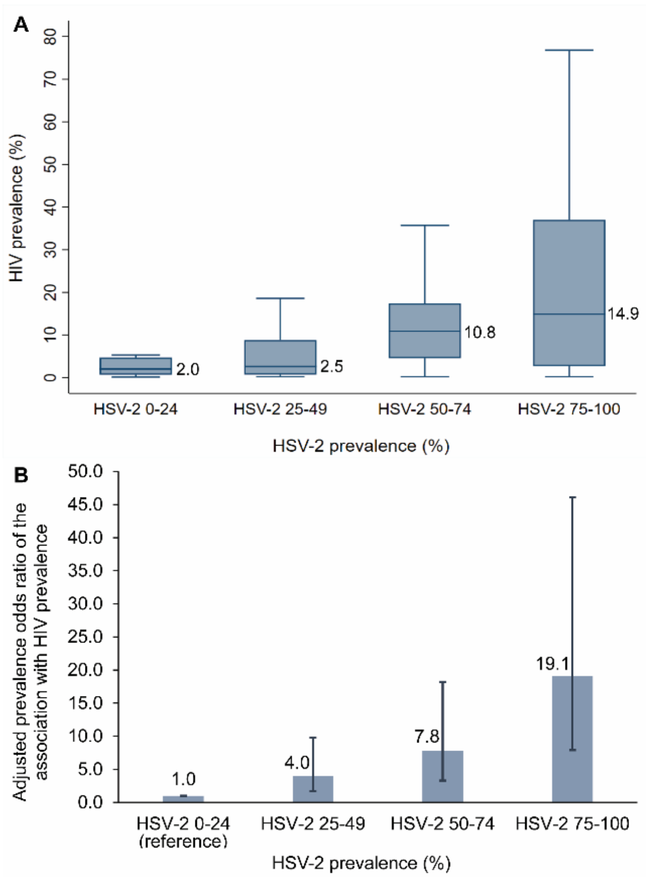
While the pattern of emerging HIV epidemics in HSWNs suggests significant potential for further epidemic growth as well as expansion into new HSWNs not yet affected by HIV, this potential cannot be ascertained with certainty. Findings of research paper 1 showed that FSWs generally have a considerable number of sexual partners with close to half of sexual acts being unprotected by condom use, suggestive of a high-risk environment in a large proportion of FSW populations. Yet, half of HSWNs still do not appear to be affected by HIV (research paper 1; [1]).

Will HIV epidemics in HSWNs grow substantially in the future? While possible, this may not necessarily materialise in many HSWNs. With the almost universal coverage of male circumcision in the region (Figure 1) and little evidence of high connectivity in the sexual networks [17, 25, 26], the potential for large HIV epidemics may be limited. It is therefore not evident that MENA will experience in the future the kind of large HIV epidemics in HSWNs that have been seen in other global regions [27]. MENA's HIV experience is rather comparable to that of West Africa where early evidence demonstrated a role for the universal coverage of male circumcision and lack of ulcerative STIs such as HSV-2 and syphilis in limiting HIV spread [28]. In this part of Africa, HIV has always been below 5% in the general population, even before ART availability, in contrast to prevalence exceeding 25% in the general population in East Africa where male circumcision is limited [29].

One approach to assess HIV epidemic potential is through the use of other STIs as proxy biomarkers of HIV epidemic potential [30]. HSV-2 in particular has been demonstrated as an effective proxy for HIV epidemic potential in HSWNs, as a consequence of a strong ecological association between HIV prevalence and HSV-2 prevalence among FSWs (research paper 3; [30]). Indeed, findings of research paper 3 showed an increasing trend of HIV prevalence with increasing HSV-2 prevalence (Figure 5A). After adjustment for regional, temporal, and behavioural (consistent condom use) differences among FSWs, there was an evident ecological association between HIV prevalence and HSV-2 prevalence, with higher HIV prevalence significantly associated with higher HSV-2 prevalence (Figure 5B).

Unfortunately, the systematic review of STIs presented in research paper 2 identified only three paired HSV-2-HIV prevalence measures [31], too few to statistically power an analysis that can predict HIV epidemic potential among FSWs in MENA. All three studies also reported zero HIV prevalence. Of these studies, two reported surprisingly lower HSV-2 prevalence among FSWs than seen elsewhere [32, 33], assessed at 4.7% [34] in Abbottabad and 8.0% [34] in Rawalpindi, Pakistan, while the third study reported an HSV-2 prevalence of 55.5% among FSWs attending sexual health clinics in Gabes, Sousse, and Tunis in Tunisia [35]. Incorporating HSV-2 surveillance in HIV surveillance efforts is an important step towards gaining a better understanding of HIV epidemic potential in the region.

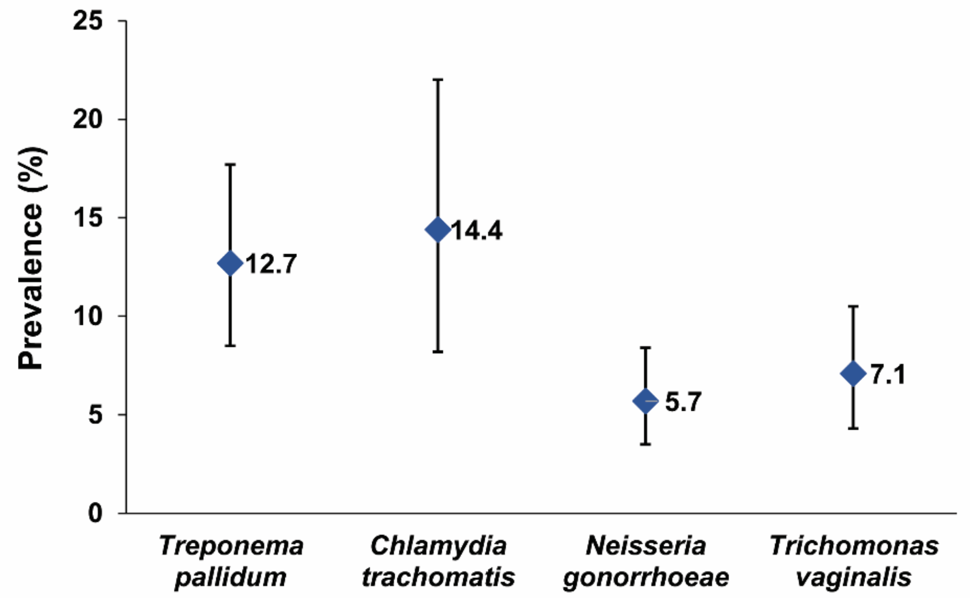
Figure 5. A) HIV prevalence across levels of HSV-2 prevalence among FSWs described through boxplots illustrating the trend in HIV prevalence with increasing HSV-2 prevalence (boxplots' centre lines indicate the median HIV prevalence, box limits indicate the 25% and 75% quartiles, and whiskers indicate maximum and minimum observations within 1.5 of interquartile range). B) The ecological association between HIV prevalence and HSV-2 prevalence after adjustment for regional, temporal, and behavioural (consistent condom use) differences among FSWs expressed in terms of adjusted odds ratios through meta-regression analyses (excluding the African Region).



6. Neglected burden of STIs among FSWs, clients, and client spouses

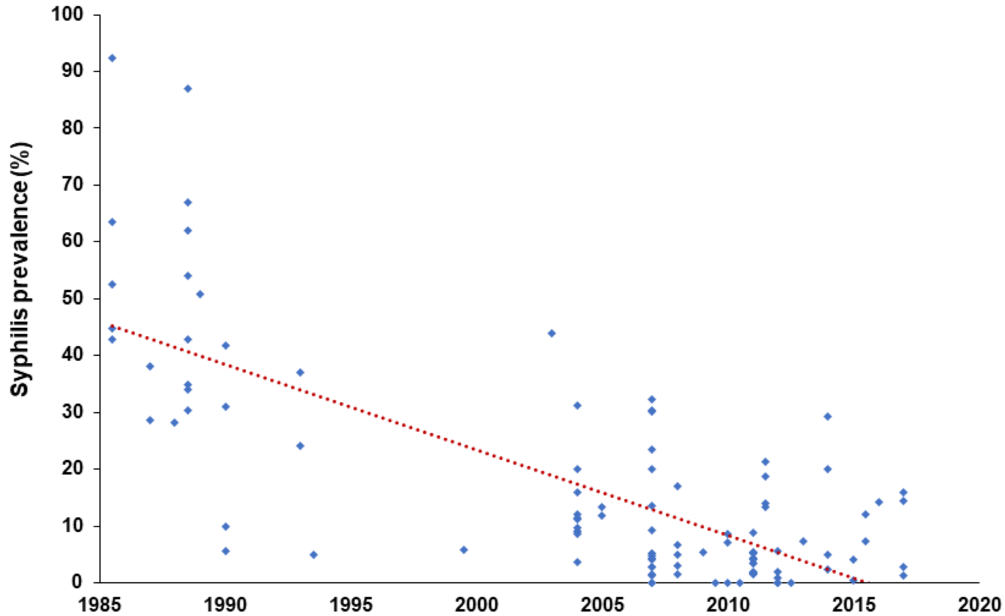
The burden of STIs among FSWs, clients and client spouses in this region continues to be poorly assessed and monitored, more so than HIV. Only 144 prevalence measures among FSWs were identified for syphilis, *C. trachomatis*, *N. gonorrhoeae*, *T. vaginalis*, and HSV-2 combined (research paper 2), compared with 485 prevalence measures for HIV (research paper 1). HIV surveillance efforts in MENA, such as through IBBSS, rarely incorporate an assessment of STIs [31], highlighting a missed opportunity for STI surveillance and prevention despite considerable infection levels (Figure 6; research paper 2; [31]). Similar to HIV (research paper 4; [10]), STI infection levels among FSWs may also translate into sizable infection levels and STI-related morbidity among clients and client spouses [17, 36, 37], but this disease burden remains largely neglected and poorly characterized [31].

Figure 6. Prevalence of curable STIs among FSWs in MENA.



This being said, research paper 2 showed declining levels of syphilis among FSWs at a rate of 7% per year (Figure 7), smaller than, the 16% decline observed among the general population in MENA [38], and the 17% annual decline needed to achieve the global target of 90% reduction in syphilis by 2030 [39]. Though still unclear, several factors may have contributed to syphilis decline among FSWs such as "safer sex" practices out of concern about HIV acquisition [40] or unwanted pregnancy [1], higher HIV-related mortality in populations with higher STI burden [41], early detection and treatment of syphilis possibly because of improvements in infection diagnostics [42, 43], and the widespread use of antibiotics (including for non-STI infections, which sometimes cure concurrent syphilis) [38]. The latter has raised global concern over HSWNs becoming a main setting for emergence of antimicrobial resistance, particularly for *N. gonorrhoeae*, given the prevalent use of STI syndromic management and presumptive treatment [44-49], instead of etiological diagnosis and treatment, and adoption of prevention measures to avert infection transmission such as condom use [44, 50, 51].

Figure 7. Temporal trend in syphilis prevalence among FSWs in MENA over the last three decades.



7. HIV response is lagging behind, but interventions have much potential for reducing HIV incidence

Although a large proportion of incident infections arise in HSWNs, HIV response remains far from reaching optimal levels [24]. The region ranks lowest globally on several indicators for HIV response such as coverage for HIV testing, linkage to care, and sustained viral suppression in PLHIV [27, 52]. MENA is also far from achieving global targets for HIV testing and linkage to care among FSWs [53]. Research paper 1 indicated that only 18% of FSWs in the region reported ever testing for HIV [1]. The proportion of FSWs testing in the past 12 months is even lower, at 12% (research paper 1; [1]), far below the 90% target of the 'UNAIDS 2016-2021 Strategy' [53], and the 95% target of the 'UNAIDS 2021-2026 Strategy' [54]. There is hardly any data on linkage to care among HIV-positive FSWs in MENA [10], but only 43% of PLHIV in MENA are on ART, which is the lowest coverage globally [52]. In 2020, MENA still has not achieved the WHO regional target of 50% coverage which was set to be reached in the year 2015

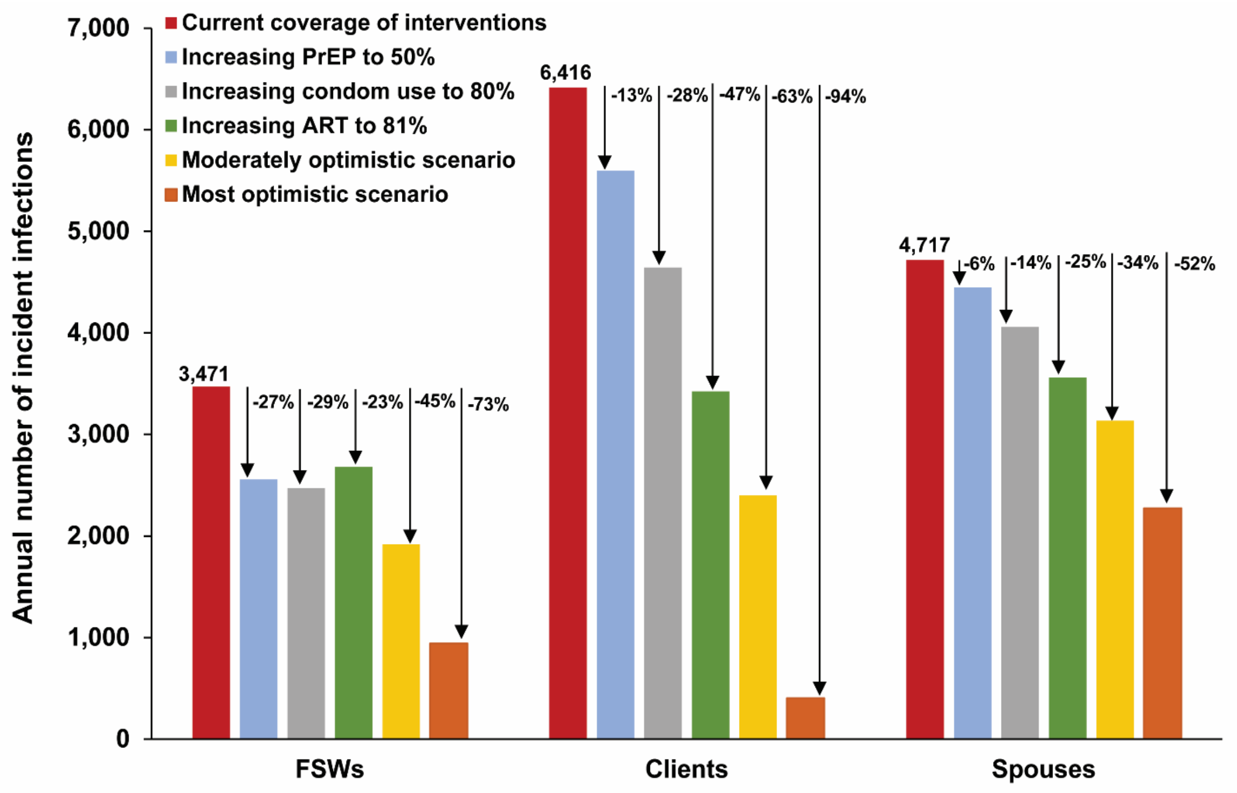
(Figure 2B in Chapter 1) [55]. No data could be identified on viral suppression among HIV-positive FSWs with access to care, but only 37% of PLHIV are virally suppressed [52]. With such poor performance on HIV response indicators, MENA is unlikely to fulfil the Sustainable Development Goal (SDG) target of ending the AIDS epidemic by 2030 [56, 57].

The situation may have worsened with the advent of COVID-19 due to interruptions in the provision of prevention and treatment services [58]. Although no data could be located for MENA, preliminary reports from 86 countries globally indicated 40% disruption in the delivery of HIV services to FSWs between March-June 2020, mainly due to facilities and road closures [27, 59]. More generally, the latest UNAIDS update reported a decline of 41% in HIV testing and of 37% in treatment uptake among PLHIV in 32 African and Asian countries during lockdowns, a 16% decline in PrEP prescriptions in the US, and 31% and 40% decline in PrEP initiation in the US and South Africa, respectively [52]. A time-series analysis of data from 65 primary care clinics in South Africa further indicated a 47.6% decrease in use of HIV testing services and a 46.2% decrease in ART initiation in PLHIV during the lockdown [60]. There was also evidence for FSWs refraining from seeking HIV prevention and treatment services out of fear of contracting COVID-19 at a health facility [59]. Disruptions were exacerbated by political decisions to shift resources towards control of COVID-19 [61]. For example, in South Africa, 28,000 HIV community healthcare workers were re-allocated to COVID-19 testing and care [52].

Lockdowns also affected delivery of essential sexual and reproductive health services [62] including supply chains of condoms [63, 64]. In Kenya, a survey among FSWs revealed that 65% had no access to condoms and HIV medications during COVID-19 lockdown [65]. Limited social and economic protection schemes were available for FSWs to alleviate financial hardship during the pandemic [59, 62, 66]. The latter increased FSWs' risk of homelessness due to defaults in rental payments [59, 62, 66], and therefore their willingness to engage in riskier sexual practices to raise income [59]. Evidence from Zimbabwe pointed to a lower ability for FSWs to negotiate safer sex and a higher likelihood for exchanging sex for food during the pandemic given the decline in the number of clients [67]. Despite introduction of alternative modes of delivery for HIV testing and medications, as well as use of telemedicine, coverage remains unknown given FSWs' mobility, fear of being identified by local authorities, and poor access to advanced technological solutions [52, 68].

Even before the COVID-19 pandemic, only half of sexual acts between FSWs and clients in MENA were protected by condom use (research paper 1; [1]). Research paper 4 shows that increasing coverage of condom use to 80% can alone avert a third of infections among each of FSWs and their clients as both benefit directly from the intervention, and also indirectly benefit client spouses by averting 15% of infections among them (Figure 8) [10]. Being an inexpensive intervention, increasing access to and coverage of condom use in HSWNs should be a priority for HIV programming, especially in MENA's low-and-middle income countries.

Figure 8. Impact of expanding coverage of prevention and treatment interventions among FSWs on HIV incidence in HSWNs in MENA. Arrows indicate the proportional decrease in incidence due to expanding coverage of PrEP to 50% (efficacy of 51%), condom use to 80% (efficacy of 80%), ART to 81% (efficacy factoring adherence of 57%), or implementing a moderately optimistic scenario that includes expanding PrEP to 25%, condom use to 50%, ART to 50% (assuming efficacy of 96%, that is optimal adherence), and voluntary male circumcision to 50% in South Sudan, or implementing a most optimistic scenario that includes expanding PrEP to 50%, condom use to 80%, ART to 81% (assuming efficacy of 96%, that is optimal adherence), and voluntary male circumcision to 80% in South Sudan.



Research paper 4 further shows that expanding current ART coverage to the 2020 global target of 81% while factoring imperfect adherence, among FSWs alone, can avert close to half of incident infections among clients who benefit directly from the reduced infection transmission from HIV-positive FSWs, and over 20% of infections among susceptible FSWs and client spouses who benefit indirectly from that intervention (Figure 8) [10]. A higher impact can be achieved by improving adherence [10], or by expanding ART coverage to reach the 95-95-95 UNAIDS target of 85.7% [54].

In 2015, WHO recommended that individuals at substantial risk of HIV should be offered PrEP [69], but PrEP delivery is virtually non-existent in MENA [10]. Research paper 4 indicated that introducing PrEP among FSWs, at a coverage of 50%, can avert close to a third of infections among FSWs who benefit directly from this intervention, and can also indirectly benefit clients and client spouses though to a lesser extent (Figure 11) [10].

These findings suggest that getting back on track towards achieving the 95-95-95 UNAIDS targets in MENA [54], and eventually the sustainable development goal target of ending the AIDS epidemic by 2030 [56, 57], is not possible without the implementation of combination prevention interventions. Research paper 4 showed that even an intervention package with modest coverage that targets only FSWs can avert over two-thirds of incident infections among clients, close to half of infections among FSWs, and over a third of infections among client spouses (Figure 11). An important outcome of this thesis is quantifying the benefit that the wider population can incur from programs targeting only FSWs, but whose benefit extends beyond FSWs to include bridging populations such as clients and general population women who are spouses of clients—a point that should be considered by policymakers.

Recommendations for policy

Criminality [24, 70] and stigma [71-73] associated with sex work are barriers against addressing the HIV epidemic in MENA. A recent UNAIDS report revealed that eighteen of the 23 MENA countries have punitive laws against sex work with the exception of one country, Lebanon, while the rest have no data [27]. In some instances, there is even resistance to acknowledging the existence of sex work [74] and a strong reluctance among policymakers to allocate resources for HIV programming among FSWs out of concern over socio-cultural sensitivities [17, 75]. These structural factors exacerbated the increased mobility and diverse typologies of FSWs who try to evade incarceration [34, 70, 76], thus making this population harder to reach. This also resulted in programs and services, where they exist, being exclusively the realm of non-governmental organizations (NGOs), which are often inadequately resourced or under legal restrictions that limit provision of comprehensive intervention packages to FSWs [17, 24].

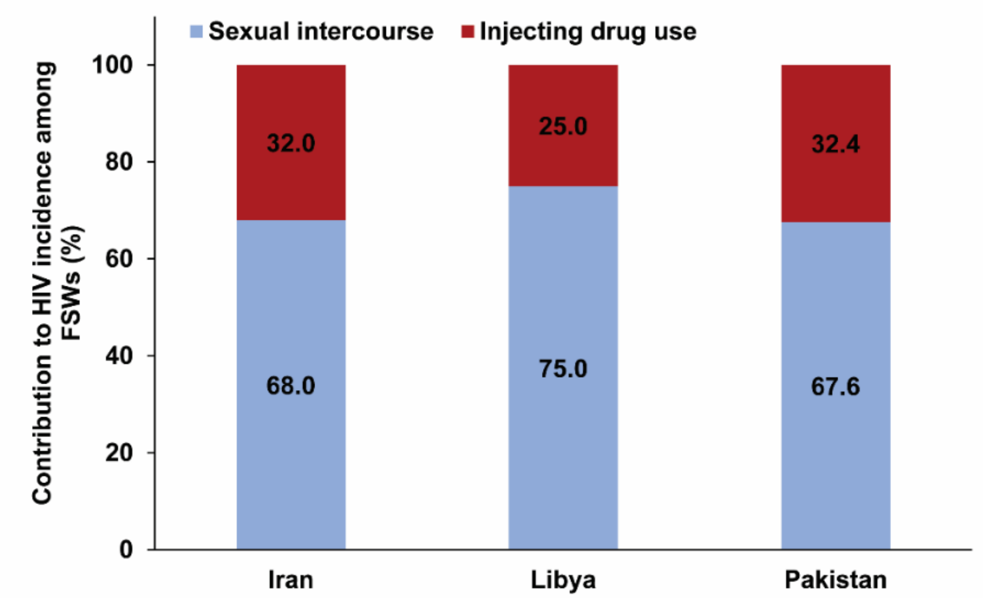
Surveillance efforts for HIV, and more so other STIs, remain largely passive and based on case notifications with variable reporting quality [75, 77-79], thus presenting a real challenge for early infection detection and linkage to care. The latter is compounded by a very limited capacity for STI prevention and treatment and broader sexual health programs [37, 75]. In many instances, possession of condoms is criminalised and treated as evidence for sex work [70, 80], thus discouraging their use despite their established effectiveness in reducing HIV transmission [10] and in offering a harm-free alternative to STI syndromic case management and presumptive treatment, thus potentially slowing down AMR [31].

The impact of these factors can be seen in the rising course of the HIV epidemic in different populations the region [2, 3, 27], the pattern of emerging HIV epidemics among FSWs (research paper 1; [1]), as well as in the burden of STIs among FSWs (research paper 2; [31]) and general population women [36, 37]. However, the resulting disease burden and associated social and economic implications continue to be underappreciated [81].

While there is a need for decriminalisation of sex work and for programs aimed at alleviating socio-cultural sensitivities related to sex work and HIV in general, such initiatives are difficult to materialise in the short term. One successful model for enacting on these challenges in the immediate term is the example of Morocco. While punitive laws remain unaltered, the government formulated an evidence-informed national strategy and channelled its HIV response through close partnerships with NGOs, who played the leading role in implementing interventions [24]. Within this framework, voluntary counselling and testing and sentinel surveillance centres were established nationwide, with FSWs estimated to constitute about a quarter of attendees in 2007 (a more recent estimate could not be attained) [82, 83]. Comprehensive services for at-risk populations, including outreach peer-education programs as well as testing and case management services, were also rapidly scaled-up [24, 83]. As a result, condom use among FSWs and ART among PLHIV rapidly reached coverage levels exceeding 50% [10].

Research paper 4 identified an additional vulnerability for FSWs who inject drugs in countries with prevalent injecting drug use among FSWs, namely Iran, Libya, and Pakistan, where between a quarter and a third of infections among FSWs are acquired through drug injection (Figure 9) [10]. This suggests the need for harm reduction services for FSWs who inject drugs in these countries, as exemplified by Iran where the expansion of harm reduction services included the establishment of the first women-operated services in MENA [2].

Figure 9. Contribution of injecting drug use versus sexual transmission to HIV incidence among FSWs in countries where injecting drug use is a main mode of HIV transmission among FSWs.



Data limitations and recommendations to address evidence gaps

Gaps in evidence for HIV in FSWs and implications for surveillance

While this thesis is grounded on a foundation of current empirical evidence for the epidemiology of HIV and other STIs in HSWNs, it is also limited by gaps in evidence. For instance, six countries had no data on HIV among FSWs, others had limited data to warrant a meaningful characterization of the epidemic (research paper 1; [1]). For these countries, the status of the epidemic remains unknown, pointing to an urgent need for establishing and/or strengthening HIV surveillance. There were also limited HIV prevalence data available for FSWs who inject drugs (research paper 1; [1]). The lack of segregation of this population in HIV surveillance activities further complicates understanding of the interplay between the sexual versus injecting modes of transmission in HSWNs (research paper 4; [10]).

The quality of HIV data varied across and within countries. Twelve of the 23 MENA countries reported data collected using probability-based sampling, 11 of which based on IBBSS with eight having multiple rounds (research paper 1; [1]). Still, a sizable fraction of data was collected using convenience sampling or had limited geographical representation, restricting data generalizability to HSWNs at the national level (research paper 1; [1]). With the recent emergence of HIV epidemics in several HSWNs and the potential for epidemic growth or epidemic emergence in other HSWNs, effort should be made to expand surveillance including establishment of voluntary counselling and testing centres and conduct of rounds of IBBSS with national coverage to identify hidden epidemics in different HSWNs, monitor epidemic trends, facilitate generation of more precise modelling estimates of HIV incidence in HSWNs including among FSWs who inject drugs, evaluate programs' effectiveness, monitor progress towards UNAIDS 2030 targets, as well as to inform HIV policy and programming.

Gaps in evidence for STIs in FSWs and implications for monitoring of HIV and antimicrobial resistance

Data gaps for STIs (other than HIV) among FSWs are even more pronounced with no evidence identified for over half of MENA countries (research paper 2; [31]). This dearth in evidence hindered in-depth regional and temporal analyses for *C. trachomatis*, *N. gonorrhoeae*, *T.*

vaginalis, and HSV-2, and therefore assessment of progress towards achieving the WHO Global Health Sector Strategy on STIs [31, 39]. Furthermore, with only three HSV-2 and HIV paired prevalence measures identified for the entire region, analyses using HSV-2 as a tool to predict HIV epidemic potential among FSWs could not be performed for MENA (research paper 3; [30]). The latter represents a missed opportunity for this region, especially considering the recent emergence of epidemics and potential for their expansion to other HSWNs within a country, or for bridging of the infection from other key populations among whom large HIV epidemics are found [2, 3]. Importantly, the neglected burden of STIs among FSWs appears to lead to a considerable disease burden in the wider population [36, 37]. This disease burden is often being recklessly managed through case syndromic management and presumptive treatment, thus posing a risk for growing AMR (research paper 2; [31]). There is therefore a critical need for strengthening STI surveillance including monitoring of drug resistance across MENA. Countries may benefit from the established infrastructure for HIV surveillance including incorporation of testing for STIs in IBBSS [84, 85], which is seldom performed [31].

There were no studies assessing HIV or STI prevalence among clients of FSWs (research paper 1; [1]). Instead, male STI clinic attendees were used as a proxy population since a significant proportion of them reported contact with FSWs (research paper 1; [1]). Although suboptimal, analysis of this proxy population presented an opportunity for gaining insights into the epidemiology of HIV among clients of FSWs—probably the most hidden and hardest-to-reach population because of social desirability, especially that clients have limited interest in being identified to access services. Feasibility studies are needed to determine whether clients could be included in future IBBSS.

Gaps in evidence on HIV continuum of care among FSWs

There were limited data on HIV testing (research paper 1; [1]), hardly any data on linkage to care (research paper 4; [10]), and no data on viral suppression among FSWs in MENA. Consequently, controlling for ART was not possible in several analyses presented within the scope of this thesis. A second-best approach relying on data for ART among PLHIV had to be implemented in estimating HIV incidence arising in HSWNs, which may have resulted in underestimation of incidence among FSWs, clients, and client spouses (research paper 4; [10]). There is therefore an urgent need to establish surveillance for FSWs along the HIV continuum of care including monitoring of HIV testing, linkage to care, adherence, CD4 levels, and retention in the testing and treatment cascade. The latter is best implemented through NGOs working closely with FSWs.

Gaps in evidence on population size estimates in FSWs

Over half of MENA countries had no data on FSWs' population size estimates, and for several, data were outdated or lacked national representation (research paper 1; [1].) The data collection methodology, as well as the time frame and type of estimate (number versus proportion) provided also varied across countries (research paper 1; [1]). Mapping studies are needed to obtain more precise estimates for population size of FSWs, as well as to gain further insights into the typology of these FSWs and connectivity of sexual networks. Such estimates will promote our understanding of HIV transmission dynamics in HSWNs and inform mathematical modelling efforts aimed at estimating infection burden and the need for prevention and treatment services.

Gaps in evidence on sexual and injecting risk behaviours in FSWs

Although abundant, sexual risk behaviour data are difficult to interpret or incorporate in analyses given the lack of standardized and validated data collection tools (research paper 1; [1]). For example, not all studies report measures of central tendency for the number of sexual partnerships or sexual acts, and many report only aggregate data using different cut-offs and different time frames [1], which complicates their synthesis and limits their use in mathematical modelling studies. Denominators for reported proportions may lack clarity rendering them useless for future analyses [1]. Stratified data by type of sexual partnership are often not included [1]. Data availability for several parameters may also vary across countries [1]. Similarly, data characterizing injecting risk behaviour among FSWs also varies between studies, across countries, and over time (research paper 1; [1]). For example, there were no data on current injecting risk behaviour among FSWs who inject drugs in Iran despite availability of lifetime data [1]. The time frame for current/recent injecting drug use also varied for other countries [1]. Data on access to harm reduction services were also largely lacking [1]. Improvements in behavioural research among FSWs would allow for better estimation of HIV incidence and evidence-informed programming of interventions among them.

Strengths and main conclusions of the thesis

In conclusion, this thesis was instrumental in filling a gap in our understanding of HIV epidemiology among FSWs and clients in MENA by synthesizing a large volume of evidence, some of which appeared for the first time in the published scientific literature. Various epidemiological aspects were investigated using different methodologies including systematic reviews, meta-analyses, meta-regression analyses, a novel individual-based mathematical model, and multiple statistical analyses. The thesis provided detailed analyses and summary measures for population size estimates, HIV and STI prevalence and incidence, and key behavioural indicators among FSWs. The thesis also identified a pattern of emerging HIV epidemics, perhaps because of bridging from other key populations, but also a window of opportunity for preventing HIV epidemics or detecting them at nascence in settings with still limited HIV circulation in

HSWNs. The thesis further demonstrated the utility of HSV-2 as a tool in predicting HIV epidemic potential in these networks.

Lasting scientific contributions of this thesis include introduction and building of a novel individual-based mathematical model for HIV transmission in HSWNs that can be adapted and used to answer different research questions for both HIV and STI epidemiology and assessment of impact of interventions. The thesis promoted our understanding of HIV transmission dynamics in HSWNs, and provided for the first time in MENA, baseline regional estimates of HIV incidence arising in HSWNs, an evaluation of the role of injecting drug use versus sexual transmission in driving HIV incidence, and an assessment of the potential impact of interventions on infection burden in these networks. The thesis unveiled the sizable contribution of HSWNs to HIV infection burden in the wider population, a fact that is often overlooked by policymakers when allocating resources for HIV programming. The thesis identified a trend of declining syphilis in FSWs, but also a serious lag in achieving targets of WHO Global Health Sector Strategy on STIs among FSWs. Gaps and serious lags were also noted in relation to indicators used for monitoring progress towards achieving UNAIDS 2030 targets for HIV.

Findings of this thesis provide the evidence-base necessary for informing HIV and STI policy and programming, advocating for a reconsideration of the criminalisation of sex work, advocating for a new framework of action that strengthens the role of NGOs in providing sexual health services and comprehensive prevention interventions and treatment packages for FSWs, and demonstrating the need for further research to improve on the limitations of this thesis in understanding HIV and STI dynamics in HSWNs in MENA.

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Appendix I

International Organizations' definitions for the Middle East and North Africa region

Table S1. The World Health Organization's Regional Office for the Eastern Mediterranean (WHO-EMRO), Joint United Nations Programme on HIV/AIDS (UNAIDS), and World Bank definitions for the Middle East and North Africa region (MENA).

Country	WHO-EMRO	UNAIDS	World Bank
Afghanistan	X	X	
Algeria		X	X
Bahrain	X	X	X
Djibouti	X	X	X
Egypt	X	X	X
Iran	X	X	X
Iraq	X	X	X
Israel			X
Jordan	X	X	X
Kuwait	X	X	X
Lebanon	X	X	X
Libya	X	X	X
Mauritania			
Morocco	X	X	X
Oman	X	X	X
Pakistan	X	X	
Palestine (West Bank and Gaza)	X	X	X
Qatar	X	X	X
Saudi Arabia	X	X	X
Somalia	X	X	
Sudan	X	X	
Syria	X	X	X
Tunisia	X	X	X
United Arab Emirates	X	X	X
Yemen	X	X	X

Appendix II

Supplementary material for Research paper 1-

HIV Epidemiology among FSWs and clients in MENA

Supplementary Information

HIV epidemiology among female sex workers and their clients in the Middle East and North Africa: Systematic review, meta-analyses, and meta-regressions

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Table S1 Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) checklist [1]

Section/topic	#	Checklist item	Reported in main text
Title	1	Identify the report as a systematic review, meta-analysis, or both.	p. 1
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	p. 2-3
Rationale	3	Describe the rationale for the review in the context of what is already known.	p. 4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	p. 4-5
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	p. 5-6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	p. 5 & Box S1 in SI
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Box S1 in SI
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	p. 5-6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	p. 6-7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	p. 6-7 & Box S2 in SI
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	p. 7-8 & Table S2 in SI
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	p. 8
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	p.6-8 & Table 5
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	p. 7-8 & Table S2 in SI
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	p. 8-9 & S3 Table in SI
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	p. 9-10 & Fig. 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	p.10-11, Tables 1-4, and Tables S4 & S5in SI
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12).	p. 12 & Tables S6-S9 in SI
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot.	p. 10-11, Tables 1-4 & Tables S4-S5 in SI
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	p.12-13 & Table 5
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	p. 12 & Tables S6-S9 in SI
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	p. 13-17, Table 6, & Tables S10-S15 in SI
		DISCUSSION	
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., health care providers, users, and policy makers).	p. 18-22

Section/topic	#	Checklist item	Reported in main text
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review level (e.g., incomplete retrieval of identified research, reporting bias).	p. 22-23
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	p. 23-24
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	p. 26

Abbreviations: *NA* not applicable, *P* page(s), *SI* Supporting information

Fig. S1 Map of the Middle East and North Africa region. The definition for this region covers 23 countries including Afghanistan, Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Somalia, Sudan (available studies for Sudan before 2011, the year of independence of South Sudan, may have come from both Sudan and the newly indpendent Republic of South Sudan), Syria, Tunisia, United Arab Emirates (UAE), and Yemen. This definition is based on definitions of the World Health Organization, the Joint United Nations Programme on HIV/AIDS, and the World Bank [2]

Box S1 Search criteria for the systematic review of size estimation, HIV incidence, and HIV prevalence studies in FSWs and their clients, in the Middle East and North Africa (MENA)

PubMed (July 29, 2018)

Sex work

"Extramarital Relations"[Mesh] OR "Sex Work*"[Mesh] OR "Sex/analysis"[Mesh] OR "Sex/statistics and numerical data"[Mesh] OR "Sexual partners"[Mesh] OR "Sex Trafficking/epidemiology"[Mesh] OR "Sex Trafficking/statistics and numerical data"[Mesh] OR Sex work*[Text] OR Sexual work*[Text] OR Sexwork*[Text] OR Sex-work*[Text] OR Sexual partner*[Text] OR Sex partner*[Text] OR Sexual contact*[Text] OR FSW[Text] OR FSWs[Text] OR CSW[Text] OR CSWs[Text] OR SW[Text] OR SWs[Text] OR TSW[Text] OR TSWs[Text] OR TS[Text] OR Travailleuse* sexe[Text] OR Travailleuse* sex[Text] OR Bar girl*[Text] OR Callgirl*[Text] OR Call girl*[Text] OR Escort*[Text] OR Masseuse*[Text] OR Hostess*[Text] OR ((Premarital[Text] OR Pre-marital[Text] OR Pre marital[Text] OR Extramarital[Text] OR Extra-marital[Text] OR Extra marital[Text] OR Illicit[Text] OR Illegal[Text]) AND (Sex[Text] OR Sexual[Text] OR Relation*[Text])) OR Outside marriage[Text] OR Out of marriage[Text] OR "Illegal social behavior"[Text] OR "Illegal social behaviour"[Text] OR Adultery[Text] OR Prostitut*[Text] OR Promiscu*[Text] OR Female entertain*[Text] OR Sex entertain*[Text] OR Sexual* entertain*[Text] OR Entertainment work*[Text] OR Sex industr*[Text] OR Sex establishment*[Text] OR Brothel*[Text] OR Red light[Text] OR Red-light[Text] OR Red district*[Text] OR Nightclub*[Text] OR Pimp[Text] OR ((Intergenerational[Text] OR Cross-generation*[Text] OR Cross-generational[Text] OR Recreational[Text] OR Commercial[Text] OR Transaction*[Text] OR Casual[Text] OR Group[Text] OR Informal[Text] OR Street[Text] OR Migrant*[Text] OR Survival[Text] OR Occupational[Text] OR Tourism[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Sex seeking[Text] OR Sex-seeking[Text] OR Solicit*[Text] OR ((Provision*[Text] OR Provider*[Text] OR Provid*[Text] OR Sell*[Text] OR Sold[Text] OR Exchang*[Text] OR Trad*[Text] OR Favor*[Text] OR Consum*[Text] OR Commodi*[Text] OR Paid[Text] OR Paying[Text] OR Pay[Text] OR Payer*[Text] OR Buying[Text] OR Buy[Text] OR Buyer*[Text] OR Charg*[Text] OR Engag*[Text] OR Service*[Text] OR Money[Text] OR Cash[Text] OR Drug*[Text] OR Goods[Text] OR Gift*[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Hidden population*[Text] OR Hard to reach population*[Text] OR Hard-to-reach population*[Text] OR Core group*[Text] OR Core risk group*[Text] OR Vulnerable women[Text] OR Vulnerable population*[Text] OR Vulnerable female*[Text] OR Most-at-risk population*[Text] OR Most at risk population*[Text] OR High risk population*[Text] OR High-risk population*[Text] OR Population* at high risk[Text] OR Population* at high-risk[Text] OR ((Traffick*[Text] OR Slave*[Text] OR Coerc*[Text] OR Abduct*[Text] OR Exploit*[Text] OR Abuse*[Text] OR Violence[Text]) AND (Sex[Text] OR Sexual*[Text]))

MENA

"Middle East"[Mesh] OR "Islam"[Mesh] OR "Arabs"[Mesh] OR "Arab World"[Mesh] OR "Africa, Northern"[Mesh] OR "Sudan"[Mesh] OR "Somalia"[Mesh] OR "Djibouti"[Mesh] OR "Pakistan"[Mesh] OR "South Sudan"[Mesh] OR "Middle East*"[Text] OR "Middle-East"[Text] OR "North Africa*"[Text] OR "North-Africa"[Text] OR "EMRO"[Text] OR "Eastern Mediterranean"[Text] OR "Arab*"[Text] OR "Arab World"[Text] OR "Islam*"[Text] OR "Afghanistan"[Text] OR "Afghan*"[Text] OR "Algeria*"[Text] OR "Bahrain*"[Text] OR "Djibouti"[Text] OR "Egypt*"[Text] OR "Jordan*"[Text] OR "Kuwait*"[Text] OR "Lebanon"[Text] OR "Leban*"[Text] OR "Libya*"[Text] OR "Iran*"[Text] OR "Iraq*"[Text] OR "Morocco"[Text] OR "Moroccan*"[Text] OR "Oman*"[Text] OR "Pakistan*"[Text] OR "Qatar*"[Text] OR "Saudi*"[Text] OR "Somalia"[Text] OR "Somal*"[Text] OR "Sudan*"[Text] OR "Syria*"[Text] OR "Tunisia*"[Text] OR "United Arab Emirates"[Text] OR "Emirat*"[Text] OR "West Bank"[Text] OR "Ghaza*"[Text] OR "Gaza*"[Text] OR "Palestine"[Text] OR "Palestinian*"[Text] OR "Yemen*"[Text] OR "UAE"[Text] OR "KSA"[Text]

Women

"Female/analysis"[Mesh] OR "Female/statistics and numerical data"[Mesh] OR "Women/epidemiology"[Mesh] OR "Women/statistics and numerical data"[Mesh] OR Women[Text] OR Girl*[Text] OR Female*[Text]

Clients/Men

"Male/complications"[Mesh] OR "Male/diagnosis"[Mesh] OR "Men/statistics and numerical data"[Mesh] OR Men[Text] OR Male[Text] OR Males[Text] OR Client*[Text] OR Paying partner*[Text] OR Sugar daddy[Text] OR Sugar daddies[Text]

FINAL PUBMED SEARCH
("Sex work" AND "MENA" AND "Women") OR ("Sex work" AND "MENA" AND "Clients/Men")

Embase (July 29, 2018)

Sex work

exp prostitution/ or exp casual sex/ or exp transactional sex/ or exp group sex/ or exp sex tourism/ or exp sexual promiscuity/ or exp extramarital sex/ or exp premarital sex/ or exp sexual relation/ or exp sexual partners/ or ((exp sex trafficking/ or exp sexual exploitation/ or exp sexual coercion/) NOT Child) or (sex* work* or sexwork* or sex-work* or sex partner* or sexual partner* or sexual contact* or premarital sex or premarital sexual or premarital relation* or pre-marital sex or pre-marital sexual or pre-marital relation* or pre marital sex or pre marital sexual or pre marital relation* or extramarital sex or extramarital sexual or extramarital relation* or extra-marital sex or extra-marital sexual or extra-marital relation* or extra marital sex or extra marital sexual or extra marital relation* or illicit sex or illicit sexual or illicit relation* or illegal sex or illegal sexual or illegal relation* or (out* ADJ1 marriage) or illegal social behavio?r or adultery or prostitut* or promiscu* or FSW or FSWs or CSW or CSWs or SW or SWs or TSW or TSWs or TS or (women ADJ4 sex*) or (Travailleuse* ADJ1 sex*) or bar girl* or call girl* or callgirl* or escort* or masseuse* or hostess* or female entertain* or sex entertain* or sexual entertain* or entertainment work* or sex industr* or sex establishment* or brothel* or red light or red-light or (red ADJ1 district*) or nightclub* or pimp or recreation* sex* or intergenerational sex* or cross-generation sex* or cross-generational sex* or commercial sex* or transactional sex* or sex* transaction* or casual sex* or informal sex* or group sex* or street sex* or (migra* ADJ4 sex*) or (sex* ADJ4 migra*) or survival sex* or occupational sex* or sex* tourism or sex seeking or sex-seeking or solicit* or (consum* ADJ4 sex*) or (sex* ADJ 4 consumer) or (sex* ADJ4 consumers) or (sex* ADJ4 provi*) or (provi* ADJ4 sex*) or (sell* ADJ4 sex*) or (sex* ADJ4 sell*) or sold sex* or (exchang* ADJ4 sex*) or (sex* ADJ4 exchange) or (trading ADJ4 sex*) or (trade* ADJ4 sex*) or sex* trade or sex* favor* or (commodi* ADJ4 sex*) or (sex* ADJ4 commodi*) or (paid ADJ4 sex*) or (pay* ADJ4 sex*) or (sex* ADJ4 pay*) or (buy* ADJ4 sex*) or (sex* ADJ4 buy*) or (charg* ADJ4 sex*) or (sex* ADJ4 charg*) or (engag* ADJ4 sex*) or (sex* ADJ4 engage*) or (sex* ADJ4 service*) or (service* ADJ4 sex*) or (money ADJ4 sex*) or (sex* ADJ4 money) or (cash ADJ4 sex*) or (sex* ADJ4 cash) or (sex* ADJ4 drug*) or (drug* ADJ4 sex*) or (sex* ADJ4 goods) or (goods ADJ4 sex*) or (sex* ADJ4 gift*) or (gift* ADJ4 sex*) or hidden population* or hard to reach population* or hard-to-reach population* or (core ADJ1 group*) or vulnerable women or vulnerable female*).mp. or ((vulnerable population* or most-at-risk population* or most at risk population* or high risk population* or high-risk population* or population* at high risk or population* at high-risk).mp. AND (sex* or infection* or STI or STIs or STD or STDs or human immunodeficiency virus or HIV* or AIDS* or acquired immune deficiency syndrome or acquired immunodeficiency syndrome).mp.) or ((sex trafficking or sexual trafficking or (traffick* ADJ4 sex*) or sex* slave* or sex* coerc* or sex* abduct* or sex* exploit* or sex* abuse* or sex* violence) NOT Child).mp. or ((women ADJ4 traffick*) or (girls ADJ4 traffick*) or (female* ADJ4 traffick*) or (traffick* ADJ4 women) or (traffick* ADJ4 girls) or (traffick* ADJ4 female*)).mp.

MENA

exp Middle East/ or exp North Africa/ or exp Arab/ or exp Afghanistan/ or exp Djibouti/ or exp Pakistan/ or exp Somalia/ or exp Sudan/ or exp South Sudan/ or Middle East.mp. or North Africa.mp. or EMRO.mp. or Eastern Mediterranean.mp. or Arab.mp. or Arabs.mp. or Arab World.mp. or Islam.mp. or Afghanistan.mp. or Afghan*.mp. or Algeria*.mp. or Bahrain*.mp. or Djibouti.mp. or Egypt*.mp. or Jordan*.mp. or Kuwait*.mp. or Leban*.mp. or Libya*.mp. or Iran*.mp. or Iraq*.mp. or Morocc*.mp. or Oman*.mp. or Pakistan*.mp. or Qatar*.mp. or Saudi*.mp. or Somal*.mp. or Sudan*.mp. or Syria*.mp. or Tunisia*.mp. or United Arab Emirates.mp. or Emirat*.mp. or West Bank.mp. or Ghaza*.mp. or Gaza*.mp. or Palestin*.mp. or Yemen*.mp. or UAE.mp. or KSA.mp.

Women

exp female/ or (women or girl* or female*).mp.

Clients/Men

exp male/ or (client* or (paying ADJ1 partner*) or sugar dadd* or men or male*).mp.

FINAL EMBASE SEARCH
(“Sex work” AND “MENA” AND “Women”) OR (“Sex work” AND “MENA” AND “Clients/Men”)

Regional databases

HIV and AIDS Asia Pacific Research Statistical Data Information (May 27, 2018)
Keyword search for: “Afghanistan” and “Pakistan”

Iran Scientific Information Database (July 23, 2018**)**
Keyword search for: “HIV”, “AIDS”, “Human immunodeficiency virus”, “Acquired immune deficiency syndrome”, “sex work”, “prostitute”, “size estim”, and “sexually transmitted infection”

Iraq Academic Scientific Journals database (July 23, 2018)
Keyword search for: “HIV OR AIDS”, “HIV”, “Human immunodeficiency virus”, “Acquired immune deficiency syndrome”, “sex work”, “prostitute”, “commercial sex”, “size estimation”, and “sexually transmitted infection”

MENA HIV/AIDS Epidemiology Synthesis Project database (June 01, 2018)
Hand search of all documents in the database

PakMediNet (July 23, 2018)
Keyword search for: “HIV”, “AIDS”, “Human immunodeficiency virus”, “Acquired immune deficiency syndrome”, “sex work”, “prostitute”, “commercial”, “size estimation”, and “sexually transmitted infection”

US Census Bureau (July 17, 2018)
Keyword search using each MENA country name

World Health Organization Index Medicus for the Eastern Mediterranean Region (July 23, 2018)
Keyword search for: “HIV OR AIDS”, “Human AND immunodeficiency AND virus”, “Acquired AND immune AND deficiency AND syndrome”, “prostitute”, and “sex AND worker”
World Health Organization Index Medicus for the Eastern Mediterranean Region (July 27, 2018)
Keyword search for: “Algeria”, “Algerie”, “Djibouti”, “Egypt”, “Egypte”, “Libya”, “Libie”, “Maroc”, “Morocco”, “Tunisia”, “Tunisie”, “Somalia”, “Somalie”, “Sudan”, and “Soudan”

Abstract archives of the International AIDS Society conferences (July 28, 2018)	
Keyword search using each MENA country name	

Abbreviations: *FSWs* female sex workers

Box S2 List of extracted variables for the systematic review of HIV epidemiology among FSWs and their clients in the Middle East and North Africa (MENA)

Report characteristics
Author(s), year of publication, full citation, type of publication, and source of data
General study characteristics
Study population and its characteristics, year(s) of data collection, country of origin, country of survey, city, study site, study design, sampling methodology, estimation methodology, sample size, population definition, eligibility criteria, and participation rate
Studies/outcome measures
Population-size estimates and population proportions of FSWs and clients HIV incidence (including number followed-up, follw-up time, sero-conversion risk, incidence rate, and details related to outcome ascertainment) HIV prevalence (including number tested, number antibody positive, and details related to outcome ascertainment)
Sexual and injecting risk behaviours and contextual measures
Socio-demographic charcateristics and sex work context (age, age at sexual debut, age at sex work intiation, and marital status), Condom use with clients and partners (over different time frames, types of sexual partnerships-regular/occasional/paying/non-paying, and sexual acts-vaginal/anal) Types of sexual partnerships (over different time frames) Injecting risk behaviour (current/recent/history of drug use, injecting drug use, sex with people who inject drugs, and substance use before or during sex) Knowledge of HIV/AIDS (knowledge of sexual and injecting modes of transmission, and of condom as HIV prevention method) Perception of risk of exposure to HIV infection HIV testing (ever, during the past 12 months, received results)

Abbreviations: *FSWs* female sex workers

Table S2 Quality assessment criteria for size estimation and HIV prevalence studies in FSWs and their clients (or proxy populations of clients) in the Middle East and North Africa, as identified in the systematic review

Quality domain	ROB assessment	Criteria	Size estimation	HIV prevalence
1. Validity of sex work definition	Low ROB	Clear and valid sex work definition/engagement in paid sex clearly established	X	X
	High ROB	Sex work/engagement in paid sex not well-defined/not clearly established		
	Unclear	Sex work definition/information on engagement in paid sex not provided		
2. Rigor of estimation methodology	Low ROB	Method likely to yield representative estimate for the number or population proportion of FSWs or clients such as multiplier unique object, time-location geographical mapping, capture-recapture, and network scale-up, among others	X	NA
	High ROB	Method unlikely to yield representative estimate for the number or population proportion of FSWs or clients such as self-report based on convenience sampling		
	Unclear	Information not reported		
3. Rigor of sampling methodology	Low ROB	Studies using probability-based sampling	NA	X
	High ROB	Studies using non-probability sampling		
	Unclear	Information not reported		
4. Response rate	Low ROB	≥60% or ≥60% of target sample size reached in studies using RDS or TLS	X	X
	High ROB	<60% or <60% of target sample size reached in studies using RDS or TLS		
	Unclear	Information not reported		
5. HIV ascertainment	Low ROB	HIV ascertainment using biological assays	NA	X
	High ROB	HIV ascertainment based on self-report		
	Unclear	Information not reported		

Abbreviations: *FSWs* female sex workers, *NA* not applicable, *RDS* respondent-driven sampling, *ROB* risk of bias assessment, *TLS* time-location sampling

Table S3 Details of variables and subcategories included in the meta-regression analyses

Variable	Sub-categories
Country/subregion*	1. Eastern MENA: Afghanistan, Iran, and Pakistan 2. Fertile Crescent: Egypt, Iraq, Jordan, Lebanon, Syria 3. Bahrain, Kuwait, and Yemen 4. Horn of Africa: Djibouti, Somalia, and South Sudan 5. North Africa: Algeria, Libya, Morocco, Sudan, and Tunisia
FSW population type	1. Street-based, venues-based, and other FSWs 2. Bar girls
Total sample size of tested FSWs	1. <100 participants 2. ≥100 participants
Median year of data collection**	1. <1993 2. 1993-2002 3. ≥2003
Sampling methodology†	1. Non-probability sampling 2. Probability-based sampling
Response rate	1. ≥60% 2. <60%/unclear 3. Not applicable‡
Validity of sex work definition	1. Clear & valid definition 2. Poorly defined/unclear 3. Not applicable‡
HIV ascertainment	1. Biological assays 2. Self-report/unclear 3. Not applicable‡

*Countries were grouped based on geography and similarity in HIV prevalence levels.
**Year grouping was driven by independent evidence identifying the emergence of HIV epidemics among both men who have sex with men [3] and people who inject drugs [4] in multiple MENA countries around 2003.
†Sampling methodology was not included in the meta-regression analyses of clients of FSWs as too few studies used probability-based sampling (only four).
‡Measures extracted only from routine databases with no reports describing the study methodology were not included in the ROB assessment.
Abbreviations: *FSWs* female sex workers

Table S4 Estimates of subnational representation for the number and population proportion of FSWs and of their clients in the Middle East and North Africa (MENA) reported by identified studies

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
FSWs									
Afghanistan									
SAR AIDS HDS, 2008 [5]	2006-07	Jalalabad	Enumeration (time-location geographical mapping)	Home & street-based FSWs	Current	90	NR	0·26	NR
SAR AIDS HDS, 2008 [5]	2006-07	Kabul	Enumeration (time-location geographical mapping)	Home & street-based FSWs	Current	898	NR	0·19	NR
SAR AIDS HDS, 2008 [5]	2006-07	Mazar-i-Sharif	Enumeration (time-location geographical mapping)	Home & street-based FSWs	Current	172	NR	0·28	NR
NACP, 2012 [6] (round II)	2012	Herat	Multiplier unique object	FSWs	Past 12 M	2,134	NR	NR	NR
NACP, 2012 [6] (round II)	2012	Kabul	Multiplier unique object	FSWs	Past 12 M	2,800	NR	NR	NR
Djibouti									
Trellu-Kane, 2005 [7]	2005	Djibouti	Conv sample (self-report)	Gen pop (13-24 years)	Past 12 M	NR	NR	4	NR
Egypt									
Jacobsen, 2014 [8]	2014	Giza	Enumeration (time-location geographical mapping)	FSWs	Current	6,092	1,407-7,615	0·17	NR
Jacobsen, 2014 [8]	2014	Alexandria	Enumeration (time-location geographical mapping)	FSWs	Current	4,225	1,011-6,500	0·34	NR
Jacobsen, 2014 [8]	2014	Sharkia	Enumeration (time-location geographical mapping)	FSWs	Current	1,345	448-1,416	0·34	NR
Jacobsen, 2014 [8]	2014	Red Sea	Enumeration (time-location geographical mapping)	FSWs	Current	1,315	404-1,384	1·92	NR
Jacobsen, 2014 [8]	2014	Menia	Enumeration (time-location geographical mapping)	FSWs	Current	278	89-323	0·11	NR
Iran									
Karami, 2017 [9]	NR	Hamadan	Capture-recapture	FSWs	Past 12 M	842	700-1,042	0·45	NR
Sharifi, 2017 [10]	2015	Ahvaz	Wisdom of the crowds	FSWs	Current	10,000	5,400	2·86	1·55-3·86
Sharifi, 2017 [10]	2015	Arak	Wisdom of the crowds	FSWs	Current	3,800	2,600	2·30	1·57-3·38
Sharifi, 2017 [10]	2015	Bandar Abbas	Wisdom of the crowds	FSWs	Current	4,000	2,200	2·87	1·58-4·45
Sharifi, 2017 [10]	2015	Isfahan	Wisdom of the crowds	FSWs	Current	12,200	7,800	2·02	1·29-2·74
Sharifi, 2017 [10]	2015	Kerman	Wisdom of the crowds	FSWs	Current	4,600	2,500	2·46	1·34-3·32
Sharifi, 2017 [10]	2015	Kermanshah	Wisdom of the crowds	FSWs	Current	1,600	1,200	0·59	0·45-1·97
Sharifi, 2017 [10]	2015	Mashhad	Wisdom of the crowds	FSWs	Current	12,000	6,700	1·43	0·80-2·01
Sharifi, 2017 [10]	2015	Sari	Wisdom of the crowds	FSWs	Current	800	400	0·85	0·42-1·17
Sharifi, 2017 [10]	2015	Shiraz	Wisdom of the crowds	FSWs	Current	13,300	8,700	2·75	1·80-3·68
Sharifi, 2017 [10]	2015	Tabriz	Wisdom of the crowds	FSWs	Current	13,100	9,000	2·84	1·95-3·94

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
Sharifi, 2017 [10]	2015	Tehran	Wisdom of the crowds	FSWs	Current	63,700	44,500	2·52	1·76-3·83
Sharifi, 2017 [10]	2015	Zahedan	Wisdom of the crowds	FSWs	Current	840	500	0·51	0·31-1·41
Sharifi, 2017 [10]	2015	Ahvaz	Multiplier unique object	FSWs	Current	1,200	180-8,500	0·35	0·05-2·43
Sharifi, 2017 [10]	2015	Arak	Multiplier unique object	FSWs	Current	3,000	500-21,900	1·81	0·28-13·2
Sharifi, 2017 [10]	2015	Bandar Abbas	Multiplier unique object	FSWs	Current	390	170-900	0·28	0·12-0·65
Sharifi, 2017 [10]	2015	Isfahan	Multiplier unique object	FSWs	Current	2,300	1,150-5,850	0·38	0·19-0·97
Sharifi, 2017 [10]	2015	Kerman	Multiplier unique object	FSWs	Current	1,400	200-9,700	0·73	0·11-5·17
Sharifi, 2017 [10]	2015	Kermanshah	Multiplier unique object	FSWs	Current	70	40-120	0·03	0·01-0·04
Sharifi, 2017 [10]	2015	Khoram Abad	Multiplier unique object	FSWs	Current	200	150-290	0·17	0·13-0·25
Sharifi, 2017 [10]	2015	Mashhad	Multiplier unique object	FSWs	Current	3,000	1,700-5,300	0·35	0·20-0·63
Sharifi, 2017 [10]	2015	Sari	Multiplier unique object	FSWs	Current	4,700	1,000-6,600	5·00	1·06-7·00
Sharifi, 2017 [10]	2015	Shiraz	Multiplier unique object	FSWs	Current	1,300	700-22,700	0·26	0·13-0·54
Sharifi, 2017 [10]	2015	Tabriz	Multiplier unique object	FSWs	Current	170	50-700	0·04	0·01-0·15
Sharifi, 2017 [10]	2015	Tehran	Multiplier unique object	FSWs	Current	7,500	1,600-42,300	0·3	0·06-1·68
Sharifi, 2017 [10]	2015	Ahvaz	Network scale-up	Gen pop	Current	4,300	3,300-5,200	1·22	0·96-1·47
Sharifi, 2017 [10]	2015	Arak	Network scale-up	Gen pop	Current	2,200	1,700-2,600	1·30	1·05-1·55
Sharifi, 2017 [10]	2015	Bandar Abbas	Network scale-up	Gen pop	Current	2,200	1,800-2,500	1·56	1·31-1·84
Sharifi, 2017 [10]	2015	Isfahan	Network scale-up	Gen pop	Current	14,700	13,100-16,500	2·44	2·16-2·74
Sharifi, 2017 [10]	2015	Kerman	Network scale-up	Gen pop	Current	2,000	1,500-2,500	1·06	0·85-1·31
Sharifi, 2017 [10]	2015	Kermanshah	Network scale-up	Gen pop	Current	4,000	3,300-4,700	1·47	1·23-1·75
Sharifi, 2017 [10]	2015	Khoram Abad	Network scale-up	Gen pop	Current	740	570-930	0·65	0·50-0·80
Sharifi, 2017 [10]	2015	Mashhad	Network scale-up	Gen pop	Current	15,200	12,500-18,100	1·81	1·49-2·16
Sharifi, 2017 [10]	2015	Sari	Network scale-up	Gen pop	Current	1,500	1,200-1,700	1·54	1·30-1·81
Sharifi, 2017 [10]	2015	Shiraz	Network scale-up	Gen pop	Current	8,100	7,100-9,100	1·67	1·46-1·89
Sharifi, 2017 [10]	2015	Tabriz	Network scale-up	Gen pop	Current	640	420-930	0·14	0·09-0·19
Sharifi, 2017 [10]	2015	Tehran	Network scale-up	Gen pop	Current	38,700	34,200-43,400	1·54	1·36-1·71
Sharifi, 2017 [10]	2015	Zahedan	Network scale-up	Gen pop	Current	2,600	2,200-3,000	1·63	1·38-1·88
Karami, 2017 [11]	2016	Tehran	Capture-recapture	FSWs	Current	690	633-747	NR	NR
Morocco									
MOH, 2012 [12]	2011-12	Agadir	Multiplier unique object	FSWs	Past 6 M	3,639-4,333	1,556-5,480	NR	NR
MOH, 2012 [12]	2011-12	Fes	Multiplier unique object	FSWs	Past 6 M	6,028	3,631-8,504	NR	NR
MOH, 2012 [12]	2011-12	Rabat	Multiplier unique object	FSWs	Past 6 M	5,683	4,760-7,333	NR	NR
MOH, 2012 [12]	2011-12	Tanger	Multiplier unique object	FSWs	Past 6 M	3,956	3,677-4,234	NR	NR
Huygens, 2013 [13]	2013	Agadir	Census	Brothel-based FSWs	Current	955	NR	NR	NR
Huygens, 2013[13]	2013	Agadir	Capture-recapture	FSWs at floating sites	Current	7,253	NR	NR	NR
Pakistan									
NACP, 2005 [14] (pilot)	2004-05	Karachi	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, & street-based FSWs	Current	11,546	10,239-12,853	NR	NR
NACP, 2005 [14] (pilot)	2004-05	Rawalpindi	Enumeration (time-location geographical mapping)	Kothikhana, home & street-based FSWs	Current	1,596	1,293-1,899	NR	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
NACP, 2005 [15] (round I)	2005	Faisalabad	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, & street-based FSWs	Current	2,050	1,600-2,500	0·46	NR
NACP, 2005 [15] (round I)	2005	Hyderabad	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, & street-based FSWs	Current	1,350	1,200-1,500	0·69	NR
NACP, 2005 [15] (round I)	2005	Karachi	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, & street-based FSWs	Current	11,550	10,200-12,900	0·58	NR
NACP, 2005 [15] (round I)	2005	Lahore	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, & street-based FSWs	Current	14,150	12,100-16,200	1·26	NR
NACP, 2005 [15] (round I)	2005	Multan	Enumeration (time-location geographical mapping)	Kothikhana, home & street-based FSWs	Current	2,500	2,000-3,000	0·99	NR
NACP, 2005 [15] (round I)	2005	Peshawar	Enumeration (time-location geographical mapping)	Kothikhana, home & street-based FSWs	Current	950	800-1,100	0·45	NR
NACP, 2005 [15] (round I)	2005	Quetta	Enumeration (time-location geographical mapping)	Kothikhana, home & street-based FSWs	Current	750	600-900	0·64	NR
NACP, 2005 [15] (round I)	2005	Sukkur	Enumeration (time-location geographical mapping)	Kothikhana, home & street-based FSWs	Current	1,750	1,500-2,000	0·88	NR
Emmanuel, 2010 [16] (round II)	2006	Bannu	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	125	NR	0·04	NR
Emmanuel, 2010 [16] (round II)	2006	Faisalabad	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	9,500	NR	1·30	NR
Emmanuel, 2010 [16] (round II)	2006	Gujranwala	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,421	NR	0·58	NR
Emmanuel, 2010 [16] (round II)	2006	Hyderabad	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	2,750	NR	0·71	NR
Emmanuel, 2010 [16] (round II)	2006	Karachi	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	25,550	NR	0·74	NR
Emmanuel, 2010 [16] (round II)	2006	Lahore	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	24,625	NR	1·34	NR
Emmanuel, 2010 [16] (round II)	2006	Larkana	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	525	NR	0·44	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
Emmanuel, 2010 [16] (round II)	2006	Multan	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	5,075	NR	1·22	NR
Emmanuel, 2010 [16] (round II)	2006	Peshawar	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	1,550	NR	0·44	NR
Emmanuel, 2010 [16] (round II)	2006	Quetta	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,500	NR	1·10	NR
Emmanuel, 2010 [16] (round II)	2006	Rawalpindi	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	1,596	NR	0·31	NR
Emmanuel, 2010 [16] (round II)	2006	Sargodha	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	1,831	NR	0·67	NR
Emmanuel, 2010 [16] (round II)	2006	Sukkur	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,550	NR	1·14	NR
Khan, 2011 [17]	2007	Lahore	Network scale-up	FSWs	NR	5,226	NR	NR	NR
Khan, 2011 [17]	2007	Lahore	Network scale-up	FSWs (<30 years)	NR	NR	NR	0·43	NR
Khan, 2011 [17]	2007	Lahore	Network scale-up	FSWs (30+ years)	NR	NR	NR	0·56	NR
NACP, 2008 [18]	2007	Faisalabad	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	86	NR	NR	NR
NACP, 2008 [18]	2007	Karachi	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	498	NR	NR	NR
NACP, 2008 [18]	2007	Lahore	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	9	NR	NR	NR
NACP, 2008 [18]	2007	Larkana	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	5	NR	NR	NR
NACP, 2008 [18]	2007	Mardan	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	2	NR	NR	NR
NACP, 2008 [18]	2007	Peshawar	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	1,030	NR	NR	NR
NACP, 2008 [18]	2007	Quetta	Enumeration (time-location geographical mapping)	Adolescent FSWs	Current	105	NR	NR	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	DG Khan	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	1,413	1,307-1,518	1·30	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Faisalabad	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	4,846	4,381-5,311	0·50	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Haripur	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,994	2,850-3,138	1·19	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Hyderabad	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	4,566	4,018-5,113	0·85	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Karachi	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	25,399	21,794-29,004	0·55	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Lahore	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	23,766	21,109-26,422	1·15	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Larkana	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	1,114	969-1,258	0·82	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Mirpurkhas	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	884	852-915	0·85	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Multan	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	5,308	4,767-5,847	0·80	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Nawabshah	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	2,011	1,672-2,352	1·42	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Peshawar	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	3,317	2,897-3,736	0·42	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Quetta	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	3,710	3,271-4,149	1·07	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Rawalpindi	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	3,635	3,263-4,021	0·34	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Sargodha	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	3,898	3,597-4,198	1·25	NR
Emmanuel, 2013 [19, 20] (round IV)	2011-12	Sukkur	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,317	2,031-2,610	1·05	NR
Punjab ACP, 2015 [21]	2014	Faisalabad	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	7,556	5,500-9,612	NR	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate N	Range	%*	Range*
Punjab ACP, 2015 [21]	2014	Lahore	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	25,716	21,685-29,746	NR	NR
Punjab ACP, 2015 [21]	2014	Multan	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	6,561	4,272-8,850	NR	NR
Punjab ACP, 2015 [21]	2014	Sargodha	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	4,327	2,987-5,667	NR	NR
NACP, 2017 [22] (round V)	2016-17	Bahawalpur	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	6,201	5,522-6,737	NR	NR
NACP, 2017 [22] (round V)	2016-17	Bannu	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	192	171-209	NR	NR
NACP, 2017 [22] (round V)	2016-17	DG Khan	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	1,349	1,201-1,466	NR	NR
NACP, 2017 [22] (round V)	2016-17	Gujranwala	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	4,069	3,624-4,420	NR	NR
NACP, 2017 [22] (round V)	2016-17	Gujrat	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	317	282-344	NR	NR
NACP, 2017 [22] (round V)	2016-17	Hyderabad	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	4426	3,942-4,808	NR	NR
NACP, 2017 [22] (round V)	2016-17	Karachi	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	25,191	22,434-27,367	NR	NR
NACP, 2017 [22] (round V)	2016-17	Kasur	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	1,739	1,549-1,889	NR	NR
NACP, 2017 [22] (round V)	2016-17	Larkana	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	4,593	4,090-4,990	NR	NR
NACP, 2017 [22] (round V)	2016-17	Mirpurkhas	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,084	1,856-2,264	NR	NR
NACP, 2017 [22] (round V)	2016-17	Nawabshah	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	1,690	1,505-1,836	NR	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
NACP, 2017 [22] (round V)	2016-17	Peshawar	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	765	681-831	NR	NR
NACP, 2017 [22] (round V)	2016-17	Rawalpindi	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	2,465	2,195-2,678	NR	NR
NACP, 2017 [22] (round V)	2016-17	Quetta	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	4,121	3,670-4,477	NR	NR
NACP, 2017 [22] (round V)	2016-17	Sheikhupura	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	6,252	5,568-6,792	NR	NR
NACP, 2017 [22] (round V)	2016-17	Sialkot	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	2,031	1,809-2,206	NR	NR
NACP, 2017 [22] (round V)	2016-17	Sukkur	Enumeration (time-location geographical mapping)	Kothikhana, home, street-based, & other FSWs	Current	3,307	2,945-3,593	NR	NR
NACP, 2017 [22] (round V)	2016-17	Turbat	Enumeration (time-location geographical mapping)	Brothel, kothikhana, home, street-based, & other FSWs	Current	523	466-568	NR	NR
Somalia									
WHO, 2011[23]	2011	Berbera & Bossaso	NR	FSWs	Current	614	NR	NR	NR
MOH, 2016 [24]	2016	Bossaso	Enumeration (time-location geographical mapping)	FSWs	Past 12 M	911	736-1,079	NR	NR
MOH, 2016 [24]	2016	Hargeisa	Enumeration (time-location geographical mapping)	FSWs	Past 12 M	1,126	842-1,409	NR	NR
MOH, 2016 [24]	2016	Mogadishu	Multiplier unique object	FSWs	Past 12 M	963	NR	NR	NR
Sudan									
NACP, 2002 [25]	2002	Khartoum, Gezira, Kassala	Pop-bsd survey (self-report)	Refugees (predom. women)	Past 12 M	NR	NR	0·83	NR
NACP, 2002 [25]	2002	Khartoum, Gezira, Kassala	Conv sample (self-report)	ANC attendees	Past 12 M	NR	NR	0·5	NR
NACP, 2005 [26]	2005	South Darfur	Conv sample (self-report)	Tea and food sellers	Lifetime	NR	NR	3·00	NR
UNHCR, 2007 [27]	2006	Juba, South Sudan	Pop-bsd survey (self-report)	Gen pop (15-49 years)	Lifetime	NR	NR	0·4	NR
UNHCR, 2007 [27]	2006	Juba, South Sudan	Pop-bsd survey (self-report)	Gen pop (15-49 years)	Past 12 M	NR	NR	0·2	NR

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
NAP, 2015 [28]	2008	Juba, South Sudan	Conv sample (self-report)	Gen pop	Past 12 M	NR	NR	10	NR
NAP, 2015 [28]	2008	Morobo, South Sudan	Conv sample (self-report)	Gen pop	Past 12 M	NR	NR	13	NR
WHO, 2011 [23]	2012	Juba, South Sudan	NR	FSWs	Current	2,511	NR	NR	NR
WHO, 2011 [23]	2012	Yambio, South Sudan	NR	FSWs	Current	375	NR	NR	NR
NAP, 2016 [29]	2015	Juba, Yei, & Nimule, South Sudan	NR	FSWs	NR	4,700	NR	NR	NR
MOH, 2016 [30]	2015-16	Juba, South Sudan	Multiplier unique object	FSWs	Past 6 M	5,800	4,927-6,673	NR	NR
MOH, 2016 [30]	2015-16	Juba, South Sudan	Capture-recapture	FSWs	Past 6 M	5,306	4,673-5,939	NR	NR
Tunisia									
Hsairi, 2012 [31]	2011	Tunis	Multiplier unique object	Street-based FSWs	Current	541	447-681	NR	NR
Hsairi, 2012 [31]	2011	Sfax	Multiplier unique object	Street-based FSWs	Current	596	477-795	NR	NR
Hsairi, 2012 [31]	2011	Sousse	Multiplier unique object	Street-based FSWs	Current	291	250-350	NR	NR
Yemen									
MOH, 2010 [32]	NR	Aden	Enumeration (time-location geographical mapping)	FSWs	Current	NR	1,875-4,260	NR	1·16-2·64
MOH, 2010 [32]	NR	Hodeida	Enumeration (time-location geographical mapping)	FSWs	Current	NR	1,580-1,759	NR	1·89-2·10
MOH, 2010 [32]	NR	Mukallah	Enumeration (time-location geographical mapping)	FSWs	Current	NR	1,488-1,786	NR	2·07-2·49
MOH, 2010 [32]	NR	Sanaa	Enumeration (time-location geographical mapping)	FSWs	Current	NR	3,092-4,495	NR	0·64-2·10
MOH, 2010 [32]	NR	Taiz	Enumeration (time-location geographical mapping)	FSWs	Current	NR	1,050-1,835	NR	0·80-1·40
Clients of FSWs									
Afghanistan									
Mansoor, 2008**[33]**	2007	Balkh, Herat, Kabul, & Nangahar	Pop-bsd survey (self-report)	Freshmen students	Past 12 M	NR	NR	5·2	NR
Djibouti									
Trellu-Kane, 2005**[7]**	2005	Djibouti	Conv sample (self-report)	Gen pop (13-24 years)	Past 12 M	NR	NR	17	NR
Iran									
Shokoohi, 2012**[34]**	NR	Kerman	Network scale-up, (probability method) based on conv sample	Gen pop	Past 12 M	9,314	7,710-10,916	7·0	5·8-8·2

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
Shokoohi, 2012 [34]	NR	Kerman	Network scale-up, (frequency method) based on conv sample	Gen pop	Past 12 M	3,203	1,704-5,130	2·4	1·3-3·9
Khalajabadi, 2018 [35]	2013-14	Tehran	Pop-bsd survey (self-report)	University students	Last sex	NR	NR	1·3	NR
Khalajabadi, 2018 [35]	2013-14	Tehran	Pop-bsd survey (self-report)	University students	Lifetime	NR	NR	6·6	NR
Lebanon									
Melikian, 1954 [36]	1952	Beirut	Conv sample (self-report)	University students in a liberal and comparatively Western college student environment	Past 12 M	NR	NR	59·3	NR
Melikian, 1967[37]	1963	Beirut	Conv sample (self-report)	University students in a liberal and comparatively Western college student environment	Past 12 M	NR	NR	40·6	NR
Ghandour, 2014[38]	2012	Beirut	Pop-bsd survey (self-report)	University students (18-30 years)	Lifetime paid sex	NR	NR	20·1	NR
Pakistan									
Faisel, 2005 [39]	2004-05	Lahore	Pop-bsd survey (self-report)	Migrant workers	Past 12 M	NR	NR	6·8	NR
Minhas, 2005 [40]	2005	NR	Self-report (conv sample)	Students	Current	NR	NR	7	NR
Somalia									
Ismail, 1990[41]	1986	Mogadishu	Self-report (conv sample)	Healthcare workers and medical students	NR	NR	NR	48	NR
Ismail, 1990 [42]	1987	Jambaluul village	Conv sample (self-report; take all)	Gen pop	Lifetime	NR	NR	29	NR
MOH, 2016 [24]	2016	Bossaso	Enumeration (time-location geographical mapping)	Secondary key informants	Past 12 M	3,469	2,480-4,453	NR	NR
MOH, 2016 [24]	2016	Bossaso	Wisdom of the crowds	Gen pop	Past 12 M	3,530	NR	NR	NR
MOH, 2016 [24]	2016	Hargeisa	Enumeration (time-location geographical mapping)	Secondary key informants	Past 12 M	1,828	1,301-2,353	NR	NR
MOH, 2016 [24]	2016	Hargeisa	Wisdom of the crowds	Gen pop	Past 12 M	1,559	NR	NR	NR
MOH, 2016 [24]	2016	Mogadishu	Enumeration (time-location geographical mapping)	Secondary key informants	Past 12 M	2,599	1,801-3,395	NR	NR
MOH, 2016 [24]	2016	Mogadishu	Wisdom of the crowds	Gen pop	Past 12 M	2,202	NR	NR	NR
Sudan									
McCarthy, 1989[43]	1987-88	Port Sudan, Kassala, Gederef, Juba & Omdurman	Conv sample (self-report)	Soldiers attending outpatient military clinics	Lifetime	NR	NR	51·6	NR
Holt, 2003 [44]	1992	Dimma refugee camp	Conv sample (self-report)	Sudanese refugees	Lifetime	NR	NR	46·0	39·0-53·0

Country Author, year [citation]	Year(s) of data collection	City/ province	Estimation methodology	Sample type	Time frame	Reported size estimate			
						N	Range	%*	Range*
Holt, 2003 [44]	1992	Dimma refugee camp	Conv sample (self-report)	Sudanese refugees	Past 3 M	NR	NR	31·0	25·0-38·0
NACP, 2002 [25]	2002	Blue Nile & Equatoria	Conv sample (self-report)	Military personnel	Past 12 M	NR	NR	11·7	NR
UNHCR, 2007 [27]	2006	Juba, South Sudan	Pop-bsd survey (self-report)	Gen pop (15-49 years)	Lifetime	NR	NR	1·7	NR
UNHCR, 2007 [27]	2006	Juba, South Sudan	Pop-bsd survey (self-report)	Gen pop (15-49 years)	Past 12 M	NR	NR	1·4	NR
United Arab Emirates									
MOH, 2014 [45]	2010-11	NR	Conv sample (self-report)	University students	Lifetime	NR	NR	0·07	NR

The table is sorted by year(s) of data collection or year of publication if year of data collection was not reported.

*The decimal places of the population proportion figures are as reported in the original reports.

Abbreviations: *ACP* AIDS Control Program, *ANC* antenatal clinic, *Conv* convenience, *DG Khan* Dera Ghazi Khan, *Gen* general, *FSWs* female sex workers, *M* months, *MOH* ministry of Health, *NACP* National AIDS Control Programme, *NAP* National AIDS Program, *NR* not reported, *Pop* population, *Pop-bsd* population-based, *SAR AIDS HDS* South Asia Region AIDS Human Development Sector, *UNHCR* United Nations Higher Commission for Refugees, *WHO* World Health Organization

Table S5 HIV point-prevalence measures in FSWs as extracted or obtained from various sources including the US Census Bureau database, the WHO-EMRO, and the UNAIDS epidemiological fact sheets databases, among other sources of data

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
Afghanistan							
MENA HIV ESP, 2013[46]	2011-12	National	NR	NR	FSWs	487	0
MENA HIV ESP, 2013 [46]	2012	National	NR	NR	FSWs	1039	0·3
Algeria							
Abu-Raddad, 2010 [2]	2004	NR	NR	NR	FSWs	NR	3·0
Abu-Raddad, 2010 [2]	2004	NR	NR	NR	FSWs	NR	4·0
Jenkins, 2003 [47]	1988	NR	NR	NR	FSWs	NR	1·2
MOH, 1990 [48]	1988	Oran	NR	Conv	FSWs	52	1·9
MOH, 1990 [48]	1988	Blida	NR	Conv	FSWs	34	0
MOH, 1990 [48]	1988	Tlemcen	NR	Conv	FSWs	43	0
MOH, 1990 [48]	1988	Ghardaia	NR	Conv	FSWs	19	0
MOH, 1990 [48]	1988	Biskra	NR	Conv	FSWs	13	7·7
MOH, 1990 [48]	1988	Constantine	NR	Conv	FSWs	237	0·4
MOH, 1990 [48]	1988	Tindouf	NR	Conv	FSWs	11	0
Addad, 1993 [49]	1991	NR	NR	NR	FSWs	NR	0
Jenkins, 2003 [47]	2000	NR	NR	NR	FSWs	20	10
MOH, 2009 [50]	2000	Tamanrasset & Oran	Sentinel surveillance	Conv	FSWs	139	2·9
UNAIDS, 2008 [51]	2000	Tamanrasset	NR	NR	FSWs	NR	20
Abu-Raddad, 2010 [2]	2004	NR	NR	NR	FSWs	NR	2·0
MOH, 2009 [50]	2004	National	Sentinel surveillance	Conv	FSWs	185	3·8
MOH, 2009 [50]	2007	National	Sentinel surveillance	Conv	FSWs	380	4·0
MOH, 2016 [52]	2008	Tamanrasset	Sentinel surveillance	Conv	FSWs	161	1·2
MOH, 2016 [52]	2012	Tamanrasset	Sentinel surveillance	Conv	FSWs	109	4·6
MOH, 2014 [53]	2014	Saida	Sentinel surveillance	Conv	FSWs	78	5·1
MOH, 2017 [54]	2017	NR	NR	NR	FSWs	NR	5·5
MOH, 2018 [55]	2018	NR	NR	NR	FSWs	NR	4·2
Bahrain							
MOH, 2012 [56]	2010-11	National	Detainment center	Conv	FSWs tested at detainment	724	0·8
Djibouti							
Jenkins, 2003 [47]	1987	NR	NR	NR	Street-based FSWs	NR	3·9
UNAIDS, 2008 [51]	1987	Djibouti	NR	NR	FSWs	NR	2·1
Bailly, 1988 [57]	1987-88	NR	NR	NR	FSWs	251	2·8
UNAIDS, 2008 [51]	1988	Djibouti	NR	NR	FSWs	NR	4·2
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	560	5·2
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	Bar girls	476	2·1
MENA HIV ESP, 2010 [2]	1990	NR	Sentinel surveillance	Conv	Bar girls	190	5·8
UNAIDS, 2008 [51]	1990	Djibouti (Major urban areas)	NR	NR	FSWs	NR	19·5
Jenkins, 2003 [47]	1991	NR	NR	NR	Bar girls	NR	14·2
MENA HIV ESP, 2010 [2]	1991	NR	Sentinel surveillance	Conv	FSWs	449	31·4
MENA HIV ESP, 2010 [2]	1991	NR	Sentinel surveillance	Conv	Bar girls	618	13·1

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
OMS, 2001 [58]	1991	NR	NR	NR	FSWs	NR	39·8
UNAIDS, 2008 [51]	1991	Djibouti (Major urban areas)	NR	NR	FSWs	NR	26·0
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	FSWs	400	43·0
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	Bar girls	724	12·4
MOH, 1993[59]	1992	NR	NR	NR	Street-based FSWs	NR	51·4
MOH, 1993 [59]	1992	NR	NR	NR	Bar girls	NR	21·7
UNAIDS, 2008[51]	1992	Djibouti (Major urban areas)	NR	NR	FSWs	NR	36·6
Jenkins, 2003 [47]	1993	NR	NR	NR	Bar girls	NR	25·6
Jenkins, 2003 [47]	1993	NR	NR	NR	Street-based FSWs	NR	55·8
MOH, 1993 [59]	1993	NR	NR	NR	Bar girls	411	23·4
MOH, 1993 [59]	1993	NR	NR	NR	Street-based FSWs	313	56·5
OMS, 2001 [58]	1993	NR	NR	NR	Bar girls	NR	27·0
Shrestha, 1999 [60]	1993	NR	Bars	NR	Bar girls	1039	14·7
Shrestha, 1999 [60]	1993	NR	NR	NR	FSWs	571	47·5
UNAIDS, 2008 [51]	1993	Djibouti (Major urban areas)	NR	NR	FSWs	NR	37·7
UNAIDS, 2008 [51]	1993	Outside major urban areas	NR	NR	FSWs	NR	26·3
UNAIDS, 2008 [51]	1993	Outside major urban areas	NR	NR	FSWs	NR	0·1
Shrestha, 1999 [60]	1994	NR	Bars	NR	Bar girls	852	12·2
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	573	45·4
UNAIDS, 2008 [51]	1994	Outside major urban areas	NR	NR	FSWs	NR	25·5
UNAIDS, 2008 [51]	1994	Outside major urban areas	NR	NR	FSWs	NR	0
Shrestha, 1999 [60]	1995	NR	Bars	NR	Bar girls	68	11·8
UNAIDS, 2008 [51]	1995	Outside major urban areas	NR	NR	FSWs	NR	36·8
UNAIDS, 2008 [51]	1995	Outside major urban areas	NR	NR	FSWs	NR	0·1
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	364	41·5
US Dep. of State, 2000 [61]	1995	NR	NR	NR	FSWs	NR	57·0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	294	32·7
UNAIDS, 2008 [51]	1996	Outside major urban areas	NR	NR	FSWs	NR	0
Shrestha, 1999 [60]	1997	NR	NR	NR	FSWs	327	32·7
UNAIDS, 2008 [51]	1997	Outside major urban areas	NR	NR	FSWs	NR	0
Bahdon, 1998 [62]	1998	NR	NR	NR	FSWs	117	28·2
MOH, 1999 [63]	1998	NR	NR	NR	FSWs	142	27·5
UNAIDS, 2008 [51]	1998	Outside major urban areas	NR	NR	FSWs	NR	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	42	38·1
UNAIDS, 2008 [51]	1999	Outside major urban areas	NR	NR	FSWs	NR	0
UNAIDS, 2008 [51]	1999	Outside major urban areas	NR	NR	FSWs	NR	0
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	FSWs	34	20·6
MOH, 2008 [64]	2007	NR	NR	NR	FSWs	66	19·7
MOH, 2010 [65]	2007	NR	Sentinel surveillance	Conv	FSWs	NR	18·0
MOH, 2008 [64]	2008	NR	NR	NR	FSWs	52	17·3
WHO, 2011 [23]	2008	NR	Clinics	Conv	FSWs	79	20·3
MOH, 2010 [65]	2009	NR	Sentinel surveillance	Conv	FSWs	NR	15·3

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
MENA HIV ESP, 2013 [46]	2012	Djibouti	Clinical center	Conv	FSWs	718	13·1
Egypt							
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	347	0
Mourad, 1992 [66]	1990-91	Cairo	NR	NR	FSWs	154	0
MOH, 2001 [67]	1992	NR	NR	Conv	FSWs	160	0
MOH, 2001 [67]	1993	NR	NR	Conv	FSWs	221	0
Murugasampillay, 1995[68]	1993	Alexandria	NR	Conv	FSWs	42	0
MOH, 2001 [67]	1994	NR	NR	Conv	FSWs	194	0
MOH, 2001 [67]	1995	NR	NR	Conv	FSWs	129	0
MENA HIV ESP, 2010 [2]	1996	NR	Sentinel surveillance	Conv	FSWs	145	0·7
MOH, 2001 [67]	1996	NR	NR	Conv	FSWs	112	0·9
MENA HIV ESP, 2010 [2]	1997	NR	Sentinel surveillance	Conv	FSWs	79	0
MOH, 2001 [67]	1997	NR	NR	Conv	FSWs	179	1·1
MENA HIV ESP, 2010 [2]	1998	NR	Sentinel surveillance	Conv	FSWs	69	0
MOH, 2001 [67]	1998	NR	NR	Conv	FSWs	269	1·5
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	172	0·6
MOH, 2001 [67]	1999	NR	NR	Conv	FSWs	183	1·1
MOH, 2001 [67]	2000	NR	NR	Conv	FSWs	129	0
MOH, 2001 [67]	2001	NR	NR	Conv	FSWs	65	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	FSWs	203	0
MENA HIV ESP, 2010 [2]	2003	NR	Sentinel surveillance	Conv	FSWs	265	0
MENA HIV ESP, 2010 [2]	2003	NR	Sentinel surveillance	Conv	Bar girls	181	0
MENA HIV ESP, 2010 [2]	2004	NR	Sentinel surveillance	Conv	FSWs	345	0
US Census Bureau, 2017 [69]	2004	NR	Sentinel surveillance	Conv	FSWs	308	0
MENA HIV ESP, 2010 [2]	2005	NR	Sentinel surveillance	Conv	FSWs	192	0
MENA HIV ESP, 2010 [2]	2006	National	NR	NR	FSWs & bar girls	975	0
Arafa, 2007 [70]	2006-07	Alexandria	Clinic	Conv	FSWs	NR	0
NAP, 2014 [71]	2010	Cairo	NGO	Conv	FSWs	137	0
NAP, 2014 [71]	2013	NR	VCT	Conv	FSWs	188	0·5
NAP, 2017 [72]	2016	NR	Sentinel surveillance	Conv	FSWs	249	1·2
Iran							
NACP, 1994 [73]	1987-91	NR	Sentinel surveillance	Conv	FSWs	3596	0·03
MENA HIV ESP, 2010 [2]	1990	NR	Sentinel surveillance	Conv	FSWs	708	0·1
MENA HIV ESP, 2010 [2]	1991-92	NR	Sentinel surveillance	Conv	FSWs	2897	0
NACP, 1994 [73]	1993-94	Evin	Sentinel surveillance	Conv	FSWs	400	0
Eltayeb, 1995 [74]	1994	NR	Rehab. centers	Conv	FSWs	31	0
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	505	0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	120	0
Shrestha, 1999 [60]	1997	NR	NR	NR	FSWs	220	0
Shrestha, 1999 [60]	1998	NR	NR	NR	FSWs	1605	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	800	0

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
Feizzadeh, 2010 [75]	2000	Charmanhal	Prison	Conv	Incarcerated FSWs	NR	14
MENA HIV ESP, 2010 [2]	2000-01	NR	Sentinel surveillance	Conv	FSWs	404	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	FSWs	309	0
MENA HIV ESP, 2010 [2]	2003-05	NR	Sentinel surveillance	Conv	FSWs	44	2·3
MENA HIV ESP, 2010 [2]	2005	Isfahan	Sentinel surveillance	Conv	FSWs	258	0
MOH, 2006 [76]	2005	Tehran	NR	Conv	FSWs	50	0
MENA HIV ESP, 2010 [2]	2006 Q1 & Q3	National	NR	NR	FSWs & bar girls	301	2·7
MENA HIV ESP, 2010 [2]	2006	Isfhan	Sentinel surveillance	Conv	FSWs	281	0
Feizzadeh, 2010 [75]	2007	Kermanshah	PHC	Conv	FSWs attending clinics	NR	3
Feizzadeh, 2010 [75]	2007	Kohkilouye	Prison	Conv	Incarcerated FSWs	NR	11
Iraq							
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	Bar girls	300	0
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	420	0
MENA HIV ESP, 2010 [2]	1990	NR	Sentinel surveillance	Conv	Bar girls	429	0
MENA HIV ESP, 2010 [2]	1990	NR	Sentinel surveillance	Conv	FSWs	678	0
MENA HIV ESP, 2010 [2]	1991	NR	Sentinel surveillance	Conv	Bar girls	334	0
MENA HIV ESP, 2010 [2]	1991	NR	Sentinel surveillance	Conv	FSWs	225	0
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	Bar girls	369	0
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	FSWs	14	0
Shrestha, 1999 [60]	1993	NR	NR	NR	Bar girls	1337	0
Shrestha, 1999 [60]	1993	NR	NR	NR	FSWs	987	0
Shrestha, 1999 [60]	1994	NR	NR	NR	Bar girls	1083	0
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	1084	0
Shrestha, 1999 [60]	1995	NR	NR	NR	Bar girls	876	0
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	1408	0
Shrestha, 1999 [60]	1996	NR	NR	NR	Bar girls	472	0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	1272	0·07
Shrestha, 1999 [60]	1997	NR	NR	NR	Bar girls	582	0
Shrestha, 1999 [60]	1997	NR	NR	NR	FSWs	475	0
Shrestha, 1999 [60]	1998	NR	NR	NR	Bar girls	1027	0
Shrestha, 1999 [60]	1998	NR	NR	NR	FSWs	12	0
Shrestha, 1999 [60]	1998	NR	NR	NR	Bar girls	33	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	Bar girls	98	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	1255	0
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	Bar girls	87	0
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	FSWs	199	0
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	Bar girls	153	0
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	FSWs	253	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	Bar girls	96	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	FSWs	294	0
Jordan							
El-Tayeb, 1995 [77]	1990	NR	NR	NR	FSWs	40	0

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
El-Tayeb, 1995 [77]	1991	NR	NR	NR	FSWs	75	1·3
El-Tayeb, 1995 [77]	1994-95	NR	NR	NR	FSWs	12	0
Lebanon							
NACP, 1994 [78]	1987-89	National	NR	Conv	FSWs	741	0
NACP, 1994 [78]	1992	National	NR	Conv	FSWs	1507	0·3
NACP, 1994 [78]	1993	National	NR	Conv	FSWs	2195	0·1
NACP, 1994 [78]	1994	National	NR	Conv	FSWs	819	0
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	2912	0·07
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	2438	0
Jenkins, 2003 [47]	1999	NR	NR	NR	FSWs	205	0
Riedner, 2009 [79]	2008	NR	NR	NR	FSWs	NR	0·7
NACP, 2010 [80]	2008-09	NR	VCT	Conv	FSWs	41	2·4
Libya							
Shazly, 1991 [81]	1990	NR	NR	NR	FSWs	22	18·2
Shrestha, 1999 [60]	1993	NR	NR	NR	FSWs	554	1·1
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	604	1·2
Morocco							
Benslimane, 1987 [82]	1984-87	Casablanca	NR	Conv	FSWs	27	3·7
Riyad, 1990 [83]	1990	Casablanca	NR	Conv	FSWs	28	7·1
MOH, 2008 [84]	2001	Souss Massa Draa	Sentinel surveillance	Conv	FSWs	NR	6·3
MOH, 2013 [85]	2001	National	Sentinel surveillance	Conv	Incarcerated FSWs	217	2·3
MOH, 2013 [85]	2002	National	Sentinel surveillance	Conv	Incarcerated FSWs	350	3·1
MOH, 2006 [86]	2003	NR	NGO	Conv	FSWs	316	2·4
MOH, 2013 [85]	2003	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	264	2·3
MOH, 2013 [85]	2004	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	771	1·9
Bennani, 2006 [87]	2005	NR	Prison	Conv	Incarcerated FSWs	NR	2·9
MOH, 2008 [84]	2005	National	Sentinel surveillance	Conv	FSWs	NR	2·0
MOH, 2013 [85]	2005	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	227	2·2
MOH, 2008 [84]	2006	Souss Massa Draa	Sentinel surveillance	Conv	FSWs	NR	4·1
MOH, 2010 [88]	2006	National	Sentinel surveillance	Conv	FSWs	NR	2·5
MOH, 2010 [88]	2006	Souss Massa Draa	Sentinel surveillance	Conv	FSWs	NR	4·3
MOH, 2013 [85]	2006	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	650	0·2
MOH, 2010 [88]	2007	NA	NR	Conv	FSWs	810	2·6
MOH, 2013 [85]	2007	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	774	2·7
MOH, 2013 [85]	2008	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	1079	2·1
MOH, 2013 [2]	2008	National	VCT	Conv	FSWs	3110	1·3

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
MOH, 2013 [85]	2009	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	965	2·4
MOH, 2013 [2]	2009	National	VCT	Conv	FSWs	3484	2·1
MOH, 2013 [85]	2010	National	Sentinel surveillance	Conv	Incarcerated FSWs & FSWs attending clinics	1158	2·7
MOH, 2013 [2]	2010	National	VCT	Conv	FSWs	4380	2·4
MOH, 2013 [89]	2011	National	Sentinel surveillance	Conv	FSWs	1432	1·8
MOH, 2013 [2]	2011	National	VCT	Conv	FSWs	4895	1·8
Loudyi, 2013[90]	2012	Fes	VCT	Conv	FSWs	927	0·9
MOH, 2013 [85]	2012	National	Sentinel surveillance	Conv	FSWs attending clinics	643	2·0
MOH, 2013 {Abu-Raddad L, 2010 #43}	2012	National	VCT	Conv	FSWs	10355	1·6
Pakistan							
Girgis, 1990 [91]	1986-90	NR	NR	NR	FSWs	84	0
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	84	0
MENA HIV ESP, 2010 [2]	1991-92	NR	Sentinel surveillance	Conv	FSWs	17	0
Shrestha, 1999 [60]	1993	NR	NR	NR	FSWs	649	1·2
Shrestha, 1999 [60]	1994-95	NR	NR	NR	FSWs	142	0·7
UNAIDS, 2008 [51]	1995	Karachi	NR	NR	FSWs	NR	0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	104	0
Rizvi, 1999 [92]	1997	Multan	Red-light district	Conv	FSWs	577	0·5
MENA HIV ESP, 2010 [2]	1999-00	NR	Sentinel surveillance	Conv	FSWs	186	3·8
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	FSWs	103	0
Shah, 2001 [93]	2001	Sindh	VCT	Conv	FSWs	60	1·7
MENA HIV ESP, 2010 [2]	2002-04	NR	Sentinel surveillance	Conv	FSWs	24	8·3
Pasha, 2008 [94]	2007	Quetta	NR	NR	FSWs	92	0
Riedner, 2009 [79]	2008	NR	NR	NR	FSWs	NR	0·2
Pasha, 2009 [95]	2009	Faisalabad	NR	NR	FSWs	92	7
Pasha, 2011 [96]	2011	NR	NR	NR	FSWs	NR	1·2
Mir, 2013 [97]	2013	NR	NR	NR	FSWs	NR	0·6
Somalia							
Omar, 1988 [98]	1986-87	Mogadishu	Community (urban areas)	Conv	FSWs	287	0·4
Jenkins, 2003 [47]	1990	NR	NR	NR	FSWs	NR	2
Jenkins, 2003 [47]	1990	NR	NR	NR	FSWs	NR	4
Duffy, 1999 [99]	1999	Somaliland	NR	NR	FSWs	17	47·1
Sudan							
Ahmed, 1990 [100]	1989	South Sudan	NR	NR	FSWs	1027	2·8
Ahmed, 1990 [100]	1989	East Equatoria, South Sudan	NR	NR	FSWs	171	7·6
Ahmed, 1990 [100]	1989	West Equatoria, South Sudan	NR	NR	FSWs	70	24·3
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	920	2·7
Basha, 2006 [101]	2006	NR	NR	NR	FSWs	NR	1·6

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
Abu-Raddad, 2010 [2]	2007	NR	NR	NR	FSWs	NR	1·7
Elrashied, 2009 [102]	2009	Khartoum	NR	NR	FSWs	345	2·7
NAP, 2015 [28]	2011	NR	NR	NR	FSWs	NR	12
NAP, 2015 [28]	2014	NR	NR	NR	FSWs	764	28·9
NAP, 2016 [29]	2015	South Sudan	NGO	Conv	FSWs	2204	21
Syria							
El-Tayeb, 1995 [103]	1987-89	NR	Sentinel surveillance	Conv	FSWs	294	0
El-Tayeb, 1995 [103]	1990	NR	Sentinel surveillance	Conv	FSWs	369	0
El-Tayeb, 1995 [103]	1991	NR	Sentinel surveillance	Conv	FSWs	650	0
El-Tayeb, 1995 [103]	1992	NR	Sentinel surveillance	Conv	FSWs	502	0
El-Tayeb, 1995 [103]	1992	NR	Sentinel surveillance	Conv	Bar girls	1043	0
El-Tayeb, 1995 [103]	1993	NR	Sentinel surveillance	Conv	FSWs	794	0
El-Tayeb, 1995 [103]	1993	NR	Sentinel surveillance	Conv	Bar girls	697	0
El-Tayeb, 1995 [103]	1994	NR	Sentinel surveillance	Conv	FSWs	555	0
El-Tayeb, 1995 [103]	1994	NR	Sentinel surveillance	Conv	Bar girls	1825	0
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	525	0
Shrestha, 1999 [60]	1994	NR	NR	NR	Bar girls	1901	0
El-Tayeb, 1995 [103]	1995	NR	Sentinel surveillance	Conv	FSWs	59	0
El-Tayeb, 1995 [103]	1995	NR	Sentinel surveillance	Conv	Bar girls	158	0
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	1289	0
Shrestha, 1999 [60]	1995	NR	NR	NR	Bar girls	1269	0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	1526	0
Shrestha, 1999 [60]	1996	NR	NR	NR	Bar girls	1507	0
Shrestha, 1999 [60]	1997	NR	NR	NR	FSWs	1707	0
Shrestha, 1999 [60]	1997	NR	NR	NR	Bar girls	1717	0
Shrestha, 1999 [60]	1998	NR	NR	NR	FSWs	1628	0·1
Shrestha, 1999 [60]	1998	NR	NR	NR	Bar girls	2313	0·03
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	2688	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	Bar girls	2278	0
Shrestha, 1999 [60]	1999	NR	NR	NR	FSWs	1408	0
Shrestha, 1999 [60]	1999	NR	NR	NR	Bar girls	1166	0
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	Bar girls	2274	0
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	FSWs	2188	0
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	Bar girls	3304	0·1
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	FSWs	2281	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	Bar girls	2688	0·04
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	FSWs	1846	0
MENA HIV ESP, 2010 [2]	2003	NR	Sentinel surveillance	Conv	Bar girls	2653	0·04
MENA HIV ESP, 2010 [2]	2003	NR	Sentinel surveillance	Conv	FSWs	1019	0
MENA HIV ESP, 2010 [2]	2004	NR	Sentinel surveillance	Conv	Bar girls	4784	0·02
MENA HIV ESP, 2010 [2]	2004	NR	Sentinel surveillance	Conv	FSWs	1324	0
MENA HIV ESP, 2010 [2]	2005	NR	Sentinel surveillance	Conv	Bar girls	2673	0

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
MENA HIV ESP, 2010 [2]	2005	NR	Sentinel surveillance	Conv	FSWs	680	0·2
MOH, 2005 [104]	2005	Damascus	Sentinel surveillance	Conv	FSWs	400	0·2
MENA HIV ESP, 2010 [2]	2006, Q1	National	NR	NR	FSWs	197	0
MENA HIV ESP, 2010 [2]	2006, Q1	National	NR	NR	Bar girls	1528	0
MENA HIV ESP, 2010 [2]	2006, Q2	National	NR	NR	FSWs	311	0
MENA HIV ESP, 2010 [2]	2006, Q2	National	NR	NR	Bar girls	1354	0
MENA HIV ESP, 2010 [2]	2006, Q3	National	NR	NR	FSWs	121	0
MENA HIV ESP, 2010 [2]	2006, Q3	National	NR	NR	Bar girls	2001	0
MENA HIV ESP, 2010 [2]	2006, Q4	National	NR	NR	FSWs	345	0
MENA HIV ESP, 2010 [2]	2006, Q4	National	NR	NR	Bar girls	1197	0
MENA HIV ESP, 2010 [2]	2007, Q2	National	NR	NR	FSWs	596	0
MENA HIV ESP, 2010 [2]	2007, Q2	National	NR	NR	Bar girls	3570	0
MENA HIV ESP, 2010 [2]	2007, Q3	National	NR	NR	FSWs	526	0
MENA HIV ESP, 2010 [2]	2007, Q3	National	NR	NR	Bar girls	3421	0
NACP, 2008 [105]	2007	NR	Sentinel surveillance	Conv	FSWs	1288	0
NACP, 2008 [105]	2007	NR	Sentinel surveillance	Conv	Bar girls	7024	0
Al-Sayed, 2010 [106]	2009	National	Sentinel surveillance	Conv	FSWs	878	0
Al-Sayed, 2010 [106]	2009	National	Sentinel surveillance	Conv	Bar girls	8479	0
MENA HIV ESP, 2013 [46]	2011	National	NR	NR	FSWs	108	0
MENA HIV ESP, 2013 [46]	2011	National	NR	NR	Bar girls	6145	0
Tunisia							
Van de Perre, 1988 [107]	1985	NR	NR	NR	FSWs	108	1·9
Giraldo, 1988 [108]	1985-87	NR	NR	NR	FSWs	373	1·9
Gharbi, 1987 [109]	1987	Tunis	NR	NR	FSWs	198	0
Taibi, 1989 [110]	1987	Sfax	NR	NR	FSWs	36	0
MOH, 1990 [111]	1988-89	NR	NR	NR	FSWs	970	0·6
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	FSWs	523	0
MENA HIV ESP, 2010 [2]	1989	NR	Sentinel surveillance	Conv	Bar girls	447	1·3
Fekih, 1991 [112]	1990	NR	Sentinel surveillance	Conv	FSWs	273	0
MENA HIV ESP, 2010 [2]	1991	NR	Sentinel surveillance	Conv	FSWs	374	0·3
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	FSWs	778	0
MENA HIV ESP, 2010 [2]	1992	NR	Sentinel surveillance	Conv	Bar girls	88	2·3
NAP, 2005 [113]	1992	NR	NR	Conv	Street-based FSWs	NR	2·3
Shrestha, 1999 [60]	1993	NR	NR	NR	FSWs	402	0·3
Shrestha, 1999 [60]	1994	NR	NR	NR	FSWs	880	0·1
Shrestha, 1999 [60]	1995	NR	NR	NR	FSWs	1091	0
Shrestha, 1999 [60]	1996	NR	NR	NR	FSWs	1020	0·4
NAP, 2005 [113]	1997	NR	NR	Conv	Street-based FSWs	NR	0
Shrestha, 1999 [60]	1997	NR	NR	NR	FSWs	992	0·1
Shrestha, 1999 [60]	1998	NR	NR	NR	FSWs	694	0
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	996	0
Shrestha, 1999 [60]	1999	NR	NR	NR	FSWs	570	0

Country Author, year [citation]	Year(s) of data collection	City/province	Study site	Sampling	Population	Sample size	HIV prev* (%)
MENA HIV ESP, 2010 [2]	2000	NR	Sentinel surveillance	Conv	FSWs	483	0
NAP, 2005 [113]	2000	NR	NR	Conv	FSWs	NR	0
Jenkins, 2003 [47]	2001	NR	NR	NR	FSWs	458	0·2
MENA HIV ESP, 2010 [2]	2001	NR	Sentinel surveillance	Conv	FSWs	554	0·2
NAP, 2005 [113]	2001	NR	Prison	Conv	Incarcerated FSWs	100	0
MENA HIV ESP, 2010 [2]	2002	NR	Sentinel surveillance	Conv	FSWs	434	0
NAP, 2005 [113]	2002	NR	NR	Conv	Legal FSWs	1051	0
NAP, 2005 [113]	2002	NR	NR	Conv	Street-based FSWs	125	0
MENA HIV ESP, 2010 [2]	2003	NR	Sentinel surveillance	Conv	FSWs	916	0
NAP, 2005 [113]	2003	NR	NR	Conv	Legal FSWs	1109	0
NAP, 2005 [113]	2003	NR	NR	Conv	Street-based FSWs	13	0
MENA HIV ESP, 2010 [2]	2004	NR	Sentinel surveillance	Conv	FSWs	200	0
MOH, 2006 [114]	2004	NR	NR	Conv	Legal FSWs	568	0
MENA HIV ESP, 2010 [2]	2005	NR	Sentinel surveillance	Conv	FSWs	210	0
MOH, 2006 [114]	2005	NR	NR	Conv	Legal FSWs	640	0
MOH, 2006 [114]	2005	NR	NR	Conv	Street-based FSWs	18	0
MENA HIV ESP, 2010 [2]	2006, Q2	National	NR	NR	FSWs & bar girls	151	0
MENA HIV ESP, 2010 [2]	2006, Q3	National	NR	NR	FSWs & bar girls	93	0
MENA HIV ESP, 2010 [2]	2006, Q4	National	NR	NR	FSWs & bar girls	213	0
MENA HIV ESP, 2010 [2]	2007, Q1 & Q2	National	NR	NR	FSWs & bar girls	83	0
UNAIDS, 2008 [115]	2008	NR	NR	NR	FSWs	NR	2·3
MOH, 2010 [116]	2008	NR	Sentinel surveillance	Conv	Legal FSWs	300	0·3
MOH, 2010 [116]	2009	NR	Sentinel surveillance	Conv	Legal FSWs	NR	0
Yemen							
Shrestha, 1999 [60]	1998	NR	NR	NR	FSWs	88	4·6
MENA HIV ESP, 2010 [2]	1999	NR	Sentinel surveillance	Conv	FSWs	73	2·7
MENA HIV ESP, 2010 [2]	2000-01	NR	Sentinel surveillance	Conv	FSWs	39	0
Jenkins, 2003 [47]	2001	NR	NR	NR	FSWs	NR	7
MENA HIV ESP, 2010 [2]	2002-03	NR	Sentinel surveillance	Conv	FSWs	434	0
MENA HIV ESP, 2010 [2]	2004	NR	Sentinel surveillance	Conv	FSWs	203	0·5
MENA HIV ESP, 2010 [2]	2005-06	NR	Sentinel surveillance	Conv	FSWs	20	0
MENA HIV ESP, 2010 [2]	2006 Q1, Q2 & Q4	National	NR	NR	FSWs & bar girls	20	0

The table is sorted by year(s) of data collection or year of publication if year of data collection was not reported.

*The decimal places of the prevalence figures are as reported in the original reports, but prevalence figures with more than one decimal places were rounded to one decimal place, with the exception of those below 0·1%.

Abbreviations: *Conv* convenience, *Dep* department, *FSWs* female sex workers, *MENA HIV ESP* MENA HIV/AIDS Epidemiology Synthesis Project, *MOH* Ministry of Health, *NACP* National AIDS Control programme, *NAP* National AIDS Program, *NGO* non-governmental organization, *NR* not reported, *OMS* Organisation Mondiale de la Sante, *PHC* primary healthcare centers, *Prev* prevalence, *Q* Quarter, *UNAIDS* The Joint United Nations Programme on HIV/AIDS, *VCT* voluntary counselling and testing, *WHO* World Health Organization, *WHO-EMRO* World Health Organization Regional Office for the Eastern Mediterranean

Table S6 Summary of the risk of bias (ROB) assessment of size estimation and HIV prevalence studies in FSWs and their clients (or proxy populations of clients), in the Middle East and North Africa (MENA). Measures only extracted from routine databases with no reports describing the study methodology were not included in the ROB assessment

ROB quality domains	Size estimation studies				HIV prevalence studies			
	FSWs		Clients		FSWs		Clients	
	n	%	n	%	n	%	n	%
Sex work definition								
Low ROB	153	95·0	39	100·0	116	78.9	12	36·4
High ROB	0	0·0	0	0·0	0	0.0	1	3·0
Unclear	8	5·0	0	0·0	31	21.1	20	60·6
Estimation methodology								
Low ROB	156	96·9	27	69·2	NA	NA	NA	NA
High ROB	5	3·1	12	30·8	NA	NA	NA	NA
Unclear	0	0·0	0	0·0	NA	NA	NA	NA
Rigor of sampling methodology								
Low ROB	NA	NA	NA	NA	101	68.7	4	12·1
High ROB	NA	NA	NA	NA	43	29.3	29	87·9
Unclear	NA	NA	NA	NA	3	2.0	0	0·0
Response rate								
Low ROB	86	53·4	19	48·7	92	62.6	4	12·1
High ROB	4	2·5	1	2·5	8	5.4	1	3·0
Unclear	71	44·1	19	48·7	47	32.0	28	84·9
HIV ascertainment								
Low ROB	NA	NA	NA	NA	146	99.3	33	100·0
High ROB	NA	NA	NA	NA	1	0.7	0	0·0
Unclear	NA	NA	NA	NA	0	0.0	0	0·0
Total number of studies	161	100·0	39	100·0	147	100.0	33	100·0
Summary								
Low ROB								
At least 1 domain	161	100·0	39	100·0	147	100.0	33	100·0
At least 2 domains	152	94·4	32	82·1	125	85.0	13	39·4
At least 3 domains	82	50·9	14	35·9	79	53.7	2	6·1
High ROB								
At least 1 domain	9	5·6	13	33·3	51	34.7	29	87·9
At least 2 domains	0	0·0	0	0·0	1	0.7	2	6·1
At least 3 domains	0	0·0	0	0·0	0	0.0	0	0·0

Abbreviations: *FSWs* female sex workers, *NA* not applicable

Table S7 Risk of bias (ROB) assessment of estimates of national and subnational representation for the number and population proportion of FSWs and of their clients, in the Middle East and North Africa

Country Author, year [citation]	Year(s) of data collection	Size estimate		Risk of bias assessment		
		N or range	%	Sex work definition	Estimation methodology	Response rate
FSWs						
National estimates						
Egypt						
Bahaa, 2010 [117]	2004-08	NR	0·4	Low ROB	High ROB	Unclear
Jacobsen, 2014 [8]	2014	22,986	0·24	Low ROB	Low ROB	Unclear
Iran						
Sharifi, 2017 [10]	2015	19,800	0·31	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	98,500	1·54	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	152,200	2·38	Low ROB	Low ROB	Unclear
Lebanon						
Kahhaleh, 2009 [118]	1996	NR	0·54	Low ROB	Low ROB	Unclear
Kahhaleh, 2009 [118]	2004	NR	0·53	Low ROB	Low ROB	Low ROB
Morocco						
Bennani, 2013 [119]	2011	85,000	NR	Low ROB	Low ROB	Unclear
MOH, 2013 [120]	2013	NR	6·9	Low ROB	Low ROB	Low ROB
MOH, 2013 [120]	2013	NR	2·4	Low ROB	Low ROB	Low ROB
Pakistan						
NACP, 2005 [15] (round I)	2005	35,050	0·78	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	167,501	0·44	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	89,178	0·72	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	64,829	NR	Low ROB	Low ROB	Low ROB
Sudan						
AFROCENTER Group, 2005 [121]	2005	NR	0·4	Low ROB	High ROB	Unclear
Yemen						
MOH, 2010 [32]	NR	58,934	1·16-2·10	Unclear	Low ROB	Unclear
Subnational estimates						
Afghanistan						
SAR AIDS HDS, 2008 [5]	2006-07	90	0·26	Low ROB	Low ROB	Unclear
SAR AIDS HDS, 2008 [5]	2006-07	898	0·19	Low ROB	Low ROB	Unclear
SAR AIDS HDS, 2008 [5]	2006-07	172	0·28	Low ROB	Low ROB	Unclear
NACP, 2012 [6] (round II)	2012	2,134	NR	Low ROB	Low ROB	Low ROB
NACP, 2012 [6] (round II)	2012	2,800	NR	Low ROB	Low ROB	Low ROB
Djibouti						
Trellu-Kane, 2005 [7]	2005	NR	4	Low ROB	High ROB	Low ROB
Egypt						
Jacobsen, 2014 [8]	2014	6,092	0·17	Low ROB	Low ROB	Unclear
Jacobsen, 2014 [8]	2014	4,225	0·34	Low ROB	Low ROB	Unclear
Jacobsen, 2014 [8]	2014	1,345	0·34	Low ROB	Low ROB	Unclear
Jacobsen, 2014 [8]	2014	1,315	1·92	Low ROB	Low ROB	Unclear
Jacobsen, 2014 [8]	2014	278	0·11	Low ROB	Low ROB	Unclear
Iran						
Karami, 2017 [9]	NR	842	0·45	Low ROB	Low ROB	Low ROB
Sharifi, 2017 [10]	2015	10,000	2·86	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	3,800	2·30	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	4,000	2·87	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	12,200	2·02	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	4,600	2·46	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	1,600	0·59	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	12,000	1·43	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	800	0·85	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	13,300	2·75	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	13,100	2·84	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	63,700	2·52	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	840	0·51	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	1,200	0·35	Low ROB	Low ROB	Unclear

Country Author, year [citation]	Year(s) of data collection	Size estimate		Risk of bias assessment		
		N or range	%	Sex work definition	Estimation methodology	Response rate
Sharifi, 2017 [10]	2015	3,000	1·81	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	390	0·28	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	2,300	0·38	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	1,400	0·73	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	70	0·03	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	200	0·17	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	3,000	0·35	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	4,700	5	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	1,300	0·26	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	170	0·04	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	7,500	0·3	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	4,300	1·22	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	2,200	1·30	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	2,200	1·56	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	14,700	2·44	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	2,000	1·06	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	4,000	1·47	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	740	0·65	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	15,200	1·81	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	1,500	1·54	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	8,100	1·67	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	640	0·14	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	38,700	1·54	Low ROB	Low ROB	Unclear
Sharifi, 2017 [10]	2015	2,600	1·63	Low ROB	Low ROB	Unclear
Karami, 2017 [11]	2016	690	NR	Low ROB	Low ROB	Low ROB
Morocco						
MOH, 2012 [12]	2011-12	3,639-4,333	NR	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	6,028	NR	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	5,683	NR	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	3,956	NR	Low ROB	Low ROB	Low ROB
Huygens, 2013 [13]	2013	955	NR	Unclear	Low ROB	Low ROB
Huygens, 2013 [13]	2013	7,253	NR	Unclear	Low ROB	Low ROB
Pakistan						
NACP, 2005 [14] (pilot)	2004-05	11,546	NR	Low ROB	Low ROB	Low ROB
NACP, 2005 [14] (pilot)	2004-05	1,596	NR	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	2,050	0·46	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	1,350	0·69	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	11,550	0·58	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	14,150	1·26	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	2,500	0·99	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	950	0·45	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	750	0·64	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	1,750	0·88	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	125	0·04	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	9,500	1·30	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	2,421	0·58	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	2,750	0·71	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	25,550	0·74	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	24,625	1·34	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	525	0·44	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	5,075	1·22	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	1,550	0·44	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	2,500	1·10	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	1,596	0·31	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	1,831	0·67	Low ROB	Low ROB	Low ROB
Emmanuel, 2010 [16] (round II)	2006	2,550	1·14	Low ROB	Low ROB	Low ROB
Khan, 2011 [17]	2007	5,226	NR	Low ROB	Low ROB	Low ROB
Khan, 2011 [17]	2007	NR	0·43	Low ROB	Low ROB	Low ROB
Khan, 2011 [17]	2007	NR	0·56	Low ROB	Low ROB	Low ROB
NACP, 2008 [18]	2007	86	NR	Low ROB	Low ROB	Unclear

Country Author, year [citation]	Year(s) of data collection	Size estimate		Risk of bias assessment		
		N or range	%	Sex work definition	Estimation methodology	Response rate
NACP, 2008 [18]	2007	498	NR	Low ROB	Low ROB	Unclear
NACP, 2008 [18]	2007	9	NR	Low ROB	Low ROB	Unclear
NACP, 2008 [18]	2007	5	NR	Low ROB	Low ROB	Unclear
NACP, 2008 [18]	2007	2	NR	Low ROB	Low ROB	Unclear
NACP, 2008 [18]	2007	1,030	NR	Low ROB	Low ROB	Unclear
NACP, 2008 [18]	2007	105	NR	Low ROB	Low ROB	Unclear
Emmanuel, 2013 [19, 20] (round IV)	2011-12	1,413	1·30	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	4,846	0·50	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	2,994	1·19	Low ROB	Low ROB	High ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	4,566	0·85	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	25,399	0·55	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	23,766	1·15	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	1,114	0·82	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	884	0·85	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	5,308	0·80	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	2,011	1·42	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	3,317	0·42	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	3,710	1·07	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	3,635	0·34	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	3,898	1·25	Low ROB	Low ROB	Low ROB
Emmanuel, 2013 [19, 20] (round IV)	2011-12	2,317	1·05	Low ROB	Low ROB	Low ROB
Punjab ACP, 2015 [21]	2014	7,556	NR	Low ROB	Low ROB	Low ROB
Punjab ACP, 2015 [21]	2014	25,716	NR	Low ROB	Low ROB	Low ROB
Punjab ACP, 2015 [21]	2014	6,561	NR	Low ROB	Low ROB	Low ROB
Punjab ACP, 2015 [21]	2014	4,327	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	6,201	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	192	NR	Low ROB	Low ROB	High ROB
NACP, 2017 [22] (round V)	2016-17	1,349	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	4,069	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	317	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	4,426	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	25,191	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	1,739	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	4,593	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	2,084	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	1,690	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	765	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	2,465	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	4,121	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	6,252	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	2,031	NR	Low ROB	Low ROB	High ROB
NACP, 2017 [22] (round V)	2016-17	3,307	NR	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	523	NR	Low ROB	Low ROB	High ROB
Somalia						
MOH, 2016 [24]	2016	911	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	1,126	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	963	NR	Low ROB	Low ROB	Unclear
Sudan						
NACP, 2002 [25]	2002	NR	0·83	Low ROB	Low ROB	Low ROB
NACP, 2002 [25]	2002	NR	0·5	Low ROB	High ROB	Low ROB
NACP, 2005 [26]	2005	NR	3	Low ROB	High ROB	Low ROB
UNHCR, 2007 [27]	2006	NR	0·4	Low ROB	Low ROB	Low ROB
UNHCR, 2007 [27]	2006	NR	0·2	Low ROB	Low ROB	Low ROB
MOH, 2016 [30]	2015-16	5,800	NR	Low ROB	Low ROB	Low ROB
MOH, 2016 [30]	2015-16	5,306	NR	Low ROB	Low ROB	Low ROB
Tunisia						
Hsairi, 2012 [31]	2011	541	NR	Low ROB	Low ROB	Low ROB
Hsairi, 2012 [31]	2011	596	NR	Low ROB	Low ROB	Low ROB
Hsairi, 2012 [31]	2011	291	NR	Low ROB	Low ROB	Low ROB
Yemen						

Country Author, year [citation]	Year(s) of data collection	Size estimate		Risk of bias assessment		
		N or range	%	Sex work definition	Estimation methodology	Response rate
MOH, 2010 [32]	NR	1,875-4,260	1·16-2·64	Unclear	Low ROB	Unclear
MOH, 2010 [32]	NR	1,580-1,759	1·89-2·10	Unclear	Low ROB	Unclear
MOH, 2010 [32]	NR	1,488-1,786	2·07-2·49	Unclear	Low ROB	Unclear
MOH, 2010 [32]	NR	3,092-4,495	0·64-2·10	Unclear	Low ROB	Unclear
MOH, 2010 [32]	NR	1,050-1,835	0·80-1·40	Unclear	Low ROB	Unclear
Clients of FSWs						
National estimates						
Afghanistan						
Todd, 2007 [122]	2005-06	NR	3·57	Low ROB	Low ROB	Unclear
Todd, 2012 [123]	2010-11	NR	12·5	Low ROB	Low ROB	Low ROB
Egypt						
Bahaa, 2010 [117]	2004-08	NR	0·9	Low ROB	High ROB	Unclear
Lebanon						
Kahhaleh, 2009 [118]	1996	NR	9·7	Low ROB	Low ROB	Unclear
Adib, 2002 [124]	1999	NR	13·84	Low ROB	Low ROB	Low ROB
Kahhaleh, 2009 [118]	2004	NR	5·65	Low ROB	Low ROB	Low ROB
Morocco						
MOH, 2007 [125]	2007	NR	35·3	Low ROB	Low ROB	Unclear
MOH, 2007 [125]	2007	NR	2	Low ROB	Low ROB	Unclear
MOH, 2013 [120]	2013	NR	10·5	Low ROB	Low ROB	Low ROB
MOH, 2013 [120]	2013	NR	0·3	Low ROB	Low ROB	Low ROB
Pakistan						
Mir, 2013 [126]	2007	NR	11·9	Low ROB	Low ROB	Low ROB
Mir, 2013 [126]	2007	NR	5·8	Low ROB	Low ROB	Low ROB
Sudan						
NACP, 2004 [127]	2004	NR	0·3	Low ROB	High ROB	Unclear
AFROCENTER Group, 2005 [121]	2005	NR	0·5	Low ROB	High ROB	Unclear
Subnational estimates						
Afghanistan						
Mansoor, 2008 [33]	2007	NR	5·2	Low ROB	Low ROB	Low ROB
Djibouti						
Trellu-Kane, 2005 [7]	2005	NR	17	Low ROB	High ROB	Low ROB
Iran						
Shokoohi, 2012 [34]	NR	9,314	7·0	Low ROB	Low ROB	Unclear
Shokoohi, 2012 [34]	NR	3,203	2·4	Low ROB	Low ROB	Unclear
Khalajabadi, 2018 [35]	2013-14	NR	1·3	Low ROB	Low ROB	Low ROB
Khalajabadi, 2018 [35]	2013-14	NR	6·6	Low ROB	Low ROB	Low ROB
Lebanon						
Melikian, 1954 [36]	1952	NR	59·3	Low ROB	High ROB	Unclear
Melikian, 1967 [37]	1963	NR	40·6	Low ROB	High ROB	Low ROB
Ghandour, 2014 [38]	2012	NR	20·1	Low ROB	Low ROB	High ROB
Pakistan						
Faisel, 2005 [39]	2004-05	NR	6·8	Low ROB	Low ROB	Low ROB
Minhas, 2005 [40]	2005	NR	7	Low ROB	High ROB	Unclear
Somalia						
Ismail, 1990 [41]	1986	NR	48	Low ROB	High ROB	Unclear
Ismail, 1990 [42]	1987	NR	29	Low ROB	Low ROB	Low ROB
MOH, 2016 [24]	2016	3,469	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	3,530	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	1,828	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	1,559	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	2,599	NR	Low ROB	Low ROB	Unclear
MOH, 2016 [24]	2016	2,202	NR	Low ROB	Low ROB	Unclear
Sudan						
McCarthy, 1989 [43]	1987-88	NR	51·6	Low ROB	High ROB	Unclear
Holt, 2003 [44]	1992	NR	46·0	Low ROB	High ROB	Low ROB
Holt, 2003 [44]	1992	NR	31·0	Low ROB	High ROB	Low ROB
NACP, 2002 [25]	2002	NR	11·7	Low ROB	High ROB	Low ROB
UNHCR, 2007 [27]	2006	NR	1·7	Low ROB	Low ROB	Low ROB

Country Author, year [citation]	Year(s) of data collection	Size estimate		Risk of bias assessment		
		N or range	%	Sex work definition	Estimation methodology	Response rate
UNHCR, 2007 [27]	2006	NR	1·4	Low ROB	Low ROB	Low ROB

The table is sorted by year(s) of data collection or year of publication if year of data collection was not reported.
Abbreviations: *ACP* AIDS Control Program, *FSWs* female sex workers, *MOH* Ministry of Health, *NACP* National AIDS Control Programme, *NAP* National AIDS Program, *NR* not reported, *SAR AIDS HDS* South Asia Region AIDS Human Development Sector, *UNHCR* United Nations Higher Commission for Refugees

Table S8 Risk of bias (ROB) assessment of HIV prevalence studies in FSWs in the Middle East and North Africa

Country Author, year [citation]	Year(s) of data collection	Sample size	HIV prev (%)	Sex work definition	Sampling methodology	Response rate	HIV ascertainment
Studies using probability-based sampling							
Afghanistan							
SAR AIDS HDS, 2008 [5]	2006-07	45	0	Low ROB	Low ROB	Unclear	Low ROB
SAR AIDS HDS, 2008 [5]	2006-07	87	0	Low ROB	Low ROB	Unclear	Low ROB
NACP, 2010 [128] (round I)	2009	368	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [6] (round II)	2012	344	0·9	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [6] (round II)	2012	333	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [6] (round II)	2012	355	0	Low ROB	Low ROB	Low ROB	Low ROB
Egypt							
MOH, 2006 [129] (round I)	2006	118	0·8	Unclear	High ROB	High ROB	Low ROB
MOH, 2010 [130] (round II)	2010	200	0	Low ROB	High ROB	Low ROB	Low ROB
Iran							
Navadeh, 2012 [131]	2010	139	0	Low ROB	Low ROB	Low ROB	Low ROB
Sajadi, 2013 [132] (round I)	2010	817	4·5	Low ROB	Low ROB	Low ROB	Low ROB
Kazerooni, 2014 [133]	2010-11	278	4·7	Low ROB	Low ROB	Low ROB	Low ROB
Moaeyedi-Nia [134]	2012-13	161	5	Low ROB	Low ROB	Unclear	Low ROB
Mirzazadeh, 2016 [135] (round II)	2015	1,337	2·1	Low ROB	High ROB	Unclear	Low ROB
Karami, 2017 [11]	2016	369	4·6	Low ROB	Low ROB	Low ROB	High ROB
Jordan							
WHO, 2011 [23] (round I)	2009	225	0	Unclear	Low ROB	Unclear	Low ROB
MOH, 2014 [136] (round II)	2013	358	0·6	Low ROB	Low ROB	Unclear	Low ROB
MOH, 2014 [136] (round II)	2013	102	0	Low ROB	Low ROB	Unclear	Low ROB
MOH, 2014 [136] (round II)	2013	212	0·5	Low ROB	Low ROB	Unclear	Low ROB
Lebanon							
Mahfoud, 2010 [137]	2007-08	95	0	Low ROB	Low ROB	High ROB	Low ROB
Libya							
Valadez, 2013 [138] (round I)	2010-11	69	15·7	Low ROB	Low ROB	High ROB	Low ROB
Morocco							
MOH, 2012 [12]	2011-12	364	5·1	Low ROB	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	359	1·8	Low ROB	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	392	0	Low ROB	Low ROB	Low ROB	Low ROB
MOH, 2012 [12]	2011-12	319	1·4	Low ROB	Low ROB	Low ROB	Low ROB
Pakistan							
Bokhari, 2007 [139]	2004	378	0·5	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	400	0·8	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	359	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	411	0·7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2005 [15] (round I)	2005	368	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	194	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	398	0·3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	403	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	425	0·02	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	423	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	398	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2007 [140] (round II)	2006	400	0	Low ROB	Low ROB	Low ROB	Low ROB
Hawkes, 2009 [141]	2007	107	0	Low ROB	Low ROB	Low ROB	Low ROB
Hawkes, 2009 [141]	2007	426	0	Low ROB	Low ROB	Unclear	Low ROB

Country Author, year [citation]	Year(s) of data collection	Sample size	HIV prev (%)	Sex work definition	Sampling methodology	Response rate	HIV ascertainment
Khan, 2011 [17]	2007	730	0·7	Low ROB	Low ROB	Unclear	Low ROB
NACP, 2010 [142] (special IBBSS among FSWs)	2009	2,197	1·0	Unclear	Unclear	Unclear	Low ROB
NACP, 2012 [20] (round IV)	2012	375	0·5	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	376	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	211	0·9	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	377	1·9	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	375	0·5	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	375	1·9	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	375	0·3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	367	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	345	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	375	0	Low ROB	Low ROB	High ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	345	0.3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [20] (round IV)	2012	375	0.8	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	351	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	196	1.5	Low ROB	Low ROB	High ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	0.8	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	304	0.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	250	0.4	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	2.2	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	387	2.6	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	4.1	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	4.1	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	3.8	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	265	3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	0.3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	363	1.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	364	8.8	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	193	0	Low ROB	Low ROB	High ROB	Low ROB
NACP, 2017 [22] (round V)	2016-17	72	0	Low ROB	Low ROB	High ROB	Low ROB
Somalia							
Testa, 2008 [143] (round I)	2008	237	5.2	Low ROB	Low ROB	Low ROB	Low ROB
IOM, 2017 [144] (round II)	2014	96	4.8	Low ROB	Low ROB	High ROB	Low ROB
Sudan							
Elkarim, 2002 [145]	2002	367	4.4	Low ROB	Low ROB	Unclear	Low ROB
Abdelrahim, 2010 [146]	2008	321	0.9	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2010 [147]	2008-09	267	0.1	Unclear	Low ROB	Unclear	Low ROB
NACP, 2012 [148]	2011	305	0.3	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	279	1.5	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	282	0.6	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	296	0.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	288	5.0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	287	0	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	303	0.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	296	1	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	293	7.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	291	0.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	303	0.7	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	299	0.2	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	284	1	Low ROB	Low ROB	Low ROB	Low ROB
NACP, 2012 [148]	2011	288	1.3	Low ROB	Low ROB	Low ROB	Low ROB
MOH, 2016 [30]	2015-16	835	37.9	Low ROB	Low ROB	Low ROB	Low ROB
Tunisia							
Hsairi, 2012 [31]	2009	703	0.4	Low ROB	Low ROB	Unclear	Low ROB
Hsairi, 2012 [31]	2011	357	0.6	Low ROB	Low ROB	Low ROB	Low ROB
Hsairi, 2012 [31]	2011	284	0	Low ROB	Low ROB	Low ROB	Low ROB
Hsairi, 2012 [31]	2011	347	1.2	Low ROB	Low ROB	Low ROB	Low ROB

Country Author, year [citation]	Year(s) of data collection	Sample size	HIV prev (%)	Sex work definition	Sampling methodology	Response rate	HIV ascertainment
Yemen							
Stulhofer, 2008 [149] (round I)	2008	244	1.3	Unclear	Low ROB	Unclear	Low ROB
MOH, 2014 [150] (round I)	2010-11	301	0	Unclear	Low ROB	Unclear	Low ROB
Studies using non-probability sampling							
Afghanistan							
Todd, 2010 [151]	2006-08	520	0.2	Low ROB	High ROB	Unclear	Low ROB
Djibouti							
Rodier, 1993 [152]	1987	66	4.6	Low ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1987	221	1.4	Low ROB	High ROB	Unclear	Low ROB
Constantine, 1992 [153]	1988	33	18.2	Unclear	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1988	78	9.0	Low ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1988	255	2.7	Low ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1990	116	41.7	Low ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1990	180	5.0	Low ROB	High ROB	Unclear	Low ROB
Couzineau, 1991 [154]	1991	300	43	Unclear	High ROB	Unclear	Low ROB
Couzineau, 1991 [154]	1991	397	13.1	Unclear	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1991	292	36.0	Low ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1991	360	15.3	Low ROB	High ROB	Unclear	Low ROB
Philippon, 1997 [155]	1995	176	49	Unclear	High ROB	Unclear	Low ROB
Marcelin, 2002 [156]	1998-99	43	70	Unclear	High ROB	Unclear	Low ROB
Marcelin, 2002 [156]	1998-99	123	7	Unclear	High ROB	Unclear	Low ROB
Egypt							
Sheba, 1988 [157]	1986-87	87	0	Unclear	High ROB	Unclear	Low ROB
Watts, 1993[158]	1986-90	349	0	Unclear	High ROB	Unclear	Low ROB
Kabbash, 2012 [159]	2009-10	431	0	Unclear	High ROB	Low ROB	Low ROB
Iran							
Jahani, 2005 [160]	2002	149	0	Unclear	High ROB	Unclear	Low ROB
Kassaian, 2012 [161]	2009-10	91	0	Low ROB	High ROB	Low ROB	Low ROB
Taghizadeh, 2015 [162]	2014	184	4	Unclear	High ROB	Low ROB	Low ROB
Asadi-Ali, 2018 [163]	2015	133	1.5	Low ROB	High ROB	Low ROB	Low ROB
Lebanon							
Naman, 1989 [164]	1985-87	291	0.3	Unclear	High ROB	Unclear	Low ROB
Morocco							
MOH, 2008 [165]	2007	141	1.4	Unclear	High ROB	Low ROB	Low ROB
Pakistan							
Iqbal, 1996 [166]	1987-94	21	0	Unclear	High ROB	Unclear	Low ROB
Baqi, 1998 [167]	1993-94	77	0	Low ROB	High ROB	Low ROB	Low ROB
Anwar, 1998 [168]	NR	103	1.9	Unclear	Unclear	Unclear	Low ROB
Bokhari, 2007 [139]	2004	421	0	Low ROB	High ROB	Low ROB	Low ROB
Shah, 2004 [169]	2004	157	0	Unclear	High ROB	Unclear	Low ROB
Shah, 2004 [170]	2004	163	1.2	Unclear	High ROB	Unclear	Low ROB
Akhtar, 2008 [171]	2007	246	0	Unclear	Unclear	Unclear	Low ROB
Raza, 2015 [172]	2014	NR	0	Unclear	High ROB	Unclear	Low ROB
Somalia							
Jama, 1987 [173]	1985-86	85	0	Unclear	High ROB	Unclear	Low ROB
Burans, 1990 [174]	NR	89	0	Unclear	High ROB	Low ROB	Low ROB
Scott, 1991 [175]	1989	57	0	Unclear	High ROB	Unclear	Low ROB
Corwin, 1991 [176]	1990	302	3	Unclear	High ROB	Unclear	Low ROB
Jama Ahmed, 1991 [177]	1991	155	0.6	Unclear	High ROB	Unclear	Low ROB
Sudan							
Burans, 1990 [178]	1987	203	0	Low ROB	High ROB	Unclear	Low ROB
McCarthy, 1995 [179]	NR	50	16	Unclear	High ROB	Low ROB	Low ROB
Tunisia							
Bchir, 1988 [180]	1987	42	0	Low ROB	High ROB	Unclear	Low ROB
Hassen, 2003 [181]	NR	51	0	Low ROB	High ROB	Low ROB	Low ROB
Znazen, 2010 [182]	2007	183	0	Low ROB	High ROB	Low ROB	Low ROB

The table is sorted by year(s) of data collection.

Abbreviations: *FSWs* female sex workers, *IBBSS* integrated bio-behavioural surveillance survey, *IOM* International Organization for Migration, *MOH* Ministry of Health, *NACP* National AIDS Control Programme, *NAP* National AIDS Program, *NR* not reported, *Prev* prevalence, *SAR AIDS HDS* South Asia Region AIDS Human Development Sector, *WHO* World Health Organization

Table S9 Risk of bias (ROB) assessment of HIV prevalence studies in clients of FSWs (or proxy populations of clients) in the Middle East and North Africa

Country Author, year [citation]	Year(s) of data collection	Sample size	HIV prev (%)	Sex work definition	Sampling method	Response rate	HIV ascertainment
Djibouti							
Rodier, 1993 [152]	1987	252	0.8	Unclear	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1988	249	0.8	Unclear	High ROB	Unclear	Low ROB
Fox, 1989 [183]	NR	105	1.0	High ROB	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1990	106	1.9	Unclear	High ROB	Unclear	Low ROB
Rodier, 1993 [152]	1991	193	10.4	Unclear	High ROB	Unclear	Low ROB
Egypt							
Sheba, 1988 [157]	1986-87	302	0	Unclear	High ROB	Unclear	Low ROB
Kuwait							
Al-Owaish, 2000 [184]	1996-97	617	0	Low ROB	Low ROB	Unclear	Low ROB
Al-Owaish, 2000 [184]	1996-97	1,367	0	Low ROB	Low ROB	Unclear	Low ROB
Al-Owaish, 2002 [185]	2002	599	0	Unclear	High ROB	Unclear	Low ROB
Al-Mutairi, 2007 [186]	2003-04	520	0	Low ROB	High ROB	High ROB	Low ROB
Morocco							
Heikel, 1999 [187]	1992-96	1,131	0.9	Unclear	High ROB	Unclear	Low ROB
Manhart, 1996 [188]	1996	223	1.4	Unclear	High ROB	Unclear	Low ROB
Alami, 2002 [189]	2001	422	0	Unclear	High ROB	Unclear	Low ROB
Pakistan							
Mujeeb, 1993 [190]	NR	32	0	Unclear	High ROB	Unclear	Low ROB
Memon, 1997 [191]	1994-95	50	0	Unclear	High ROB	Unclear	Low ROB
NAP, 1996 [192]	1995	402	0	Unclear	High ROB	Unclear	Low ROB
NAP, 1996 [192]	1995	295	0	Unclear	High ROB	Unclear	Low ROB
Rehan, 2003 [193]	1999	138	0	Unclear	High ROB	Unclear	Low ROB
Rehan, 2003 [193]	1999	148	0	Unclear	High ROB	Unclear	Low ROB
Rehan, 2003 [193]	1999	93	1.1	Unclear	High ROB	Unclear	Low ROB
Rehan, 2003 [193]	1999	86	0	Unclear	High ROB	Unclear	Low ROB
Bhutto, 2011 [194]	2000-09	4,288	0.06	Low ROB	High ROB	Unclear	Low ROB
Bokhari, 2007 [139]	2004	120	0	Low ROB	Low ROB	Low ROB	Low ROB
Razvi, 2014 [195]	2010-14	465	1.1	Low ROB	High ROB	Unclear	Low ROB
NAP, 2012 [196]	2011	381	0	Low ROB	Low ROB	Low ROB	Low ROB
Somalia							
Ismail, 1990 [41]	1986	101	0	Low ROB	High ROB	Unclear	Low ROB
Scott, 1991 [175]	1989	50	0	Unclear	High ROB	Unclear	Low ROB
Burans, 1990 [174]	NR	45	0	Low ROB	High ROB	Low ROB	Low ROB
Corwin, 1991 [176]	1990	26	0	Unclear	High ROB	Unclear	Low ROB
Ismail, 2007 [197]	2007	NR	7.4	Unclear	High ROB	Low ROB	Low ROB
Sudan							
McCarthy, 1989 [198]	1987	157	0	Low ROB	High ROB	Unclear	Low ROB
McCarthy, 1989 [43]	1987-88	398	2.5	Low ROB	High ROB	Unclear	Low ROB
McCarthy, 1995 [179]	NR	37	13.5	Low ROB	High ROB	Unclear	Low ROB

The table is sorted by year(s) of data collection or year of publication if year of data collection was not reported.
Abbreviations: *FSWs* female sex workers, *MOH* Ministry of Health, *NAP* National AIDS Program, *NR* not reported, *Prev* prevalence

Table S10 Results of meta-regression analyses to identify associations with HIV prevalence, sources of between-study heterogeneity, and trend in HIV prevalence in clients of FSWs (or proxy populations of clients such as male STI clinic attendees), in the Middle East and North Africa (MENA)

		Studies	Samples	Univariable analyses			Multivariable analysis		
Sources of heterogeneity*		**Total N**	**Total N**	**OR (95% CI)**	**LR test p-value‡**	**Variance explained $R^{2£}$ (%)**	**AOR (95% CI)**	**p-value**	**LR test p-value¥**
Country/subregion**									
Pakistan	Pakistan	12	6,498	1.00	<0.001	29.0	1.00		<0.001
Egypt	Egypt	6	1,362	1.34 (0.28-6.30)			1.56 (0.32-7.53)	0.581	
Kuwait & Yemen	Kuwait & Yemen†	7	6,535	0.24 (0.06-1.06)			0.26 (0.06-1.13)	0.072	
Horn of Africa	Djibouti, Somalia, South Sudan	27	3,269	19.58 (6.69-57.36)			17.85 (6.02-52.87)	<0.001	
North Africa	Algeria, Morocco, Sudan	95	11,867	3.00 (1.16-7.76)			2.77 (0.95-8.05)	0.062	
Total sample size of tested clients/male STI clinic attendees	<100	18	502	1.00	0.021	3.0	1.00		0.271
	≥100	129	29,029	0.34 (0.14-0.84)			0.63 (0.28-1.44)	0.271	
Median year of data collection‡	<2003	42	13,889	1.00	0.506	0	1.00		0.588
	≥2003	105	15,642	1.25 (0.64-2.46)			1.24 (0.57-2.72)	0.588	

*Only country, sample size, and year of data collection had sufficient number of studies to warrant conduct of meta-regression analyses.

**Countries were grouped based on geography and similarity in HIV prevalence levels. Given the large fraction of studies with zero HIV prevalence, particularly in the Fertile Crescent, an increment of 0.1 was added to number of events in all studies when generating log odds, and Eastern MENA was thus used also as a statistically better reference. While this choice of increment was arbitrary, other increments yielded the same findings, though some of the effect sizes changed in scale.

‡Year grouping was driven by independent evidence identifying the emergence of HIV epidemics among both men who have sex with men[3] and people who inject drugs[4] in multiple MENA countries around 2003. Missing values for year of data collection (only four stratified measures) were imputed using data for year of publication adjusted by the median difference between year of publication and median year of data collection (for studies with complete information).

†Only one study was from Yemen.

‡Predictors with p-value ≤0.1 were considered as showing strong evidence for an association with (prevalence) odds, and were hence included in the multivariable analysis. Median year was also included in the multivariable model given its importance.

£Adjusted R-squared in the final multivariable model=28.78%

¥Predictors with p-value ≤0.1 in the multivariable model were considered as showing strong evidence for an association with (prevalence) odds.

Abbreviations: *AOR* adjusted odds ratio, *CI* confidence interval, *Coll* collection, *FSWs* female sex workers, *LR* likelihood ratio, *OR* odds ratio, *STI* sexually transmitted infection

Table S11 Condom use among FSWs and their clients in the Middle East and North Africa

Country Author, year [citation]	Year(s) of data collection	City/province	Population	Condom use Time frame	Use (%)	Consistent use (always/most of the time among all FSWs) (%)
FSWS						
VAGINAL SEX						
With client						
Afghanistan						
SAR AIDS HDS, 2008 [5]	2006-07	Jalalabad	All FSWs	Ever	29.0	16.0
SAR AIDS HDS, 2008 [5]	2006-07	Mazar-i-Sharif	All FSWs	Ever	40.0	32.0
Todd, 2010 [151]	2006-08	Kabul, Jalalabad, Mazar-i-Sharif	All FSWs	Ever	30.2	38.2*
NACP, 2010 [128]	2009	Kabul	All FSWs	Last sex	58.1	NR
NACP, 2012 [6]	2012	Herat	All FSWs	Last sex	67.0	NR
NACP, 2012 [6]	2012	Kabul	All FSWs	Last sex	64.0	NR
NACP, 2012 [6]	2012	Mazar-i-Sharif	All FSWs	Last sex	26.1	NR
Algeria						
MOH, 2014 [53]	2014	Saida	All FSWs	Last sex	84.1	NR
Djibouti						
Rodier, 1993 [152]	1990	Djibouti	All FSWs	NR	NR	41.9
Rodier, 1993 [152]	1990	Djibouti	All bar girls	NR	NR	92.7
Rodier, 1993 [152]	1991	Djibouti	All FSWs	NR	NR	28.4
Rodier, 1993 [152]	1991	Djibouti	All bar girls	NR	NR	90.9
Philippon, 1997 [155]	1995	Djibouti	All FSWs	NR	86.0	48.0
Trellu-Kane, 2005 [7]	2005	Djibouti	All FSWs	Last sex	25.0	NR
MOH, 2010 [65]	2007	Djibouti	All FSWs	Last sex	94.2	NR
Egypt						
MOH, 2006 [129]	2006	Cairo	All FSWs	Last sex	31.4	NR
Kabbash, 2012 [159]	2009-10	Cairo	FSWs who heard of condoms	Last sex	22.4	16.7†
Kabbash, 2012 [159]	2009-10	Cairo	FSWs who heard of condoms	Past 1 M	32.6	NR
MOH, 2010 [130]	2010	Cairo	All FSWs	Last sex	25.0	16.5
MOH, 2010 [130]	2010	Cairo	All FSWs	Past 1 M	41.0	NR
NAP, 2014 [71]	2010	Cairo	All FSWs	Last sex	10.0	NR
Iran						
Jahani, 2005 [160]	2002	NR	All FSWs	NR	NR	83.2
Kassaian, 2012 [161]	2009-10	Isfahan	All FSWs	NR	64.8	48.4
Sajadi, 2013 [132]	2010	National	All FSWs	Last sex	57.1	49.1
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Last sex	54.0	45.3*
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Past 1 M	79.8	NR
Moayedi-Nia, 2016 [134]	2012-13	Tehran	All FSWs	Last sex	65.2	NR
Taghizadeh, 2015 [162]	2014	Sari	All FSWs	Last sex	78.5	62.4
Asadi-Ali, 2018 [163]	2015	Northern Iran	All FSWs	Last sex	43.3	42.3*
Asadi-Ali, 2018 [163]	2015	Northern Iran	All FSWs	Ever	83.6	NR
Mirzazadeh, 2016 [135]	2015	National	NR	NR	NR	26.0
Karami, 2017 [11]	2016	Tehran	All FSWs	Last sex	56.1	39.3
Navadeh, 2012 [131]	2010	Kerman	All FSWs	Last sex	83.1	NR
Jordan						
MOH, 2010 [199]	2009	4 governorates	All FSWs	Last sex	51.0	NR
MOH, 2014 [136]	2013	Amman	All FSWs	Last sex	80.0	NR

MOH, 2014 [136]	2013	Irbid	All FSWs	Last sex	67.0	NR
Morocco						
MOH, 2006 [86]	2003	NR	All FSWs	Last sex	37.3	NR
MOH, 2008 [165]	2007	Agadir, Rabat Sale, Tanger	Al FSWs	NR	83.0	40.4
MOH, 2012 [12]	2011-12	Agadir	All FSWs	Last sex	42.0	28.7
MOH, 2012 [12]	2011-12	Fes	All FSWs	Last sex	49.5	26.3
MOH, 2012 [12]	2011-12	Rabat	All FSWs	Last sex	51.1	34.6
MOH, 2012 [12]	2011-12	Tanger	All FSWs	Last sex	63.1	58.3
MOH, 2013 [120]	2013	National	All FSWs	Past 12 M	61.0	6.4
Lebanon						
Mahfoud, 2010 [137]	2007-08	Greater Beirut	All FSWs	Past 1 M	97.7	95.2
Pakistan						
Baqi, 1998 [167]	1993-94	Karachi	All FSWs	Ever	9.8	0
NACP, 2005[200]	2004	Karachi	All FSWs	Last sex	25.0	NR
NACP, 2005 [200]	2004	Lahore	All FSWs	Last sex	53.0	NR
NACP, 2005 [14]	2004-05	Karachi	All FSWs	Last sex	36.7	18.1
NACP, 2005 [14]	2004-05	Rawalpindi	All FSWs	Last sex	49.3	16.7
NACP, 2005 [15]	2005	Faisalabad	All FSWs	Last sex	19.0	3.0
NACP, 2005 [15]	2005	Hyderabad	All FSWs	Last sex	17.0	13.0
NACP, 2005 [15]	2005	Karachi	All FSWs	Last sex	50.0	30.0
NACP, 2005 [15]	2005	Lahore	All FSWs	Last sex	68.0	42.0
NACP, 2005 [15]	2005	Multan	All FSWs	Last sex	35.0	14.0
NACP, 2005 [15]	2005	Peshawar	All FSWs	Last sex	23.0	11.0
NACP, 2005 [15]	2005	Quetta	All FSWs	Last sex	40.0	16.0
NACP, 2005 [15]	2005	Sukkur	All FSWs	Last sex	17.0	13.0
NACP, 2007 [140]	2006	National	All FSWs	Last sex	45.0	23.0
NACP, 2007 [140]	2006	Bannu	All FSWs	NR	NR	5.0
NACP, 2007 [140]	2006	Faisalabad	All FSWs	NR	NR	16.0
NACP, 2007 [140]	2006	Gujranwala	All FSWs	NR	NR	12.0
NACP, 2007 [140]	2006	Hyderabad	All FSWs	NR	NR	36.0
NACP, 2007 [140]	2006	Karachi	All FSWs	NR	NR	44.0
NACP, 2007 [140]	2006	Lahore	All FSWs	NR	NR	31.0
NACP, 2007 [140]	2006	Larkana	All FSWs	NR	NR	28.0
NACP, 2007 [140]	2006	Multan	All FSWs	NR	NR	5.0
NACP, 2007 [140]	2006	Peshawar	All FSWs	NR	NR	33.0
NACP, 2007 [140]	2006	Quetta	All FSWs	NR	NR	33.0
NACP, 2007 [140]	2006	Rawalpindi	All FSWs	NR	NR	31.0
NACP, 2007 [140]	2006	Sargodha	All FSWs	NR	NR	12.0
NACP, 2007 [140]	2006	Sukkur	All FSWs	NR	NR	7.0
Hawkes, 2009 [141]	2007	Abbottabad, Rawalpindi	All FSWs	Last sex	38.0	12.0
Khan, 2011 [17]	2007	Lahore	All FSWs	NR	NR	65.0
NACP, 2010 [142]	2009	Punjab	All FSWs	Last sex	43.3	NR
NACP, 2012 [20]	2011	DG Khan	All FSWs	Last sex	32.0	8.0
NACP, 2012 [20]	2011	Faisalabad	All FSWs	Last sex	43.0	30.0
NACP, 2012 [20]	2011	Karachi	All FSWs	Last sex	67.0	48.0
NACP, 2012 [20]	2011	Haripur	All FSWs	Last sex	44.0	24.0
NACP, 2012 [20]	2011	Lahore	All FSWs	Last sex	46.0	31.0
NACP, 2012 [20]	2011	Larkana	All FSWs	Last sex	58.0	53.0
NACP, 2012 [20]	2011	Multan	All FSWs	Last sex	48.0	24.0
NACP, 2012 [20]	2011	Peshawar	All FSWs	Last sex	43.0	27.0
NACP, 2012 [20]	2011	Quetta	All FSWs	Last sex	57.0	38.0

NACP, 2012 [20]	2011	Rawalpindi	All FSWs	Last sex	14.0	8.0
NACP, 2012 [20]	2011	Sargodha	All FSWs	Last sex	35.5	14.0
NACP, 2012 [20]	2011	Sukkur	All FSWs	Last sex	21.0	5.0
Punjab NACP, 2015 [201]	2014	Faisalabad	All FSWs	Last sex	71.2	38.2
Punjab NACP, 2015 [201]	2014	Lahore	All FSWs	Last sex	66.2	32.4
Punjab NACP, 2015 [201]	2014	Multan	All FSWs	Last sex	68.4	34.6
Punjab NACP, 2015 [201]	2014	Sargodha	All FSWs	Last sex	74.4	37.2
NACP, 2017 [22]	2016-17	Bahawalpur	All FSWs	Last sex	58.0	39.8
NACP, 2017 [22]	2016-17	Bannu	All FSWs	Last sex	74.0	46.4
NACP, 2017 [22]	2016-17	DG Khan	All FSWs	Last sex	65.1	29.4
NACP, 2017 [22]	2016-17	Gujranwala	All FSWs	Last sex	65.8	65.5
NACP, 2017 [22]	2016-17	Gujrat	All FSWs	Last sex	31.0	16.7
NACP, 2017 [22]	2016-17	Hyderabad	All FSWs	Last sex	59.9	37.9
NACP, 2017 [22]	2016-17	Larkana	All FSWs	Last sex	11.8	11.3
NACP, 2017 [22]	2016-17	Karachi	All FSWs	Last sex	61.5	45.5
NACP, 2017 [22]	2016-17	Kasur	All FSWs	Last sex	29.4	23.6
NACP, 2017 [22]	2016-17	Mirpurkhas	All FSWs	Last sex	28.8	17.3
NACP, 2017 [22]	2016-17	Nawabshah	All FSWs	Last sex	14.8	4.7
NACP, 2017 [22]	2016-17	Peshawar	All FSWs	Last sex	67.9	46.8
NACP, 2017 [22]	2016-17	Quetta	All FSWs	Last sex	89.8	75.0
NACP, 2017 [22]	2016-17	Rawalpindi	All FSWs	Last sex	4.1	1.1
NACP, 2017 [22]	2016-17	Sheikhupura	All FSWs	Last sex	74.4	72.7
NACP, 2017 [22]	2016-17	Sialkot	All FSWs	Last sex	94.8	93.3
NACP, 2017 [22]	2016-17	Sukkur	All FSWs	Last sex	61.4	55.8
NACP, 2017 [22]	2016-17	Turbat	All FSWs	Last sex	45.8	12.5
Somalia						
Testa, 2008 [143]	2008	Hargeisa	All FSWs	Last sex	25.6	6.0
IOM, 2017 [144]	2014	Hargeisa	All FSWs	Last sex	31.5	17.5
Sudan						
Elkarim, 2002 [145]	2002	National	All FSWs	Last sex	1.2	0.9
Abdelrahim, 2010 [146]	2008	Khartoum	All FSWs	Last sex	45.0	35.9
Elhadi, 2013 [202]	2011	Alshamalia	All FSWs	Last sex	41.0	24.1
Elhadi, 2013 [202]	2011	Blue Nile	All FSWs	Last sex	4.7	23.9
Elhadi, 2013 [202]	2011	Gadarif	All FSWs	Last sex	16.2	12.4
Elhadi, 2013 [202]	2011	Gezira	All FSWs	Last sex	8.2	5.0
Elhadi, 2013 [202]	2011	Kassala	All FSWs	Last sex	55.1	0.7
Elhadi, 2013 [202]	2011	Khartoum	All FSWs	Last sex	30.3	18.5
Elhadi, 2013 [202]	2011	North Darfur	All FSWs	Last sex	23.0	11.4
Elhadi, 2013 [202]	2011	North Kodofan	All FSWs	Last sex	15.8	8.9
Elhadi, 2013 [202]	2011	Red Sea	All FSWs	Last sex	18.7	13.7
Elhadi, 2013 [202]	2011	River Nile	All FSWs	Last sex	28.8	18.6
Elhadi, 2013 [202]	2011	Sinnar	All FSWs	Last sex	8.4	3.1
Elhadi, 2013 [202]	2011	South Darfur	All FSWs	Last sex	21.6	24.5
Elhadi, 2013 [202]	2011	West Darfur	All FSWs	Last sex	14.6	7.6
Elhadi, 2013 [202]	2011	White Nile	All FSWs	Last sex	12.5	5.0
MOH, 2016 [30]	2015-16	Juba, South Sudan	All FSWs	Last sex	72.4	72.4
Syria						
MOH, 2005 [104]	2005	NR	All FSWs	NR	84.8	33.8
Tunisia						
Znazen, 2010 [182]	2007	Gabes, Sousse, Tunis	All FSWs	NR	NR	60.6
Hassen, 2003 [181]	NR	Sousse	All FSWs	NR	65.0	36.8

MOH, 2010 [203]	2009	Sfax, Sousse, Tunis	All FSWs	Last sex	51.6	23.7
Yemen						
Stulhofer, 2008 [149]	2008	Aden	All FSWs	Last sex	57.1	NR
MOH, 2014 [150]	2010	Hodeida	All FSWs	Last sex	34.9	NR
With regular client						
Lebanon						
Mahfoud, 2010 [137]	2007-08	Greater Beirut	FSWs with regular client in past 1 M	Last sex	92.0	99.0
Libya						
Valadez, 2013 [138]	2010-11	Tripoli	FSWs with regular client in past 6 M	Last sex	76.7	56.8
Morocco						
MOH, 2012 [12]	2011-12	Agadir	FSWs with regular client in past 1 M	Last sex	50.1	69.3*
MOH, 2012 [12]	2011-12	Fes	FSWs with regular client in past 1 M	Last sex	43.2	56.9*
MOH, 2012 [12]	2011-12	Rabat	FSWs with regular client in past 1 M	Last sex	55.9	81.7*
MOH, 2012 [12]	2011-12	Tanger	FSWs with regular client in past 1 M	Last sex	68.9	85.0*
Pakistan						
Bokhari, 2007 [139]	2004	Karachi	FSWs with regular client in past 7 days	Last sex	25.5	3.3
Bokhari, 2007 [139]	2004	Lahore	FSWs with regular client in past 7 days	Last sex	47.0	20.1
Sudan						
MOH, 2016 [30]	2015-16	Juba, South Sudan	FSWs with regular client in past 6 M	Last sex	68.0	NR
Tunisia						
Hsairi, 2012 [31]	2011	Sfax, Sousse, Tunis	FSWs with regular client in past 1 M	Last sex	44.3	41.5
Yemen						
Stulhofer, 2008 [149]	2008	Aden	FSWs with regular client in past 1 M	Last sex	56.7	57.8
With one-time client						
Lebanon						
Mahfoud, 2010 [137]	2007-08	Greater Beirut	FSWs with one-time client in past 1 M	Last sex	96.0	100
Libya						
Valadez, 2013 [138]	2010-11	Tripoli	FSWs with one-time client in past 6 M	Last sex	83.1	63.4
Morocco						
MOH, 2012 [12]	2011-12	Agadir	FSWs with one-time client in past 1 M	Last sex	58.3	NR
MOH, 2012 [12]	2011-12	Fes	FSWs with one-time client in past 1 M	Last sex	54.6	NR
MOH, 2012 [12]	2011-12	Rabat	FSWs with one-time client in past 1 M	Last sex	60.3	NR
MOH, 2012 [12]	2011-12	Tanger	FSWs with one-time client in past 1 M	Last sex	72.5	NR
Pakistan						
Bokhari, 2007 [139]	2004	Karachi	FSWs with one-time client in past 7 days	Last sex	28.5	2.4
Bokhari, 2007 [139]	2004	Lahore	FSWs with one-time client in past 7 days	Last sex	47.9	21.8
Sudan						
MOH, 2016 [30]	2015-16	Juba, South Sudan	FSWs with one-time client in past 6 M	Last sex	61.0	NR
Tunisia						
Hsairi, 2012 [31]	2011	Sfax, Sousse, Tunis	FSWs with one-time client in past 1 M	Last sex	54.8	45.5
Yemen						
Stulhofer, 2008 [149]	2008	Aden	FSWs with one-time client in past 7 days	Last sex	57.4	49.6
With non-paying partner						
Egypt						
MOH, 2006 [129]	2006	Cairo	FSWs with non-paying partner	Last sex	6.8	NR
MOH, 2010 [130]	2010	Cairo	FSWs with non-paying partner	Last sex	11.0	5.5
MOH, 2010 [130]	2010	Cairo	FSWs with non-paying partner	Past 12 M	27.4	NR
Kabbash, 2012 [159]	2009-10	Greater Cairo	FSWs who heard of condoms and with non-paying partner in past 6 M	Last sex	13.4	10.3†
Iran						
Sajadi, 2013 [132]	2010	National	FSWs with non-paying partner in past 7 days	Last sex	36.3	28.0

Navadeh, 2012 [131]	2010	Kerman	All FSWs	Last sex	78.3	NR
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Last sex	45.8	27.1*
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Past 1 M	77.4	NR
Lebanon						
Mahfoud, 2010 [137]	2007-08	Greater Beirut	FSWs with non-paying partner in past 1 M	Last sex	48.0	64.0
Pakistan						
Bokhari, 2007 [139]	2004	Karachi	FSWs with non-paying partner in past 7 days	Last sex	22.5	8.3
Bokhari, 2007 [139]	2004	Lahore	FSWs with non-paying partner in past 7 days	Last sex	21.8	8.0
NACP, 2005 [14]	2004-05	Karachi	FSWs with non-paying partner	Last sex	22.2	NR
NACP, 2005 [14]	2004-05	Rawalpindi	FSWs with non-paying partner	Last sex	13.3	NR
NACP, 2005 [14]	2004-05	Karachi	FSWs with non-paying partner in past 1 M	Past 1 M	48.6	19.1
NACP, 2005 [14]	2004-05	Rawalpindi	FSWs with non-paying partner in past 1 M	Past 1 M	26.7	4.8
Hawkes, 2009 [141]	2007	Abbottabad, Rawalpindi	FSWs with non-paying partner	NR	49.0	NR
Punjab NACP, 2015 [201]	2014	Punjab	FSWs with non-paying partner	Past 1 M	NR	15.1
NACP, 2017 [22]	2016-17	National	FSWs with non-paying partner	Last sex	NR	10.9
Somalia						
Testa, 2008 [143]	2008	Hargeisa	FSWs with non-paying partner	Last sex	4.9	8.3
IOM, 2017 [144]	2014	Hargeisa	All FSWs	Last sex	18.8	18.7
Sudan						
MOH, 2016 [30]	2015-16	Juba, South Sudan	FSWs with non-paying partner	Last sex	75.0	71.0
Syria						
MOH, 2005 [104]	2005	NR	FSWs with non-paying partner	NR	68.6	28.2
Tunisia						
MOH, 2010 [203]	2009	Sfax, Sousse, Tunis	All FSWs	NR	NR	19.2
Hsairi, 2012 [31]	2011	Sfax, Sousse, Tunis	FSWs with non-paying partner in past 1 M	Last sex	12.1	11.6
Yemen						
Stulhofer, 2008 [149]	2008	Aden	FSWs with non-paying partner	Last sex	28.8	25.7
With regular non-paying partner						
Iran						
Moayedi-Nia, 2016 [134]	2012-13	Tehran	FSWs with a stable partner	NR	49.0	NR
Morocco						
MOH, 2012 [12]	2011-12	Agadir	FSWs with regular partner in past 1 M	Last sex	20.3	48.7*
MOH, 2012 [12]	2011-12	Fes	FSWs with regular partner in past 1 M	Last sex	36.9	60.8*
MOH, 2012 [12]	2011-12	Rabat	FSWs with regular partner in past 1 M	Last sex	23.8	82.8*
MOH, 2012 [12]	2011-12	Tanger	FSWs with regular partner in past 1 M	Last sex	43.3	60.6*
Pakistan						
Hawkes, 2009 [141]	2007	Abbottabad, Rawalpindi	FSWs with regular non-paying partner	Last sex	46.0	15.0
NACP, 2012 [20]	2011	National	FSWs with regular non-paying partner	NR	NR	20.6
Sudan						
MOH, 2016 [30]	2015-16	Juba, South Sudan	FSWs with regular partner in past 6 M	Last sex	NR	40
With occasional non-paying partner						
Morocco						
MOH, 2012 [12]	2011-12	Agadir	FSWs with occasional partner in past 1 M	Last sex	59.0	2.7*
MOH, 2012 [12]	2011-12	Fes	FSWs with occasional partner in past 1 M	Last sex	43.8	46.3*
MOH, 2012 [12]	2011-12	Rabat	FSWs with occasional partner in past 1 M	Last sex	64.8	50.0*
MOH, 2012 [12]	2011-12	Tanger	FSWs with occasional partner in past 1 M	Last sex	80.1	64.1*
ANAL SEX						
With clients						
Iran						
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Past 1 M	66.7	NR

Libya						
Valadez, 2013 [138]	2010-11	Tripoli	FSWs reporting anal sex in past 1 M	Last sex	0	NR
Morocco						
MOH, 2012 [12]	2011-12	Agadir	FSWs reporting anal sex in past 1 M	Last sex	52.6	63.6*
MOH, 2012 [12]	2011-12	Fes	FSWs reporting anal sex in past 1 M	Last sex	35.5	55.6*
MOH, 2012 [12]	2011-12	Rabat	FSWs reporting anal sex in past 1 M	Last sex	86.5	33.3*
MOH, 2012 [12]	2011-12	Tanger	FSWs reporting anal sex in past 1 M	Last sex	68.2	86.7*
Pakistan						
Bokhari, 2007 [139]	2004	Karachi	FSWs reporting anal sex with regular client	Last sex	6.8	NR
Bokhari, 2007 [139]	2004	Lahore	FSWs reporting anal sex with regular client	Last sex	22.3	NR
Bokhari, 2007 [139]	2004	Karachi	FSWs reporting anal sex with one-time client	Last sex	6.7	NR
Bokhari, 2007 [139]	2004	Lahore	FSWs reporting anal sex with one-time client	Last sex	37.5	NR
NACP, 2005 [14]	2004-05	Karachi	FSWs reporting anal sex in past 1 M	Last sex	17.0	NR
NACP, 2005 [14]	2004-05	Rawalpindi	FSWs reporting anal sex in past 1 M	Last sex	17.2	NR
NACP, 2005 [14]	2005	Faisalabad	FSWs reporting anal sex	Last sex	25.0	NR
NACP, 2005 [14]	2005	Hyderabad	FSWs reporting anal sex	Last sex	14.0	NR
NACP, 2005 [14]	2005	Karachi	FSWs reporting anal sex	Last sex	29.0	NR
NACP, 2005 [14]	2005	Lahore	FSWs reporting anal sex	Last sex	55.0	NR
NACP, 2005 [14]	2005	Multan	FSWs reporting anal sex	Last sex	17.0	NR
NACP, 2005 [14]	2005	Peshawar	FSWs reporting anal sex	Last sex	17.0	NR
NACP, 2005 [14]	2005	Quetta	FSWs reporting anal sex	Last sex	14.0	NR
NACP, 2005 [14]	2005	Sukkur	FSWs reporting anal sex	Last sex	35.0	NR
NACP, 2007 [140]	2006	National	FSWs reporting anal sex	Last sex	7.9	NR
Hawkes, 2009 [141]	2007	Abbottabad & Rawalpindi	FSWs reporting anal sex	Last sex	61.0	NR
NACP, 2010 [142]	2009	Punjab	FSWs reporting anal sex	Last sex	5.2	NR
NACP, 2012 [20]	2011	Karachi	FSWs reporting anal sex	Last sex	52.0	NR
NACP, 2012 [20]	2011	DG Khan	FSWs reporting anal sex	Last sex	36.0	NR
NACP, 2012 [20]	2011	Faisalabad	FSWs reporting anal sex	Last sex	46.0	NR
NACP, 2012 [20]	2011	Haripur	FSWs reporting anal sex	Last sex	36.0	NR
NACP, 2012 [20]	2011	Lahore	FSWs reporting anal sex	Last sex	49.0	NR
NACP, 2012 [20]	2011	Larkana	FSWs reporting anal sex	Last sex	13.0	NR
NACP, 2012 [20]	2011	Multan	FSWs reporting anal sex	Last sex	23.0	NR
NACP, 2012 [20]	2011	Peshawar	FSWs reporting anal sex	Last sex	12.0	NR
NACP, 2012 [20]	2011	Quetta	FSWs reporting anal sex	Last sex	56.0	NR
NACP, 2012 [20]	2011	Rawalpindi	FSWs reporting anal sex	Last sex	10.0	NR
NACP, 2012 [20]	2011	Sargodha	FSWs reporting anal sex	Last sex	19.0	NR
NACP, 2012 [20]	2011	Sukkur	FSWs reporting anal sex	Last sex	39.0	NR
Punjab NACP, 2015 [201]	2014	Faisalabad	FSWs reporting anal sex in past 1 M	Last sex	26.2	NR
Punjab NACP, 2015 [201]	2014	Lahore	FSWs reporting anal sex in past 1 M	Last sex	15.2	NR
Punjab NACP, 2015 [201]	2014	Multan	FSWs reporting anal sex in past 1 M	Last sex	16.0	NR
Punjab NACP, 2015 [201]	2014	Sargodha	FSWs reporting anal sex in past 1 M	Last sex	18.9	NR
NACP, 2017 [22]	2016-17	Bannu	FSWs reporting anal sex	Last sex	60.2	NR
NACP, 2017 [22]	2016-17	Bahawalpur	FSWs reporting anal sex	Last sex	11.9	NR
NACP, 2017 [22]	2016-17	DG Khan	FSWs reporting anal sex	Last sex	4.9	NR
NACP, 2017 [22]	2016-17	Gujranwala	FSWs reporting anal sex	Last sex	19.7	NR
NACP, 2017 [22]	2016-17	Gujrat	FSWs reporting anal sex	Last sex	24.6	NR
NACP, 2017 [22]	2016-17	Hyderabad	FSWs reporting anal sex	Last sex	30.8	NR
NACP, 2017 [22]	2016-17	Karachi	FSWs reporting anal sex	Last sex	4.1	NR
NACP, 2017 [22]	2016-17	Kasur	FSWs reporting anal sex	Last sex	10.4	NR
NACP, 2017 [22]	2016-17	Larkana	FSWs reporting anal sex	Last sex	1.6	NR
NACP, 2017 [22]	2016-17	Mirpurkhas	FSWs reporting anal sex	Last sex	8.5	NR

NACP, 2017 [22]	2016-17	Nawabshah	FSWs reporting anal sex	Last sex	1.4	NR
NACP, 2017 [22]	2016-17	Peshawar	FSWs reporting anal sex	Last sex	13.2	NR
NACP, 2017 [22]	2016-17	Quetta	FSWs reporting anal sex	Last sex	42.9	NR
NACP, 2017 [22]	2016-17	Rawalpindi	FSWs reporting anal sex	Last sex	0	NR
NACP, 2017 [22]	2016-17	Sheikhupura	FSWs reporting anal sex	Last sex	27.5	NR
NACP, 2017 [22]	2016-17	Sialkot	FSWs reporting anal sex	Last sex	6.2	NR
NACP, 2017 [22]	2016-17	Sukkur	FSWs reporting anal sex	Last sex	18.1	NR
NACP, 2017 [22]	2016-17	Turbat	FSWs reporting anal sex	Last sex	6.9	NR
With non-paying partner						
Iran						
Kazerooni, 2014 [133]	2010-11	Shiraz	FSWs reporting anal sex	Past 1 M	39.0	NR
CLIENTS OF FSWS						
Afghanistan						
Todd, 2012 [123]	2010-11	National	Army recruits ever clients of FSWs	Last sex	17.9	9.3
Djibouti						
Trellu-Kane, 2005 [7]	2005	Djibotui	Men aged 13-24 years clients of FSWs in past 12 M	Last sex	53.0	NR
Morocco						
MOH, 2007 [125]	2007	National	Men aged 15-24 ever clients of FSWs	Ever	77.2	35.0
MOH, 2013 [120]	2013	National	Men aged 15-24 years clients of FSWs in past 12 M	Past 12 M	90.4	45.2
Pakistan						
Bokhari, 2007 [139]	2004	Karachi	Truck drivers clients of FSWs in past 12 M	Last sex	1.7	NR
Bokhari, 2007 [139]	2004	Lahore	Truck drivers clients of FSWs in past 12 M	Last sex	6.9	NR
Faisel, 2005 [39]	2004-05	Lahore	Migrant men clients of FSWs in past 12 M	Last sex	10.0	15.0*
Mir, 2013 [126]	2007	National	Men clients of FSWs in past 12 M	Past 12 M	33.1	17.3
Sudan						
UNHCR, 2007 [27]	2006	Juba, South Sudan	Men clients of FSWs in past 12 M	Last sex	0	NR

The table is sorted by year(s) of data collection.

*Consistent condom use among FSWs who reported condom use with client/partner.

†Consistent condom use among FSWs who ever heard of condoms.

Abbreviations: *CI* confidence interval, *FSWs* female sex workers, *IOM* International Organization for Migration, *M* month(s), *MOH* Ministry of Health, *NACP* National AIDS Control Programme, *NAP* National AIDS Program, *NR* not reported, *SAR AIDS HDS* South Asia Region AIDS Human Development Sector, *STI* sexually transmitted infections, *UNHCR* United Nations High Commissioner for Refugees

Table S12 Measures of injecting drug use and overlap with people who inject drugs (PWID) among FSWs in the Middle East and North Africa

Country Author, year [citation]	Year(s) of data collection	City/ province	Drug use			Injecting drug use			Sex with PWID		
			Pop	Time frame	Proportion (%)	Pop	Time frame	Proportion (%)	Pop	Time frame	Proportion (%)
FSWS											
Afghanistan											
Todd, 2010 [151]	2006-08	Jalalabad, Kabul, Mazar-i-Sharif	All FSWs	Ever	6.9	All FSWs	Ever	0.4	NR	NR	NR
NACP, 2010 [128]	2009	Kabul	All FSWs	Ever	1.9	All FSWs	Ever	0	All FSWs	Past 1 M	0.5
NACP, 2012 [6]	2012	Kabul	All FSWs	Ever	1.7	All FSWs	Ever	0.1	All FSWs	Past 12 M	3.8
NACP, 2012 [6]	2012	Herat	All FSWs	Ever	11.7	All FSWs	Ever	7.1	All FSWs	Past 12 M	13.6
NACP, 2012 [6]	2012	Mazar-i-Sharif	All FSWs	Ever	5.5	All FSWs	Ever	0	All FSWs	Past 12 M	6.5
Egypt											
MOH, 2006 [129]	2006	Cairo	All FSWs	Ever	78.8	All FSWs	Past 12 M	9.3	NR	NR	NR
Kabbash, 2012 [159]	2009-10	Cairo	All FSWs	Ever	49.0	All FSWs	Past 12 M	5.6	NR	NR	NR
MOH, 2010 [130]	2010	Cairo	All FSWs	Ever	51.5	All FSWs	Past 12 M	6.0	NR	NR	NR
Iran											
Kassaian, 2012 [161]	2009-10	Isfahan	All FSWs	Ever	61.3	All FSWs	NR	19.0	NR	NR	NR
Kassaian, 2012 [161]	2009-10	Isfahan	NR	NR	NR	Ever DU	Ever	24.1	NR	NR	NR
Sajadi, 2013 [132]	2010	National	All FSWs	Ever	73.8	Ever DU	Ever	20.5	NR	NR	NR
Sajadi, 2013 [132]	2010	National	NR	NR	NR	Ever IDU	Active IDU	26.6	NR	NR	NR
Mirzazadeh, 2016 [135]	2010	National	NR	NR	NR	All FSWs	Ever	13.6	NR	NR	NR
Navadeh, 2012 [131]	2010	Kerman	NR	NR	NR	All FSWs	Ever	18.0	NR	NR	NR
Kazerooni, 2014 [133]	2010-11	Shiraz	All FSWs	Ever	69.9	Ever DU	Ever	16.4	NR	NR	NR
Moayedi-Nia, 2016 [134]	2012-13	Tehran	All FSWs	Ever	90.7	NR	NR	NR	NR	NR	NR
Moayedi-Nia, 2016 [134]	2012-13	Tehran	Ever DU	Current	50.9	Active DU	Ever	25.5	NR	NR	NR
Taghizadeh, 2015 [162]	2014	Sari	All FSWs	Current	59.0	Active DU	Current	1.1	NR	NR	NR
Asadi-Ali, 2018 [163]	2015	Northern Iran	All FSWs	Past 12 M	39.7	All FSWs	NR	NR	NR	NR	NR
Mirzazadeh, 2016 [135]	2015	National	All FSWs	Ever	59.8	All FSWs	Ever	6.1	NR	NR	NR
Karami, 2017 [11]	2016	Tehran	NR	NR	NR	NR	NR	NR	All FSWs	NR	23.6
Lebanon											
Naman, 1989 [164]	1985-87	NR	NR	NR	NR	All FSWs	NR	1.4	NR	NR	NR
Mahfoud, 2010 [137]	2007-08	Beirut	NR	NR	NR	All FSWs	Ever	0	NR	NR	NR
Libya											
Valadez, 2013 [138]	2010-11	Tripoli	All FSWs	Past 6 M	1.2	All FSWs	Ever	0	NR	NR	NR
Morocco											
MOH, 2012 [12]	2011-12	Agadir	All FSWs	Ever	13.2	Ever DU	Ever	0.3	NR	NR	NR
MOH, 2012 [12]	2011-12	Fes	All FSWs	Ever	17.7	Ever DU	Ever	6.8	NR	NR	NR
MOH, 2012 [12]	2011-12	Rabat	All FSWs	Ever	8.1	Ever DU	Ever	0	NR	NR	NR
MOH, 2012 [12]	2011-12	Tanger	All FSWs	Ever	7.9	Ever DU	Ever	11.8	NR	NR	NR
MOH, 2012 [12]	2011-12	Agadir	Ever DU	Past 6 M	81.6	NR	NR	NR	NR	NR	NR
MOH, 2012 [12]	2011-12	Fes	Ever DU	Past 6 M	95.0	NR	NR	NR	NR	NR	NR
MOH, 2012 [12]	2011-12	Rabat	Ever DU	Past 6 M	85.8	NR	NR	NR	NR	NR	NR
MOH, 2012 [12]	2011-12	Tanger	Ever DU	Past 6 M	79.4	NR	NR	NR	NR	NR	NR
Pakistan											
Baqi, 1998 [167]	1993-94	Karachi	All FSWs	Current	1.2	All FSWs	Ever	0	NR	NR	NR
Bokhari, 2007 [139] & NACP, 2005 [14]	2004	Karachi	NR	NR	NR	All FSWs	Past 12 M	4.4	All FSWs	NR	18.2

Bokhari, 2007 [139] & NACP, 2005 [14]	2004	Lahore	NR	NR	NR	All FSWs	Past 12 M	1.2	All FSWs	NR	22.8
NACP, 2005 [14]	2004-05	Karachi	All FSWs	Current	23.1	All FSWs	Current	4.6	NR	NR	NR
NACP, 2005 [14]	2004-05	Rawalpindi	All FSWs	Current	8.9	All FSWs	Current	0	NR	NR	NR
NACP, 2005 [14]	2005	Faisalabad	NR	NR	NR	All FSWs	Past 6 M	8.0	All FSWs	Past 6 M	33.0
NACP, 2005 [14]	2005	Hyderabad	NR	NR	NR	All FSWs	Past 6 M	0	All FSWs	Past 6 M	5.0
NACP, 2005 [14]	2005	Karachi	NR	NR	NR	All FSWs	Past 6 M	1.0	All FSWs	Past 6 M	3.0
NACP, 2005 [14]	2005	Lahore	NR	NR	NR	All FSWs	Past 6 M	2.5	All FSWs	Past 6 M	19.0
NACP, 2005 [14]	2005	Multan	NR	NR	NR	All FSWs	Past 6 M	3.0	All FSWs	Past 6 M	8.0
NACP, 2005 [14]	2005	Peshawar	NR	NR	NR	All FSWs	Past 6 M	0	All FSWs	Past 6 M	17.0
NACP, 2005 [14]	2005	Quetta	NR	NR	NR	All FSWs	Past 6 M	5.0	All FSWs	Past 6 M	15.0
NACP, 2005 [14]	2005	Sukkur	NR	NR	NR	All FSWs	Past 6 M	8.0	All FSWs	Past 6 M	8.0
NACP, 2007 [140]	2006	Bannu	NR	NR	NR	All FSWs	Past 6 M	3.2	All FSWs	Past 6 M	6.8
NACP, 2007 [140]	2006	Faisalabad	NR	NR	NR	All FSWs	Past 6 M	7.5	All FSWs	Past 6 M	31.0
NACP, 2007 [140]	2006	Gujranwala	NR	NR	NR	All FSWs	Past 6 M	5.3	All FSWs	Past 6 M	30.3
NACP, 2007 [140]	2006	Hyderabad	NR	NR	NR	All FSWs	Past 6 M	3.3	All FSWs	Past 6 M	2.3
NACP, 2007 [140]	2006	Karachi	NR	NR	NR	All FSWs	Past 6 M	0.7	All FSWs	Past 6 M	4.2
NACP, 2007 [140]	2006	Lahore	NR	NR	NR	All FSWs	Past 6 M	1.6	All FSWs	Past 6 M	16.9
NACP, 2007 [140]	2006	Larkana	NR	NR	NR	All FSWs	Past 6 M	1.0	All FSWs	Past 6 M	0.3
NACP, 2007 [140]	2006	Multan	NR	NR	NR	All FSWs	Past 6 M	1.0	All FSWs	Past 6 M	2.3
NACP, 2007 [140]	2006	Peshawar	NR	NR	NR	All FSWs	Past 6 M	1.7	All FSWs	Past 6 M	6.7
NACP, 2007 [140]	2006	Quetta	NR	NR	NR	All FSWs	Past 6 M	1.5	All FSWs	Past 6 M	3.3
NACP, 2007 [140]	2006	Sargodha	NR	NR	NR	All FSWs	Past 6 M	1.3	All FSWs	Past 6 M	12.5
NACP, 2007 [140]	2006	Sukkur	NR	NR	NR	All FSWs	Past 6 M	0	All FSWs	Past 6 M	0
Hawkes, 2009 [141]	2007	Abbottabad, Rawalpindi	NR	NR	NR	All FSWs	Past 12 M	3.0	All FSWs	Past 12 M	36.0
Khan, 2011 [17]	2007	Lahore	NR	NR	NR	All FSWs	NR	0.4	NR	NR	NR
NACP, 2010 [142]	2009	Punjab	NR	NR	NR	All FSWs	Past 6 M	6.0	All FSWs	Past 6 M	7.0
NACP, 2012 [20]	2011	DG Khan	NR	NR	NR	All FSWs	Past 6 M	5.1	All FSWs	Past 6 M	1.1
NACP, 2012 [20]	2011	Faisalabad	NR	NR	NR	All FSWs	Past 6 M	6.4	All FSWs	Past 6 M	13.8
NACP, 2012 [20]	2011	Haripur	NR	NR	NR	All FSWs	Past 6 M	2.4	All FSWs	Past 6 M	1.9
NACP, 2012 [20]	2011	Karachi	NR	NR	NR	All FSWs	Past 6 M	1.9	All FSWs	Past 6 M	5.6
NACP, 2012 [20]	2011	Lahore	NR	NR	NR	All FSWs	Past 6 M	5.1	All FSWs	Past 6 M	7.2
NACP, 2012 [20]	2011	Larkana	NR	NR	NR	All FSWs	Past 6 M	0.3	All FSWs	Past 6 M	0.5
NACP, 2012 [20]	2011	Multan	NR	NR	NR	All FSWs	Past 6 M	16.8	All FSWs	Past 6 M	24.8
NACP, 2012 [20]	2011	Peshawar	NR	NR	NR	All FSWs	Past 6 M	0	All FSWs	Past 6 M	0.3
NACP, 2012 [20]	2011	Quetta	NR	NR	NR	All FSWs	Past 6 M	6.7	All FSWs	Past 6 M	30.3
NACP, 2012 [20]	2011	Rawalpindi	NR	NR	NR	All FSWs	Past 6 M	1.3	All FSWs	Past 6 M	2.1
NACP, 2012 [20]	2011	Sargodha	NR	NR	NR	All FSWs	Past 6 M	5.2	All FSWs	Past 6 M	23.2
NACP, 2012 [20]	2011	Sukkur	NR	NR	NR	All FSWs	Past 6 M	6.1	All FSWs	Past 6 M	39.7
PNACP, 2015 [201]	2014	Faisalabad	NR	NR	NR	All FSWs	Past 6 M	1.4	All FSWs	Past 6 M	0.5
PNACP, 2015 [201]	2014	Lahore	NR	NR	NR	All FSWs	Past 6 M	1.0	All FSWs	Past 6 M	3.1
PNACP, 2015 [201]	2014	Multan	NR	NR	NR	All FSWs	Past 6 M	4.0	All FSWs	Past 6 M	3.8
PNACP, 2015 [201]	2014	Sargodha	NR	NR	NR	All FSWs	Past 6 M	2.1	All FSWs	Past 6 M	2.6
NACP, 2017 [22]	2016-17	Bahawalpur	NR	NR	NR	All FSWs	Past 12 M	1.1	All FSWs	Past 12 M	0.3
NACP, 2017 [22]	2016-17	Bannu	NR	NR	NR	All FSWs	Past 12 M	0	All FSWs	Past 12 M	0.5
NACP, 2017 [22]	2016-17	DG Khan	NR	NR	NR	All FSWs	Past 12 M	0.3	All FSWs	Past 12 M	0
NACP, 2017 [22]	2016-17	Gujranwala	NR	NR	NR	All FSWs	Past 12 M	0.7	All FSWs	Past 12 M	0.3
NACP, 2017 [22]	2016-17	Gujrat	NR	NR	NR	All FSWs	Past 12 M	5.6	All FSWs	Past 12 M	19.4
NACP, 2017 [22]	2016-17	Hyderabad	NR	NR	NR	All FSWs	Past 12 M	10.4	All FSWs	Past 12 M	25.5
NACP, 2017 [22]	2016-17	Karachi	NR	NR	NR	All FSWs	Past 12 M	0	All FSWs	Past 12 M	3.4

NACP, 2017 [22]	2016-17	Kasur	NR	NR	NR	All FSWs	Past 12 M	0.3	All FSWs	Past 12 M	5.5
NACP, 2017 [22]	2016-17	Larkana	NR	NR	NR	All FSWs	Past 12 M	0.5	All FSWs	Past 12 M	0.5
NACP, 2017 [22]	2016-17	Mirpurkhas	NR	NR	NR	All FSWs	Past 12 M	0.5	All FSWs	Past 12 M	4.9
NACP, 2017 [22]	2016-17	Nawabshah	NR	NR	NR	All FSWs	Past 12 M	9.3	All FSWs	Past 12 M	3.8
NACP, 2017 [22]	2016-17	Peshawar	NR	NR	NR	All FSWs	Past 12 M	1.1	All FSWs	Past 12 M	14.0
NACP, 2017 [22]	2016-17	Quetta	NR	NR	NR	All FSWs	Past 12 M	9.3	All FSWs	Past 12 M	54.9
NACP, 2017 [22]	2016-17	Rawalpindi	NR	NR	NR	All FSWs	Past 12 M	0.3	All FSWs	Past 12 M	4.9
NACP, 2017 [22]	2016-17	Sheikhupura	NR	NR	NR	All FSWs	Past 12 M	5.5	All FSWs	Past 12 M	45.2
NACP, 2017 [22]	2016-17	Sialkot	NR	NR	NR	All FSWs	Past 12 M	0	All FSWs	Past 12 M	0
NACP, 2017 [22]	2016-17	Sukkur	NR	NR	NR	All FSWs	Past 12 M	5.5	All FSWs	Past 12 M	16.5
NACP, 2017 [22]	2016-17	Turbat	NR	NR	NR	All FSWs	Past 12 M	2.8	All FSWs	Past 12 M	25.0
Somalia											
Burans, 1990 [174]	NR	Mogadishu	All FSWs	Current	13.5	All FSWs	NR	0	NR	NR	NR
Testa, 2008 [143]	2008	Hargeisa	All FSWs	Past 1 M	0.6	All FSWs	Past 12 M	0	NR	NR	NR
IOM, 2017 [144]	2014	Hargeisa	All FSWs	Ever	85.2	All FSWs	Past 12 M	0.6	NR	NR	NR
IOM, 2017 [144]	2014	Hargeisa	All FSWs	Past 1 M	4.7	NR	NR	NR	NR	NR	NR
Sudan											
Elhadi, 2013 [202]	2011	Alshamalia	NR	NR	NR	All FSWs	Ever	1.5	NR	NR	NR
Elhadi, 2013 [202]	2011	Blue Nile	NR	NR	NR	All FSWs	Ever	0.9	NR	NR	NR
Elhadi, 2013 [202]	2011	Gadarif	NR	NR	NR	All FSWs	Ever	0.5	NR	NR	NR
Elhadi, 2013 [202]	2011	Gezira	NR	NR	NR	All FSWs	Ever	0.4	NR	NR	NR
Elhadi, 2013 [202]	2011	Kassala	NR	NR	NR	All FSWs	Ever	0.9	NR	NR	NR
Elhadi, 2013 [202]	2011	Khartoum	NR	NR	NR	All FSWs	Ever	2.3	NR	NR	NR
Elhadi, 2013 [202]	2011	North Darfur	NR	NR	NR	All FSWs	Ever	5.0	NR	NR	NR
Elhadi, 2013 [202]	2011	North Kodofan	NR	NR	NR	All FSWs	Ever	0.1	NR	NR	NR
Elhadi, 2013 [202]	2011	Red Sea	NR	NR	NR	All FSWs	Ever	0	NR	NR	NR
Elhadi, 2013 [202]	2011	River Nile	NR	NR	NR	All FSWs	Ever	0.6	NR	NR	NR
Elhadi, 2013 [202]	2011	Sinnar	NR	NR	NR	All FSWs	Ever	1.0	NR	NR	NR
Elhadi, 2013 [202]	2011	South Darfur	NR	NR	NR	All FSWs	Ever	2.6	NR	NR	NR
Elhadi, 2013 [202]	2011	West Darfur	NR	NR	NR	All FSWs	Ever	1.6	NR	NR	NR
Elhadi, 2013 [202]	2011	White Nile	NR	NR	NR	All FSWs	Ever	1.6	NR	NR	NR
MOH, 2016 [30]	2015-16	Juba, South Sudan	All FSWs	Past 6 M	14.0	NR	NR	NR	NR	NR	NR
Syria											
MOH, 2005 [104]	2005	NR	NR	NR	NR	All FSWs	Ever	10.0	NR	NR	NR
Tunisia											
MOH, 2010 [203]	2009	Sfax, Sousse, Tunis	All FSWs	Ever	31.3	NR	NR	NR	NR	NR	NR
Hsairi, 2012 [31]	2011	Sfax	All FSWs	Ever	29.2	Ever DU	Past 12 M	0	NR	NR	NR
Hsairi, 2012 [31]	2011	Sousse	All FSWs	Ever	24.8	Ever DU	Past 12 M	4.7	NR	NR	NR
Hsairi, 2012 [31]	2011	Tunis	All FSWs	Ever	18.8	Ever DU	Past 12 M	8.8	NR	NR	NR
Yemen											
Stulhofer, 2008 [149]	2008	Aden	All FSWs	Past 1 M	2.4	All FSWs	Past 1 M	2.1	NR	NR	NR
CLIENTS OF FSWS											
Afghanistan											
Todd, 2012 [123]	2010-11	National	Army recruits-clients	Ever	32.9	NR	NR	NR	NR	NR	NR
Somalia											
Burans, 1990 [174]	NR	Mogadishu	NR	NR	NR	STI clinic attendees	NR	0	NA	NA	NA
Rehan, 2003 [193]	1999	Lahore, Karachi, Peshawar, Quetta	STI clinic attendees	NR	10.5	NR	NR	NR	NA	NA	NA

The table is sorted by year(s) of data collection.
Abbreviations: *DU* drug users, *FSWs* female sex workers, *IDU* injecting drug users, *IOM* International Organization for Migration, *M* month(s), *MOH* Ministry of Health, *NA* not applicable, *NACP* National AIDS Control Programme, *NR* not reported, *PNACP* Punjab National AIDS Control Programme, *Prp* proportion, *PWID* people who inject drugs

Table S13 HIV/AIDS knowledge among FSWs in the Middle East and North Africa

	Afghanistan	Egypt	Iran	Lebanon	Morocco	Pakistan	Somalia	Sudan	Syria	Tunisia	Yemen
Aware of HIV/AIDS											
Ever heard of HIV/AIDS (%)	25.4 [6], 32.4 [128], 37.8 [6], 39.9 [6], 54.0 [5], 75.0 [5]	100.0 [129], 89.0 [130]	92.7 [132], 98.7 [162]		84.3 [12], 99.0 [12], 99.6 [12], 100.0 [12]	35.0 [141], 64.1 [15], 68.4 [139], 66.9 [22], 68.7 [140], 75.2 [139], 80.3 [14], 80.4 [20], 80.7 [14], 83.0 [17], 87.3 [201]	64.9 [176], 96.2 [143], 97.3 [144]	98.4 [146]	97.5 [204]	94.2 [31], 95.0 [203]	
Aware of sex as a mode of HIV transmission											
In all FSWs (%)	59.0 [5], 72.0 [5]				72.0 [86]	50.8 [22], 63.8 [14], 68.6 [14]		78.5 [30], 85.4 [146]	94.9 [204]		
In FSWs who ever heard of HIV (%)						68.9 [140], 70.2 [140], 71.9 [140], 74.0 [140], 75.5 [140], 75.9 [140], 81.7 [15], 84.6 [140], 84.8 [201], 86.5 [140], 86.6 [140], 87.1 [140], 87.3 [140], 93.7 [140], 94.3 [20]					
Aware of HIV transmission through unprotected sex											
In all FSWs (%)	14.1 [128], 24.2 [6], 32.0 [5], 34.7 [6], 34.8 [6], 47.0 [5]		89.8 [132]	88.0 [137]	50.6 [12], 58.4 [12], 59.8 [12], 61.0 [12], 72.0 [86]	15.4 [14], 26.0 [139], 39.7 [142], 45.3 [14], 46.8 [22], 54.5 [139], 75.8 [20]	51.6 [144], 70.6 [143]	57.9 [30]	76.6 [204]		77.9 [149]
In FSWs who ever heard of HIV (%)		49.4 [130]				38.6 [140], 44.0 [140], 44.9 [140], 47.6 [140], 47.8 [140], 60.4 [15], 68.5 [140], 71.7 [140], 72.9 [140], 73.2 [20], 78.2 [140], 78.8 [140], 81.2 [140], 86.3 [201], 86.8 [140]				66.1 [31], 78.9 [203], 83.1 [31], 86.7 [31]	
Aware of sharing needles as a mode of HIV transmission											
In all FSWs (%)	30.7 [128]		95.4 [132]	91.0 [137]	84.9 [12], 93.4 [12], 95.3 [12], 99.6 [12]	11.5 [14], 18.9 [22], 57.0[14], 63.3 [139], 72.1 [139]	95.8 [143], 99.5 [144]	91.3 [146]	86.4 [104]		
In FSWs who ever heard of HIV (%)		88.2 [130]				32.6 [20], 37.3 [140], 42.4 [15], 67.1 [201]				92.4 [31], 92.9 [31], 96.4 [31]	

Abbreviations: FSWs female sex workers

Table S14 Perception of risk among FSWs in the Middle East and North Africa

Perception of being at risk of HIV	Iran	Lebanon	Pakistan	Sudan	Syria	Yemen
No risk (%)				4.9 [148], 7.0 [200], 11.2 [30], 12.5 [148], 14.3 [148], 15.1 [148], 15.9 [146], 21.4 [148], 22.7 [148], 23.7 [148], 25.8 [148], 26.9 [148], 27.6 [148], 29.0 [200], 34.2 [148], 35.8 [148], 37.8 [148], 44.4 [148]	16.1 [204]	
At risk						
Among all FSWs (%)	48.5 [132]	44.0 [137]	22.8 [22], 23.0 [14], 25.2 [14], 45.0 [17]			
Among FSWs who ever heard of HIV (%)			28.0 [15], 38.0 [140], 45.1 [20], 65.9 [201]			
Low risk (%)				7.1 [148], 8.6 [148], 8.8 [148], 11.6 [148], 12.1 [148], 12.1 [148], 12.4 [148], 13.7 [148], 18.3 [148], 19.8 [148], 24.1 [148], 27.0 [146], 27.3 [148], 31.5 [148], 32.1 [148], 46.9 [30]	46.2 [104]	
Medium risk (%)				5.3 [148], 5.5 [148], 9.1 [148], 10.6 [148], 11.2 [148], 11.4 [148], 15.3 [148], 16.3 [148], 16.4 [148], 19.9 [148], 20.2 [148], 22.9 [148], 23.5 [148], 27.3 [30], 32.9 [148], 36.1 [146]		
High risk (%)				5.9 [148], 6.6 [148], 7.4 [148], 8.6 [148], 9.6 [148], 10.9 [148], 13.8 [148], 14.3 [148], 14.5 [148], 14.6 [30], 15.5 [148], 15.8[148], 20.7 [148], 21.0 [146], 21.4 [148], 32.0 [148]	18.7 [204]	14.1 [149]

Abbreviations: *FSWs* female sex workers

Table S15 HIV testing among FSWs in the Middle East and North Africa

HIV testing	Afg	Alg	Egypt	Iran	Leb	Lib	Mor	Pakistan	Somal	Sudan	Syria	Tunisia	Yemen
Ever tested													
Ever tested among all FSWs (%)	4.0 [5], 4.3 [128], 12.0 [5], 21.7 [6], 93.2 [6], 96.2 [6]			45.0 [205], 80.6 [205], 99.4 [162]	79.0 [137]		24.3 [12], 33.5 [12], 34.8 [12], 36.0 [12]	4.9 [14], 6.0 [141], 8.5 [14], 17.2 [22]	5.0 [143], 29.6 [144]	4.4 [148], 5.2 [148], 5.4 [148], 8.0 [148], 8.6 [148], 9.4 [148], 10.4 [148], 12.2 [148], 14.4 [148], 14.6 [148], 17.6 [148], 17.9 [148], 22.0 [148], 23.9 [148], 78.7 [30]	45.0 [104]		20.1 [149]
Ever tested among FSWs who ever heard of HIV (%)			3.4 [130]					0.5 [140], 0.5 [140], 1.5 [140], 2.8 [140], 2.8 [140], 3.3 [140], 4.1 [140], 6.2 [15], 8.3 [140], 8.5 [140], 14.4 [140], 15.7 [20], 15.8 [140], 16.5 [140], 55.9 [201]				21.8 [31], 27.7 [31], 38.0 [31], 15.5 [203]	
Ever received results among FSWs who ever tested for HIV (%)	78.6 [6], 81.0 [6], 96.9 [6]				99.0 [137]		91.9 [12], 95.5 [12], 96.0 [12], 96.7 [12]	60.0 [201]			75.8 [104]	87.2 [31]	
Ever tested and received results among all FSWs (%)								0.7 [139], 0.9 [139]	4.0 [143]			8.8 [203]	
Tested in past 12 M													
Tested in past 12 months among all FSWs (%)				35.9 [206]			13.4 [12], 17.9 [12], 20.3 [12], 25.3 [12]			0.9 [148], 2.5 [148], 3.1 [148], 4.5 [148], 5.2 [148], 6.2 [148], 8.1 [148], 8.5 [148], 9.6 [148], 11.1 [148], 12.1 [148], 12.4 [148], 12.7 [148], 19.1 [148]	38.0 [204]	14.3 [31]	
Tested in past 12 months among FSWs who ever tested for HIV (%)	43.1 [6], 57.1 [6], 75.0 [6]		33.3 [130]		82.0 [137]		58.9 [12], 59.4 [12], 65.1 [12], 71.7 [12]		47.7 [143], 77.2 [144]				38.9 [149]
Received results in past 12 M among all FSWs (%)										0.4 [148], 1.7 [148], 2.4 [148], 4.1 [148], 5.4 [148], 6.0 [148], 7.8 [148], 8.3 [148], 9.2 [148], 10.0 [148], 10.8 [148], 11.5 [148], 11.6 [148], 18.4 [148]			
Received results among FSWs who				79.0 [206]					86.7 [144],	38.5 [148], 51.8 [148], 86.0 [148], 89.8 [148], 91.6 [148], 93.3 [148],			

tested for HIV in past 12 M (%)									100.0 [143]	93.5 [148], 93.5 [148], 93.8 [148], 93.9 [148], 96.0 [148], 96.4 [148], 99.3 [148], 100.0 [148]			
Tested & received results in past 12 M among all FSWs (%)		20.0 [53], 29.5 [53]	1.1 [71, 130], 100 [71] (identified by NGO)	27.5 [205], 32.9 [134], 70.4 [205]		38.6 [138]	14.2 [12], 16.3 [12], 18.5 [12], 25.0 [12]	14.1 [142], 15.5 [142]		7.0 [146]		13.4 [31], 14.1 [203]	6.0 [150]

Abbreviations: *Afg* Afghanistan, *Alg* Algeria, *FSWs* female sex workers, *Leb* Lebanon, *Lib* Libya, *M* month(s), *Mor* Morocco, *Somal* Somalia

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Appendix III

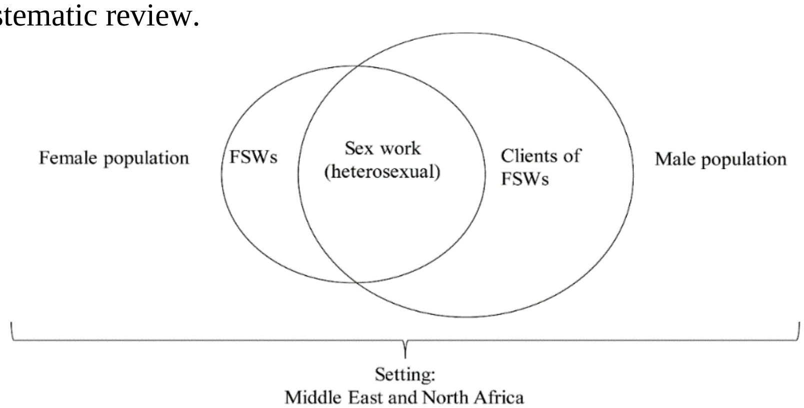
Supplementary material for Research paper 1-

Search criteria

1. Conceptual framework

The search strategy is informed by the interaction between three main spheres: 1) context: sex work, 2) setting: MENA, and 3) populations: a. female and b. male. The conceptual framework guiding the development of the search strategy is illustrated in Figure S1.

Figure S1. Conceptual framework informing the development of the search strategy for the systematic review.



2. Systematic review of systematic reviews of studies of FSWs and clients globally

Any systematic review focused on FSWs or clients of FSWs regardless of geographic area was eligible for inclusion. Search was conducted in PubMed and Embase using broad search terms for sex work:

PubMed (22 Feb 2017)

“Sex Work”[Mesh] OR "Sex workers"[Mesh] OR Sex work*[Text] OR Prostitut*[Text] OR Female sex work*[Text] OR FSW*[Text] OR CSW*[Text] OR Sex worker* client*[Text] OR Sex client*[Text] OR female sex work* client*[Text] OR Client* of female sex work*[Text] OR Client of sex work*[Text] OR Commercial sex*[Text] OR Transactional sex*[Text]
N= 62 citations retrieved after limiting to Humans and Systematic reviews.

Embase (22 Feb 2017)

((exp prostitution/ or exp sexual promiscuity/ or exp sex trafficking/ or exp sexual exploitation/ or exp transactional sex/) OR (prostitut* or sex work* or female sex work* or FSW* or CSW* or sex work* client* or sex client* or female sex work* client* or client* of sex* or client* of female sex work* or commercial sex* or transactional sex*)) AND (exp "systematic review"/)

N=178 citations retrieved after limiting to Humans.

The search identified a total of 240 citations, of which 195 were unique. Screening of these citations identified 40 relevant, 21 potentially relevant and 134 not relevant citations.

The detailed extraction of the search strategies from relevant and potentially relevant systematic reviews can be found in Table S2.

Table S2. Search criteria for other systematic reviews on FSWs and their clients.

Citation	Research area/Theme	Region/Country	Search terms
Relevant articles			
Abad, N., et al., *A review of HIV/STD behavioral prevention interventions for female sex workers in the United States.* Sexually Transmitted Diseases, 2014. **41**: p. S114.	Behavioral interventions	US	Commercial sex, sex trade, prostitution, paying partners (Conference abstract)
Baral, S., et al., *High and disproportionate burden of HIV among female sex workers in low-and middle-income countries: A systematic review and meta-analysis.* Journal of the International AIDS Society, 2012. **15**: p. 90-91.	HIV prevalence	Low and middle income countries	Could not be retreived
Baral, S., 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. **12**(7): p. 538-549.	HIV incidence	Low and middle income countries	MeSH terms for HIV or AIDS, and terms associated with sex work (prostitute [MeSH] or “sex work” or “sex work*” or “female sex worker” or “commercial sex worker”)
Buzdugan, R., S.S. Halli, and F.M. Cowan, *The female sex work typology in India in the context of HIV/AIDS.* Trop Med Int Health, 2009. **14**(6): p. 673-87.	Typology of FSW	India	Text words: ‘India’ AND (‘sex work’ OR ‘prostitution’ OR ‘sex worker’ OR ‘prostitute’) Google: ‘India’ AND (‘sex work typology’ OR ‘typology of sex work’ OR ‘typologies of sex work’ OR ‘sex work typologies’ OR ‘sex work type’ OR ‘type of sex work’ OR ‘types of sex work’ OR ‘form of sex work’)
Chersich, M.F., 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. **16 (no pagination)**(17980).	Interventions	Africa	Search terms were: prosti (or any term with this word) or ‘‘sex work’’ or ‘‘sex worker’’ or ‘‘sex workers’’, and Africa (MeSH term or any field)
Chow, E.P., et al., *Risk behaviours among female sex workerin China: a systematic review and data synthesis.* PLoS One, 2015. **10**(3): p. e0120595.	Risk behaviors among FSWs	China	(“China [MeSH]” OR “Chinese [MeSH]”) AND (“sex workers [MeSH]” OR “prostitute” OR “women who sell sex” OR “sex industry” OR “commercial sex”) AND (“risk behaviour” OR “risk behavior” OR “condom” OR “HIV test” OR “drug use” OR “unprotected sex”)
Chow, E.P., et al., *Behavioral Interventions Improve Condom Use and HIV Testing Uptake Among Female Sex Workers in China: A Systematic Review and Meta-Analysis.* AIDS Patient Care STDS, 2015. **29**(8): p. 454-60.	Behavioral interventions (impact)	China	The search was conducted using free-text terms and MeSH terms: (‘human immunodeficiency virus’ OR ‘HIV’ OR ‘Acquired immune deficiency syndrome’ OR ‘AIDS’) AND (‘prevention’ OR ‘intervention’ OR ‘control’) AND (‘female sex workers’ OR ‘commercial sex workers’ OR ‘women who sell sex’ OR ‘FSW’ or ‘CSW’) AND (‘China’ OR ‘Chinese’).

Dhana, A., et al., *Systematic review of facility-based sexual and reproductive health services for female sex workers in Africa.* Globalization and Health, 2014. **10 (1) (no pagination)**(46).	Facility-based prevention and care services for FSWs	Low and middle income countries in Africa	combined MeSH and free text terms for low- and middle-income countries [9] together with sex work. In Web of Science, we used text search terms to locate all articles that included Africa or India, and sex work or high-risk populations.
Footer, K.H.A., et al., *Policing practices as a structural determinant for HIV among sex workers: A systematic review of empirical findings.* Journal of the International AIDS Society, 2016. **19 (no pagination)**(20883).	Structural determinants of HIV among sex workers (policing)	Global	PubMed: "Sex Workers"[Mesh] OR "Prostitution"[Mesh] OR sex work*[tw] OR sexual work*[tw] OR sexwork*[tw] OR prostitut*[tw] OR commercial sex*[tw] OR transactional sex*[tw] OR trading sex*[tw] OR traded sex*[tw] OR sex transaction*[tw] OR sexual transaction*[tw] OR exchanging sex*[tw] OR exchanged sex*[tw] OR sexual favor*[tw] OR trade sex*[tw] OR exchange sex*[tw] Embase: 'prostitution'/exp OR 'transactional sex'/exp OR ((sex NEXT/1 work*) OR (sexual NEXT/1 work*) OR sexwork* OR prostitut* OR (commercial NEXT/1 sex*) OR (transaction* NEXT/1 sex*) OR (trading NEXT/1 sex*) OR (trade* NEXT/1 sex*) OR (sex* NEXT/1 transaction*) OR (exchang* NEXT/1 sex*) OR (sex* NEXT/1 favor*)):ab,ti text terms only searched in tile/abstract
Harcourt, C. and B. Donovan, *The many faces of sex work.* Sexually Transmitted Infections, 2005. **81**(3): p. 201-206.	Typology of CSW	15 countries	''prostitution''
Hong, Y. and X. Li, *Behavioral studies of female sex workers in China: a literature review and recommendation for future research.* AIDS Behav, 2008. **12**(4): p. 623-36.	Behavioral studies of FSWs	China	China, sex workers, prostitutes, entertainment workers, prostitution, commercial sex, and HIV risks
Hong, Y., A.N. Poon, and C. Zhang, *HIV/STI prevention interventions targeting FSWs in China: a systematic literature review.* AIDS Care, 2011. **23 Suppl 1**: p. 54-65.	HIV/STI prevention interventions among FSWs	China	China, female sex workers, prostitutes (prostitution), entertainment workers, commercial sex, STI(STD), sexual behavior, prevention, condom use, sexual risks, intervention, and HIV/AIDS
Jeal, N., et al., *Systematic review of interventions to reduce illicit drug use in female drug-dependent street sex workers.* BMJ Open, 2015. **5 (11) (no pagination)**(e009238).	Interventions to reduce drug use among FSWs	UK	Medline on Ovid 1. prostitution 2. prostitut*.tw 3. sex adj1 work*.tw 4. substance-related disorders 5. amphetamine-related disorders 6. cocaine-related disorders 7. crack cocaine 8. heroin dependence 9. morphine dependence 10. opioid-related disorders 11. street drugs 12. substance abuse, intravenous
Kerrigan, D., et al., *A community empowerment approach to the HIV response among sex workers: Effectiveness, challenges, and considerations for implementation and scale-up.* The Lancet, 2015. **385**(9963): p. 172-185.	Interventions among sex workers	Low and middle income countries	("sex work*" OR prostitut*) AND (empower* OR power OR mobiliz* OR mobilis* OR "community development" OR "community led" OR "community-led" OR collective OR solidarity OR "social cohesion" OR "social capital" OR "social vulnerability" OR "social inclusion" OR "social exclusion" OR "social environment" OR participat* OR rights OR environmental OR structural OR peer) AND (HIV OR AIDS OR STI OR STD OR "condom use")
Lancaster, K.E., et al., *HIV care and treatment experiences among female sex workers living with HIV in sub-Saharan Africa: A systematic review.* African Journal of AIDS Research, 2016. **15**(4): p. 377-386.	HIV care and treatment among FSWs	Sub-Saharan Africa	(('HIV-positive' OR 'HIV positive' OR 'HIV seropositive' OR 'living with HIV' OR 'living with AIDS' OR PLWH OR PLWA OR PLWHA OR PLHIV) AND ('sex work' OR 'sex worker' OR 'sex workers' OR prostitute*) AND (female* OR women)).
Li, Q., X. Li, and B. Stanton, *Alcohol use among female sex workers and male clients: an integrative review of global*	Alcohol use among FSWs and clients	Global	'female', 'women', 'sex workers', 'prostitutes', 'entertainment workers', 'prostitution', 'commercial sex', 'sex work', 'sex industry', 'sex

literature. Alcohol Alcohol, 2010. **45**(2): p. 188-99.			trade', 'sell sex', 'exchange sex', 'alcohol', 'drinking', 'drunk', 'drunkenness' and 'intoxication'
MacAllister, J., et al., *A comprehensive review of available epidemiologic and HIV service data for female sex workers, men who have sex with men, and people who inject drugs in select West and Central African countries.* Journal of Acquired Immune Deficiency Syndromes, 2015. **68**: p. S83-S90.	HIV epidemiology, treatment and size estimation of key populations	Central Africa: Cameroon, Chad, Cote d'Ivoire, Democratic Republic of Congo, Ghana, Guinea-Bissau, Niger, and Nigeria	"sex worker*"[tw] OR "sex workers"[Mesh] OR "FSW" [tw] OR "SW" [tw] OR "prostitute*"[tw] OR "prostitution" [tw] OR "commercial sex" [tw] OR "commercial sex worker*"[tw] OR "CSW" [tw] OR "transactional sex" [tw] OR "transactional sex worker*"[tw] OR "TSW" [tw] OR "travailleuse du sexe"[tw] OR "TS"[tw] OR "intravenous drug user"[tw] OR "IVDU"[tw] OR "IDU"[tw] OR "drug user"[tw] OR "men who have sex with men"[tw] OR "MSM"[tw] OR "males who have sex with males"[tw] OR "bisexual men"[tw] OR "bisexual male"[tw] OR "bisexual males"[tw] OR "HSH"[tw] OR "Hommes ayant des rapports Sexuels avec des Hommes"[tw] OR "Homosexuality, Male"[Mesh] OR "male homosexual*"[tw] OR "gay men"[tw] OR "gay man"[tw] OR "gay male*"[tw] OR "homosexual male*"[tw] OR "homosexual males"[tw] OR "homosexual man"[tw] OR "homosexual men" OR "sex for money"[tw] OR "transgender"[tw] OR "trans"[tw]
Malta, M., et al., *HIV prevalence among female sex workers, drug users and men who have sex with men in Brazil: a systematic review and meta-analysis.* BMC Public Health, 2010. **10**: p. 317.	HIV prevalence among key populations	Brazil	This search combined standardized search terms (keywords and medical subject heading terms ? MESH) that reflect key domains: (a) HIV/AIDS, (b) prevalence or incidence, (c) location (Brazil), and (d) target populations (i.e., FSW, MSM, IDU or non-injection drug users).
McLaughlin, M.M., et al., *Sexually transmitted infections among heterosexual male clients of female sex workers in China: a systematic review and meta-analysis.* PLoS One, 2013. **8**(8): p. e71394.	STIs among clients of FSWs	China	china[mesh] AND "china"[tw] prostitution[mesh] OR "sex work"[tiab] OR "sex worker"[tiab] OR "sex workers"[tiab] OR "sex workers"[tiab] OR "prostitution"[tiab] OR "prostitutes"[tiab] OR "prostitute"[tiab] OR "commercial sex"[tiab] Sexually Transmitted Diseases"[Mesh] OR "STD"[tiab] OR "STDs"[tiab] OR "STI"[tiab] OR "STIs"[tiab] OR "sexually transmitted infection"[tiab] OR "sexually transmitted infections"[tiab] OR "sexually transmitted diseases"[tiab] OR "sexually transmitted disease"[tiab] OR "venereal disease"[tiab] OR "venereal diseases"[tiab] OR aids[sb] OR "chlamydia"[tiab] OR "gonorrhea"[tiab] OR "syphilis"[tiab] OR "hepatitis"[tiab] OR "herpes"[tiab] OR "HPV"[tiab] OR "human papillomavirus"[tiab] OR "genital warts"[tiab] OR "chancroid"[tiab] OR "trichomoniasis"[tiab]
Moore, L., et al., *Community empowerment and involvement of female sex workers in targeted sexual and reproductive health interventions in Africa: A systematic review.* Globalization and Health, 2014. **10 (1) (no pagination)**(47).	Interventions among female sex workers	Africa	Search terms used in Medline were: "prostit*" or "sex work" or "sex worker" or "sex workers", and all low- and middle-income countries (MeSH term or any field). Articles were located in Web of Science using the terms "sex work" or "prostitution"
Mountain, E., et al., *Antiretroviral therapy uptake, attrition, adherence and outcomes among hiv-infected female sex workers: A systematic review and meta-analysis.* PLoS ONE, 2014. **9 (9) (no pagination)**(e105645).	ART among HIV positive FSWs	Global	''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''))
Muldoon, K.A., *A systematic review of the clinical and social epidemiological research among sex workers in Uganda.* BMC Public Health, 2015. **15**: p. 1226.	HIV epidemiology among FSWs	Uganda	Sex work terms included: "sex work" or "sex workers" or prostitut* or brothel* or escort or "sex adj3 buy*" or "commercial adj3 sex*" or "sex adj3 industry."

Ota, E., et al., *Behavioral interventions to reduce the transmission of HIV infection among sex workers and their clients in high-income countries.* Cochrane Database Syst Rev, 2011(12): p. Cd006045.	Behavioural interventions among FSws and their clients	High income countries	PubMed: prostitute[tiab] OR prostitutes[tiab] OR sex worker[tiab] OR sex workers[tiab] OR prostitution[mh] OR prostitution[tiab] Embase: 'prostitute'/de OR prostitute OR prostitutes OR'prostitution'/de OR prostitution OR 'sex worker' OR 'sex workers' OR 'callgirl'/de OR callgirl OR callgirls
Owen, B.N., et al., *Lifetime prevalence of anal intercourse among sexually active female youth and young female sex workers: A comparative systematic review and meta-analysis.* Sexual Health, 2013. **10 (6)**: p. 585.	Anal sex among FSWs	Global	Not available- conference abstract
Papworth, E., et al., *Epidemiology of HIV among female sex workers, their clients, men who have sex with men and people who inject drugs in West and Central Africa.* J Int AIDS Soc, 2013. **16 Suppl 3**: p. 18751.	HIV epidemiology among key populations	West and Central Africa	"female sex worker" OR "sex worker" OR "FSW" OR "SW" OR "prostitute" OR "prostitution" OR "commercial sex" OR "commercial sex worker" OR "CSW" OR "transactional sex" OR "transactional sex worker" OR "TSW" OR "travailleuse du sexe" OR "TS"
Peng, R.R., et al., *Prevalence and genotype distribution of cervical human papillomavirus infection among female sex workers in Asia: A systematic literature review and meta-analysis.* Sexual Health, 2012. **9**(2): p. 113-119.	HPV among FSWs	Asia	'female sex workers', 'commercial sex workers', or 'prostitutes'
Pitpitan, E.V., et al., *HIV/STI risk among venue-based female sex workers across the globe: a look back and the way forward.* Curr HIV/AIDS Rep, 2013. **10**(1): p. 65-78.	Typology of sex work and STI prevalence among venue-based FSWs	Global	"female sex work," "commercial sex," "sex industry," "sell sex," "exchange sex," "sex trafficked," "prostitution," with "HIV risk," "HIV infection," "HIV prevalence," "sexually transmitted infection"
Platt, L., et al., *Systematic review examining differences in HIV, sexually transmitted infections and health-related harms between migrant and non-migrant female sex workers.* Sex Transm Infect, 2013. **89**(4): p. 311-9.	STI prevalence among migrant and non-migrant FSWs	Global	MESH terms "sex worker" and "prostitute" with the free words "sex work*" "prostitut*", "entertainment worker*", "(exchang* adj3 sex)", "(sell* adj3 sex)", "(sold* adj3 sex)", "(sex adj3 money)", "(transaction* adj3 sex)", "(commerc adj3 sex)", "(surviv* adj3 sex)", "(sex adj3 drug*)", "sex trade", "sex industry", "(sex* servic*)", " brothel*", "red-light", "solicit*", "bar girl*", "hostess*", " escort*", " masseu*" with "OR".
Platt, L., et al., *Factors mediating HIV risk among female sex workers in Europe: A systematic review and ecological analysis.* BMJ Open, 2013. **3 (7) (no pagination)**(e002836).	STI epidemiology and structural determinants of STIs among FSWs	Europe	MESH terms "sex worker" and "prostitute" with the free words "sex work*" "prostitut*", "entertainment worker*", "(exchang* adj3 sex)", "(sell* adj3 sex)", "(sold* adj3 sex)", "(sex adj3 money)", "(transaction* adj3 sex)", "(commerc adj3 sex)", "(surviv* adj3 sex)", "(sex adj3 drug*)", "sex trade", "sex industry", "(sex* servic*)", " brothel*", "red-light", "solicit*", "bar girl*", "hostess*", " escort*", " masseu*" with "OR".
Poon, A.N., et al., *Review of HIV and other sexually transmitted infections among female sex workers in China.* AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV, 2011. **23**(SUPPL. 1): p. 5-25.	STI epidemiology among FSWs	China	female sex worker (FSW), commercial sex worker (CSW), commercial sex, sex work, prostitution, prostitute, China, HIV, sexually transmitted infections/ diseases (STI/STD), prevalence, and incidence.
Ross, M.W., et al., *Occupational health and safety among commercial sex workers.* Scandinavian Journal of Work, Environment and Health, 2012. **38**(2): p. 105-119.	Occupational health among FSWs	Global	"sex work" and "prostitution", and "occupational health" and "safety"
Shahmanesh, M., et al., *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 and International Health, 2008. **13**(5): p. 659-679.	Prevention interventions among FSWs	Resource-poor settings	Mesh terms and text words (in italics): (Prostitution OR prostitut* OR 'sex work*') AND (HIV OR HIV infection OR HIV seroprevalence OR HIV OR sexually transmitted disease OR 'sexually transmitted infection').

Steen, R., et al., *Periodic presumptive treatment of curable sexually transmitted infections among sex workers: a systematic review.* Aids, 2012. **26**(4): p. 437-45.	STI treatment among FSWs	Global	MEDLINE was searched using the following search terms: prostitution or prostitut_ or 'sex work_' and HIV or STI or STD or 'sexually transmitted disease' or 'sexually transmitted infection' or syphilis or 'chlamydia' or gonor_.
Stoebenau, K., et al., *Revisiting the understanding of "transactional sex" in sub-Saharan Africa: A review and synthesis of the literature.* Social Science and Medicine, 2016. **168**: p. 186-197.	Context of FSW	Sub-Saharan Africa	["transactional sex" or "survival sex" or "consumption sex" or "intergenerational sex" or "commodified sex" or "cross-generational sex" or "informal sex", or "sex* exchange", or "sex* trade" or "sugar daddy*", or "globalization and sex*" or "modernity and sex*" and Africa]
Su, S., et al., *Sustained high prevalence of viral hepatitis and sexually transmissible infections among female sex workers in China: A systematic review and meta-analysis.* BMC Infectious Diseases, 2016. **16 (1) (no pagination)**(2).	Hepatitis and STIs among FSWs	China	China', 'Chinese', 'CSW (commercial sex workers)', 'FSW', 'hepatitis', 'sexually transmitted diseases' and 'sexually transmitted infections', and other keywords associated with each STI: 'chlamydia', 'Chlamydia trachomatis', 'gonorrhoea', 'Neisseria gonorrhoea', 'syphilis', 'genital warts', 'hepatitis', 'HBV', 'hepatitis B', 'HCV', 'hepatitis C', 'HSV', 'herpes simplex virus', 'HPV', 'human papillomavirus' and 'trichomonas vaginitis'.
Tan, S.Y. and G.J. Melendez-Torres, *A systematic review and metasynthesis of barriers and facilitators to negotiating consistent condom use among sex workers in Asia.* Cult Health Sex, 2016. **18**(3): p. 249-64.	Barriers or facilitators of consistent condom use among FSWs	Asia	('sex work*' OR prostitut* OR 'sex-work') AND ('condom use' OR 'condom bargain*' OR 'condom negotiat*') AND (qualitative OR focus group OR focus-group OR interview OR 'semi-structured interview' OR 'unstructured interview' OR 'qualitative research' OR 'thematic analysis' OR ethnograph* OR 'grounded theory' OR 'mixed-method' OR 'mixed method').
Tao, F., et al., *Effects of condom use before and after AIDS behaviour intervention among Chinese unlicensed prostitutes: A meta-analysis. [Chinese].* Chinese Journal of Evidence-Based Medicine, 2015. **15**(1): p. 69-74.	Behavioral intervention among FSWs	China	Could not be retreived
Wariki, W.M., et al., *Behavioral interventions to reduce the transmission of HIV infection among sex workers and their clients in low- and middle-income countries.* Cochrane Database Syst Rev, 2012(2): p. Cd005272.	Behavioral intervention among FSWs	Low and middle income countries	PubMed: Search prostitute[tiab] OR prostitutes[tiab] OR sex worker[tiab] OR sex workers[tiab] OR prostitution[mh] OR prostitution[tiab] Embase: 'prostitute'/de OR prostitute OR prostitutes OR 'prostitution'/de OR prostitution OR 'sex worker' OR 'sex workers' OR 'callgirl'/de OR callgirl OR callgirls
Yuen, W.W.Y., et al., *Psychological health and HIV transmission among female sex workers: a systematic review and meta-analysis.* AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV, 2016. **28**(7): p. 816-824.	Mental Health an HIV among FSWs	Global	"sex workers", "prostitutes", "prostitution" AND "risk factors" or "correlates", AND "HIV" or "condom use" or "safe sex"
Zhang, L., et al., *A systematic review and meta-analysis of the prevalence, trends, and geographical distribution of HIV among Chinese female sex workers (2000-2011): Implications for preventing sexually transmitted HIV.* International Journal of Infectious Diseases, 2015. **39**: p. 76-86.	HIV epidemiology among FSWs	China	(''HIV'' OR ''AIDS'' OR ''human immunodeficiency virus'' OR ''acquired immunodeficiency syndrome'') AND (''FSW'' OR ''female sex worker'' OR ''CSW'' OR ''commercial sex worker'' OR ''sex worker'' OR ''prostitute'' OR ''women who sell sex'' OR ''sex industry'') AND (''China'' OR ''Chinese'') AND (''prevalence'' OR ''infection'' OR ''associated risk'' OR ''infection status'' OR ''epidemic status'' OR ''surveillance'')
Potentially relevant articles			
Awasthi, K.R., K. Adefemi, and M. Tamrakar, *HIV/AIDS: A persistent health issue for women and children in mid and far Western Nepal.* Kathmandu University Medical Journal, 2015. **13**(49): p. 88-93.	Risk factors for HIV among male migrants	Nepal	HIV/ AIDS, Nepal, India, South East Asia, migration, sex workers, conflict and social stigma
Baral, S., et al., *Enhancing benefits or increasing harms: Community responses for HIV among men who have sex with*	Structural determinants of HIV	Low and middle income countries	"sex worker*"[tw] OR "sex workers"[Mesh] OR "FSW" [tw] OR "SW" [tw] OR "prostitute*"[tw] OR "prostitution" [tw] OR "commercial sex" [tw]

men, transgender women, female sex workers, and people who inject drugs. Journal of Acquired Immune Deficiency Syndromes, 2014. **66**(SUPPL.3): p. S319-S328.	among populations at risk		OR “commercial sex worker*”[tw] OR “CSW” [tw] OR “transactional sex” [tw] OR “transactional sex worker*”[tw] OR “TSW” [tw] OR “travailleuse du sexe”[tw] OR “TS”[tw] OR “intravenous drug user”[tw] OR “IVDU”[tw] OR “IDU”[tw] OR “drug user”[tw] OR “men who have sex with men”[tw] OR “MSM”[tw] OR “males who have sex with males”[tw] OR “bisexual men”[tw] OR “bisexual male”[tw] OR “bisexual males”[tw] OR “HSH”[tw] OR “Hommes ayant des rapports Sexuels avec des Hommes”[tw] OR "Homosexuality, Male"[Mesh] OR “male homosexual*”[tw] OR “gay men”[tw] OR “gay man”[tw] OR “gay male*”[tw] OR “homosexual male*”[tw] OR “homosexual males”[tw] OR “homosexual man”[tw] OR “homosexual men” OR “sex for money”[tw] OR “transgender”[tw] OR “trans”[tw]
Barros, A.B., S.F. Dias, and M.R.O. Martins, *Hard-to-reach populations of men who have sex with men and sex workers: A systematic review on sampling methods.* Systematic Reviews, 2015. **4 (1) (no pagination)**(141).	Sampling methods (could include population proportion)	Global	Men who have Sex with Men, Sex Work, Sex Workers, recruit, recruited, participants, enrol, enrolled, sample, sampling.
Boily, M. and S. Mishra, Examining the population-level impact of scaling-up ART for FSWs across epidemic context. Sexually Transmitted Infections. Conference: STI and AIDS World Congress, 2013. 89(no pagination).	Interventions (ART)- modeling but includes link to systematic review of FSWs	India	Not available- conference abstract
Chen, L., et al., *Sexual risk factors for HIV infection in early and advanced HIV epidemics in sub-Saharan Africa: systematic overview of 68 epidemiological studies.* PLoS One, 2007. **2**(10): p. e1001.	Sexual risk factors for HIV hetrosexual transmission (may include population proportion of FSWs and their clients)	Africa	‘HIV’, ‘HIV-1’or ‘delta retrovirus’, ‘horizontal transmission’, ‘risk factor’, ‘sexually-transmitted infections or disease’, ‘herpes’ or ‘HSV’, and ‘Africa’ (exploded to include countries within Africa
Doherty, S., et al., *Suitability of measurements used to assess mental health outcomes in men and women trafficked for sexual and labour exploitation: A systematic review.* The Lancet Psychiatry, 2016. **3**(5): p. 464-471.	Mental health assessment tools for women and men trafficked for sexual exploitation	Global	trafficked AND people, sex AND traffick*, sexual AND exploitation AND health, sex AND traffick* AND health, traffick* AND mental AND health, human trafficking AND health AND mental, trafficking, human trafficking AND health, human AND traffick* AND health.
Foss, A.M., et al., *A systematic review of published evidence on intervention impact on condom use in sub-Saharan Africa and Asia.* Sex Transm Infect, 2007. **83**(7): p. 510-6.	Impact of interventiosn (condom use)	Sub-Saharan Africa, Asia	PubMed, MEDLINE and the Cochrane Library were searched using the MeSH terms: “condoms[MeSH] AND (intervention studies OR program evaluation OR randomized controlled trials OR observation)[MeSH]”. PubMed was also searched using MeSH terms: “condoms[MAJR]a AND (HIV[MAJR] OR HIV infections[MAJR] OR sexually transmitted diseases[MAJR]) AND (education[MeSH] OR prevention and control[Subheading] OR preventive health services[MeSH:NoExp]b OR safe sex[MeSH] OR counseling[MeSH:NoExp] OR health promotion[MeSH:NoExp] OR program evaluation[MeSH:NoExp]) AND (sexual behavior[MeSH:NoExp] OR sexual partners[MeSH]) AND (developing countries[MeSH] OR Africa[MeSH] OR Asia[MeSH])”, and a free-text search using: “condom* AND (HIV OR AIDS OR human immunodeficiency syndrome OR acquired immunodeficiency syndrome OR sexually transmit* OR STD OR STDs OR STI OR STIs) AND (promot* OR educat* OR counsel* OR prevent* OR control* OR safe* sex) AND (sex*

			behaviour OR sex* behavior OR sex* partner*) AND (Africa* OR Asia*)" in Title/abstract.
Furber, A.S., J.N. Newell, and M.M. Lubben, *A systematic review of current knowledge of HIV epidemiology and of sexual behaviour in Nepal.* Trop Med Int Health, 2002. **7**(2): p. 140-8.	HIV and sexual behavior	Nepal	Hiv*, aids, sexual behaviour and nepal*
Hampton, M.D. and K. Shade, *The experience of adolescent victims of commercial sexual exploitation in the United States: A qualitative systematic review protocol.* JBI Database of Systematic Reviews and Implementation Reports, 2015. **13**(8): p. 110-119.	Commercial sexual exploitation of adolescents	US	Commercial sexual exploitation, sex trafficking, human trafficking, prostitution, and sexual slavery in combination with adolescent, teen, youth, juvenile or minor.
Hoffmann, O., T. Boler, and B. Dick, *Achieving the global goals on HIV among young people most at risk in developing countries: Young sex workers, injecting drug users and men who have sex with men*. 2006, World Health Organization: 20 Ave. Appia, Geneva 27 CH-1211, Switzerland. p. 287-315.	Evaluations among young people at high risk	Global	Not mentioned in the book
Liu, H., S. Li, and M.W. Feldman, *Forced bachelors, migration and HIV transmission risk in the context of China's gender imbalance: a meta-analysis.* AIDS Care, 2012. **24**(12): p. 1487-95.	Male migrants and sexual risk	China	''migrants,'' ''floating population,'' ''HIV,'' and ''sexual risk.''
McAlpine, A., M. Hossain, and C. Zimmerman, *Sex trafficking and sexual exploitation in settings affected by armed conflicts in Africa, Asia and the Middle East: systematic review.* BMC International Health and Human Rights, 2016. **16**(1): p. 1-16.	Sex trafficking	Armed-conflict settings (Africa, Asia, and Middle East)	[(sex* adj3 traffick*) or sex* trade or (sex* adj3 exploit*) or (sex* adj3 abduct*) or (sex* adj3 slave*) or forced prostitute* or child* prostitute* or arranged marriage or early marriage or forced marriage or child* bride or child* soldier or kidnap* or brothel] AND [armed conflict* or war* or combat* or refugee or (complex adj3 emergency) or terroris* or military* or (rebel adj3 group) or genocide or army or soldier]
Ojo, O., et al., *Behavioural interventions for reducing HIV infection in workers in occupational settings, a cochrane systematic review.* Sexually Transmitted Infections, 2011. **87**: p. A247.	Sexual risk behavior among workers	Global	Not available- conference abstract
Oldenburg, C.E., et al., *Global burden of HIV among men who engage in transactional sex: a systematic review and meta-analysis.* PLoS One, 2014. **9**(7): p. e103549.	HIV among men who engage in transactional sex	Global	''commercial sex'', ''sex work*'', ''male sex worker*'', ''prostitution'', ''exchange sex'', and ''transactional sex''
Omare, D. and A. Kanekar, *Determinants of HIV/AIDS in armed conflict populations.* Journal of Public Health in Africa, 2011. **2**(1): p. 34-37.	Social determinants of HIV among displaced populations	Global	Search terms not available.
Oram, S., et al., *Prevalence and risk of violence and the physical, mental, and sexual health problems associated with human trafficking: Systematic review.* PLoS Medicine, 2012. **9 (5) (no pagination)**(e1001224).	HIV among women trafficked for sexual exploitation	Global	(human trafficking.mp OR people trafficking.mp OR trafficking in people.mp OR sex trafficking.mp OR woman trafficking.mp OR child trafficking.mp OR trafficked people.mp OR trafficked women.mp OR trafficked men.mp OR trafficked children.mp OR forced labour.mp OR forced labor.mp OR forced prostitution.mp OR sexual slavery.mp) AND (health/ OR well-being.mp OR wellbeing.mp OR ill-health.mp OR illness.mp OR "Wounds and injuries/" OR wound.mp OR injur$.mp OR disease/ OR disability.mp OR infection/ OR symptom.mp OR trauma.mp OR "mental illness"/ OR "mental disorder"/ OR anxiety/ OR depression/ OR fear/ OR guilt/ OR hostility/ OR suicide/ OR "Behavioral symptom"/ OR "Self-injurious behaviour"/ OR "Reproductive behavior" OR

			"Risk taking"/ OR "Sexual behavior"/ OR "Social behavior"/ OR violence/ OR rape/ OR "sexually transmitted diseases"/ OR HIV/ OR pregnancy/ OR "abortion, induced"/)
Ottisova, L., et al., *Prevalence and risk of violence and the mental, physical and sexual health problems associated with human trafficking: An updated systematic review*. Epidemiology and Psychiatric Sciences, 2016. **25**(4): p. 317-341.	Sexual health among trafficked populations	Global	1. human trafficking.mp 2. people trafficking.mp 3. trafficking in people.mp 4. sex trafficking.mp 5. woman trafficking.mp 6. child trafficking.mp 7. trafficked people.mp 8. trafficked women.mp 9. trafficked men.mp 10. trafficked children.mp 11. trafficking in persons.mp 12. trafficking of men.mp 13. post-trafficking.mp 14. labour exploitation.mp 15. domestic workers.mp 16. forced labour.mp 17. forced labor.mp 18. forced prostitution.mp 19. sexual slavery.mp
Wondergem, P., et al., *A short history of HIV prevention programs for female sex workers in Ghana: Lessons learned over 3 decades.* Journal of Acquired Immune Deficiency Syndromes, 2015. **68**: p. S138-S145.	Context of FSW, interventions and epidemiology (historical review) among FSWs	Ghana	"female sex worker" or "prostitute," or "transactional sex" or "sex trade" or "sexual exchange," and "HIV" or "AIDS" or "STI," and "Ghana."
Yang, H., et al., *Heterosexual transmission of HIV in China: a systematic review of behavioral studies in the past two decades.* Sex Transm Dis, 2005. **32**(5): p. 270-80.	Behavioral risk factors promoting heterosexual transmission	China	China, HIV, AIDS, STD, sexual behavior, and drug use
Yang, Z., et al., *A decline in HIV and syphilis epidemics in Chinese female sex workers (2000-2011): A systematic review and meta-analysis.* PLoS ONE, 2013. **8 (12) (no pagination)**(e82451).	STIs among FSWs	China	"Prostitution"[Mesh], prostitution, "Sex Workers"[Mesh], sex worker, sex work sex work*, female sex worker, commercial sex worker

Appendix IV

Supplementary material for Research paper 1-

Study selection criteria

Table S3. Eligibility criteria for inclusion of studies in the systematic review of female sex workers (FSWs) and their clients in MENA.

	Inclusion criteria	Exclusion criteria
Country	• Afghanistan • Djibouti • Iraq • Lebanon • Oman • Saudi Arabia • Syria • West Bank & Gaza • Algeria • Egypt • Jordan • Libya • Pakistan • Somalia • Tunisia • Yemen • Bahrain • Iran • Kuwait • Morocco • Qatar • Sudan • UAE	• Cyprus (not part of WHO, World Bank, or UNAIDS definition) • Israel (part of only World Bank definition) • Mauritania (not part of WHO, World Bank, or UNAIDS definitions) • Turkey (not part of WHO, World Bank, or UNAIDS definitions) • Western Sahara (part of only WHO definition) Note: Countries were eligible for inclusion if they were part of at least 2 international organizations' definition for the Middle East and North Africa (MENA).
Year	• All years.	
Language	All languages. Data from the region are normally published in English, French, Arabic, or Farsi. These will be extracted from full texts.	
Type of publication	• Original research • Letters to editor (may contain primary unpublished data)	• Editorials • Commentaries/ authors' reply
Study design	• Cross sectional • Cohort (retrospective, prospective) • Case-control • Randomized controlled trials	• Reviews • Case reports • Case series
Methodology	• Quantitative	• Qualitative only
Study Population(s)	• FSWs defined as women who exchange sex for money/goods. • Clients of FSWs defined as men who "buy" sex from FSWs using money/goods. STI clinic attendees were included as proxy. Mixed samples of STI patients were considered if ≥70% were males.	• Casual sex
Reported outcomes	• The proportion of FSWs or clients of FSWs in the population (size estimation of both populations) • HIV incidence among FSWs or clients of FSWs • HIV prevalence among FSWs or clients of FSWs	• Paper presents contradictory/unclear numbers on the relevant outcomes that could not be verified.
Other	• Paper presents unique findings on relevant outcomes. • For HIV prevalence, sample size ≥10 (prevalence measures based on very small samples are not informative)	• Paper has the same dataset as another included study and does not provide any additional data point (selecting the study with the larger sample size). • Conference abstracts for which there are full text articles.
HIV prevalence ascertainment	• Self-report or using biological assay	

*Abbreviations: FSWs: female sex workers; UNAIDS: the Joint United Nations Programme on HIV/AIDS; WHO: World Health Organization.

Appendix V

Supplementary material for Research paper 1-

Screening of available quality assessment tools

1. Assessment of the risk of bias (ROB)

The ROB for studies included in the review will be evaluated and reported using a domain-based approach where each criterion/domain is assessed separately as per Cochrane Collaboration handbook guidelines [6]. Scales attributing weights to different quality measures and checklists yielding a summary estimate for the quality of identified studies will be avoided. This is because of the lack of adequate justification of weights to be used and of validated tools that can tailor for populations' and settings' specificities, thus limiting the ability of a single tool to produce an objective and valid summary measure for quality [6]. Quality domains were developed following a careful evaluation of available quality assessment tools summarized in Table S4.

Table S4. Summary of available quality assessment tools and their applicability to the systematic review of FSWs and their clients in MENA.

Tool	Items	Rating	Decision	Justification	Relevant and potentially relevant items
Revised Cochrane risk of bias tool for randomized trials (RoB 2.0) [7]	5 domains	"Low risk of bias", "Some concerns", and "High risk of bias"	No	• Designed for different types of randomized controlled trials (RCTs) • Items are not applicable: ○ Bias arising from randomization ○ Bias due to deviations from intended interventions ○ Bias due to missing outcome data	• Bias in the measurement of the outcome (ascertainment) • Bias in the selection of reported result
Cochrane approach [8]	6 domains	"Yes (low risk of bias)", "No (high risk of bias)", and "Unclear"	No	• Suitable for RCTs • Items that are not applicable: ○ Sequence generation ○ Allocation concealment ○ Blinding of participants personnel and outcome assessors ○ Incomplete outcome data ○ Selective reporting	
NIH Quality assessment tool [9]	14	"Good", "Fair", and "Poor"	No (also not recommended by Cochrane)	• Combines items for quality of reporting and ROB. • Items for ROB assessment that are not applicable: ○ Blinding of assessors ○ Measure adjusted for confounding factors	• Study population specified and defined • Participation rate >=50% • Outcome clearly defined, valid and reliable • Loss to follow-up <=20% • Time frame sufficient to see an association between exposure and outcome
The GRACE checklist [10]	11	Items rated individually as "sufficient" or "insufficient", no summary quantitative measure for the entire checklist	No	• Checklist for observational studies of comparative effectiveness (of treatments) • Combines items for quality of reporting and ROB. • Most items for ROB assessment are not applicable: ○ Equivalent assessment of primary outcome across intervention and comparison groups ○ Study participants newly infected vs. living with the disease ○ Effect size adjusted for confounders and effect modifiers ○ Length of follow-up time appropriate for exposed and unexposed ○ Meaningful analyses conducted to test key assumptions	• Primary outcome validated against a gold standard for diagnosis • Clinical outcome measured objectively and not subject to expert opinion
STROBE checklist for cross-sectional studies [11, 12]	22	Rating individual criteria as "Met criterion", "Did not meet criterion", and "Not applicable"	No	• Useful to assess quality of reports describing studies (of HIV prevalence/incidence/size estimation). Does not assess ROB.	
STROBE checklist for cohort studies [11, 12]	22	Rating individual criteria as "Met criterion", "Did not meet criterion", and "Not applicable"	No	• Useful to assess quality of reports describing studies (of HIV prevalence/incidence/size estimation). Does not assess ROB.	
The Newcastle-Ottawa Scale [13]	8 items assessing 3 domains	Rating individual criteria using a star system (a star indicates that a criterion was met)	No	• Designed to assess the quality of case-control and of cohort studies and not of cross-sectional studies • One of the three domains was not relevant: ○ Comparability of study groups	• Selection of study groups ○ Representativeness of study population (participation rate, sampling methodology) ○ Outcome not present at the start of the study (for cohort studies)

					• Outcome ○ Assessment of outcome (blinded, ascertainment, self-report...) ○ Appropriate length of follow-up time ○ Loss to follow-up specified
Methodological Evaluation of Observational Research (MORE) [14]	13 (2 general, 6 assessing external validity, and 5 assessing internal validity)	Rating individual criterion as having a "majot flaw", "minor flaw", or "poor reporting" if no information is available	No	• The scale yielded poor interrater reliability • Combines items for quality of reporting and ROB • Many items are overlapping such as: ○ Subject flow, Response rate, and Exclusion rate: Subject flow (Reported number screened, number eligible, number enrolled); Exclusion rate from the analysis (<10%); Source to measure outcomes and validation of outcome measure • Items assessing ROB that are not relevant: ○ Measurement of outcomes (severity of disease, frequency of symptoms, reliability of measure assessed) ○ Study design specified (cross-sectional studies are the most suitable for assessing prevalence, cohort studies/RCTs are the best for assessing incidence)	• Sampling method • Response rate • Sampling bias addressed (weighting of results) • Source to measure outcomes (self-reported proxy...)
Loney, 1998 [15]	8 items	1 point assigned to each item	No	• Combines items for quality of reporting and ROB • Items assessing ROB that are not relevant: ○ Outcome measured by unbiased assessors ○ Study design appropriate (cross-sectional studies are adequate for assessing prevalence and cohort studies are adequate for assessing incidence)	• Sampling frame appropriate • Outcome measures objective • Response rate adequate and refusals described
RoBANS [16]	6 domains	Rating individual criterion as "Low ROB", "High ROB", and "Unclear"	No	• Items assessing ROB that are not relevant: ○ Confounding variables considered ○ Exposure measurement (inadequate) ○ Blinding of outcome assessment ○ Selective outcome reporting	• Selection of participants (that is the sampling method) • Incomplete outcome data (attrition bias)
Downs and Black Checklist [17]	27	Rating individual criterion as "yes", "no", and "unable to determine"	No	• Combines items for quality of reporting and ROB • Items assessing ROB that are not applicable: ○ Treatment venues are representative of were the source population normally gets treated ○ Blinding study participants to interventions ○ Blinding of investigators measuring outcomes ○ Equal lengths of follow-up in intervention and control groups ○ Reliability in adherence to treatment ○ Selection of participants equal across cases and controls. ○ Participants from comparative groups recruited from the same source (hospital) ○ Participants from comparative groups recruited over the same time period ○ Randomization of intervention ○ Assignment of randomized intervention concealed ○ Adjustment for confounding ○ Adjustment for loss to follow-up	• Characteristics of patients lost to follow-up described • Representativeness of eligible population (sampling method) • Representativeness of participants (response rate) • Accuracy of outcome measure (ascertainment)
The Trend checklist [18]	22	Rating individual criterion	No	• Useful to assess quality of reports describing studies (of HIV prevalence/incidence/size estimation). Does not assess ROB.	
MOOSE [19]			No	These are guidelines for reporting systematic reviews	

Quality assessment checklist for observational studies (QATSO score) [20]	5	Rating individual studies as “Bad” (0-33%), “Satisfactory” (33-66%), and “Good” (67-100%) Scoring method: Total score divided by total number of applicable items	No	• Some items are not applicable: ○ Control of confounding	• Sampling method representative • Outcome measurement objective • Response rate (>=60%) • Privacy or sensitivity of the nature of outcome(HIV) considered

GRADE [21]		“High”, “Moderate”, “Low”, and “Very low”.	No	• More suitable for assessing interventions’ effects
				• Items assessing ROB that are not applicable:
				  ○ Study design (observational studies are normally rated as having low quality)
				  ○ Assessing quality of interventions (randomization, allocation concealment, blinding...)
				  ○ Indirectness that is use of surrogates to measure outcome
				• Upgrading of studies is based on 3 criteria (all of which are not applicable):
				  ○ Large magnitude of effect
				  ○ Evidence of a dose-response effect
				  ○ Plausible confounding taken into account	

Appendix V references

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Appendix VI

Supplementary material for Research paper 2-

Sexually transmitted infections among FSWs in MENA

J Glob Health 2019; 9: 020408

Online Supplementary Document

Table S1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) checklist [1]

Section/topic	#	Checklist item	Reported in main text
Title	1	Identify the report as a systematic review, meta-analysis, or both.	p. 1
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	p. 2-3
Rationale	3	Describe the rationale for the review in the context of what is already known.	p. 4-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	p. 5
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	p. 6-7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	p. 6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Box S1 in the OSD
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	p. 6-7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	p. 7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	p. 7 and Box S2 in the OSD
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	p. 8 and Table S3 in the OSD
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	p. 8-9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	p. 8-9
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	p. 8
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	p.8- 9 and Table S4 in the OSD
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	p. 10 and Figure 1

Section/topic	#	Checklist item	Reported in main text
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	p. 11 and Tables 1-3
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12).	p. 11- and Tables S5-S6 in the OSD
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot.	p. 12 and Table 4
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	p. 12 and Table 4
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	p. 11-12 and Tables S5-S6 in the OSD
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	p. 12-13 and Table 5
		DISCUSSION	
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., health care providers, users, and policy makers).	p. 14-17
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review level (e.g., incomplete retrieval of identified research, reporting bias).	p. 17-18
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	p. 18
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	p. 19

NA, not applicable. P, page(s). OSD, Online Supplementary Document.

Box S1. Search criteria for the systematic review of *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and herpes simplex virus type 2 (HSV-2) among FSWs in the Middle East and North Africa (MENA)

PubMed (September 04, 2018)

Sexually transmitted infections

"Sexually transmitted diseases"[Mesh] OR "Reproductive tract infections"[Mesh] OR "Genital diseases, female"[Mesh] OR "Chlamydia trachomatis"[Mesh] OR "Chlamydia"[Mesh] OR "Pelvic inflammatory disease"[Mesh] OR Chlamydia trachomatis[Text] OR Chlamydia[Text] OR Trachomatis[Text] OR Pelvic inflammatory disease[Text] OR Chlamydial[Text] OR Chlamydial infection[Text] OR Chlamydia infection[Text] OR "Neisseria gonorrhoeae"[Mesh] OR "Gonorrhea"[Mesh] OR Neisseria gonorrhoeae[Text] OR Gonorrhoeae[Text] OR Gonorrhea[Text] OR Gonococcus[Text] OR Gonococci[Text] OR Gonococcal[Text] OR Gonococcal infection[Text] OR "Syphilis"[Mesh] OR "Treponema pallidum"[Mesh] OR Syphilis[Text] OR Treponema pallidum[Text] OR Great Pox[Text] OR "Simplexvirus"[Mesh] OR "Herpes Simplex"[Mesh] OR Simplex virus[Text] OR "Herpes Genitalis"[Mesh] OR HSV type-2[Text] OR HSV type 2[Text] OR HSV2[Text] OR HSV-2[Text] OR HSV[Text] OR Human herpes virus[Text] OR Herpes simplex virus type 2[Text] OR Herpes simplex virus type-2[Text] OR Herpes simplex virus 2[Text] OR Herpes simplex virus-2[Text] OR Herpes simplex type 2[Text] OR Herpes simplex type-2[Text] OR Herpes simplex 2[Text] OR Herpes simplex-2[Text] OR Herpesvirus type 2[Text] OR Herpesvirus type-2[Text] OR Herpesvirus 2[Text] OR Herpesvirus-2[Text] OR Herpes virus type 2[Text] OR Herpes virus type-2[Text] OR Herpes virus[Text] OR Herpes virus-2[Text] OR genital herpes[Text] OR Herpes genitalis[Text] OR Stomatitis herpetic[Text] OR Herpes labialis[Text] OR HSV type-1[Text] OR HSV type 1[Text] OR HSV1[Text] OR HSV-1[Text] OR HSV 1[Text] OR Herpes simplex virus type 1[Text] OR Herpes simplex virus type-1[Text] OR Herpes simplex virus 1[Text] OR Herpes simplex virus-1[Text] OR Herpes simplex type 1[Text] OR Herpes simplex type-1[Text] OR Herpes simplex 1[Text] OR Herpes simplex-1[Text] OR Herpesvirus type 1[Text] OR Herpesvirus type-1[Text] OR Herpesvirus 1[Text] OR Herpesvirus-1[Text] OR Herpes virus type 1[Text] OR Herpes virus type-1[Text] OR Herpes virus 1[Text] OR Herpes virus-1[Text] OR Sexually transmitted[Text] OR Venereal[Text] or STI[Text] or STD[Text] or genital[Text] or infection[Text] or infections[Text] or infected[Text]

Sex work

"Extramarital Relations"[Mesh] OR "Sex Work*"[Mesh] OR "Sex/analysis"[Mesh] OR "Sex/statistics and numerical data"[Mesh] OR "Sexual partners"[Mesh] OR "Sex Trafficking/epidemiology"[Mesh] OR "Sex Trafficking/statistics and numerical data"[Mesh] OR Sex work*[Text] OR Sexual work*[Text] OR Sexwork*[Text] OR Sex-work*[Text] OR Sexual partner*[Text] OR Sex partner*[Text] OR Sexual contact*[Text] OR FSW[Text] OR FSWs[Text] OR CSW[Text] OR CSWs[Text] OR SW[Text] OR SWs[Text] OR TSW[Text] OR TSWs[Text] OR TS[Text] OR Travailleuse* sexe[Text] OR Travailleuse* sex[Text] OR Bar girl*[Text] OR Callgirl*[Text] OR Call girl*[Text] OR Escort*[Text] OR Masseuse*[Text] OR Hostess*[Text] OR ((Premarital[Text] OR Pre-marital[Text] OR Pre marital[Text] OR Extramarital[Text] OR Extra-marital[Text] OR Extra marital[Text] OR Illicit[Text] OR Illegal[Text]) AND (Sex[Text] OR Sexual[Text] OR Relation*[Text])) OR Outside marriage[Text] OR Out of marriage[Text] OR "Illegal social behavior"[Text] OR "Illegal social behaviour"[Text] OR Adultery[Text] OR Prostitut*[Text] OR Promiscu*[Text] OR Female entertain*[Text] OR Sex entertain*[Text] OR Sexual* entertain*[Text] OR Entertainment work*[Text] OR Sex industr*[Text] OR Sex establishment*[Text] OR Brothel*[Text] OR Red light[Text] OR Red-light[Text] OR Red district*[Text] OR Nightclub*[Text] OR Pimp[Text] OR ((Intergenerational[Text] OR Cross-generation*[Text] OR Cross-generational[Text] OR Recreational[Text] OR Commercial[Text] OR Transaction*[Text] OR Casual[Text] OR Group[Text] OR Informal[Text] OR Street[Text] OR Migrant*[Text] OR Survival[Text] OR Occupational[Text] OR Tourism[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Sex seeking[Text] OR Sex-seeking[Text] OR Solicit*[Text] OR ((Provision*[Text] OR Provider*[Text] OR Provid*[Text] OR Sell*[Text] OR Sold[Text] OR Exchang*[Text] OR Trad*[Text] OR Favor*[Text] OR Consum*[Text] OR Commodi*[Text] OR Paid[Text] OR Paying[Text] OR Pay[Text] OR Payer*[Text] OR Buying[Text] OR Buy[Text] OR Buyer*[Text] OR Charg*[Text] OR Engag*[Text] OR Service*[Text] OR Money[Text] OR Cash[Text] OR Drug*[Text] OR Goods[Text] OR Gift*[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Hidden population*[Text] OR Hard to reach population*[Text] OR Hard-to-reach population*[Text] OR Core group*[Text] OR Core risk group*[Text] OR Vulnerable women[Text] OR Vulnerable population*[Text] OR Vulnerable female*[Text] OR Most-at-risk population*[Text] OR Most at risk population*[Text] OR High risk population*[Text] OR High-risk population*[Text] OR Population* at high risk[Text] OR Population* at high-risk[Text] OR ((Traffick*[Text] OR Slave*[Text] OR Coerc*[Text] OR Abduct*[Text] OR Exploit*[Text] OR Abuse*[Text] OR Violence[Text]) AND (Sex[Text] OR Sexual*[Text]))

MENA

"Middle East"[Mesh] OR "Islam"[Mesh] OR "Arabs"[Mesh] OR "Arab World"[Mesh] OR "Africa, Northern"[Mesh] OR "Sudan"[Mesh] OR "Somalia"[Mesh] OR "Djibouti"[Mesh] OR "Pakistan"[Mesh] OR "South Sudan"[Mesh] OR "Middle East*"[Text] OR "Middle-East"[Text] OR "North Africa*"[Text] OR "North-Africa"[Text] OR "EMRO"[Text] OR "Eastern Mediterranean"[Text] OR "Arab*"[Text] OR "Arab World"[Text] OR "Islam*"[Text] OR "Afghanistan"[Text] OR "Afghan*"[Text] OR "Algeria*"[Text] OR "Bahrain*"[Text] OR "Djibouti"[Text] OR "Egypt*"[Text] OR "Jordan*"[Text] OR "Kuwait*"[Text] OR "Lebanon"[Text] OR "Leban*"[Text] OR "Libya*"[Text] OR "Iran*"[Text] OR "Iraq*"[Text] OR "Morocco"[Text] OR "Moroccan*"[Text] OR "Oman*"[Text] OR "Pakistan*"[Text] OR "Qatar*"[Text] OR "Saudi*"[Text] OR "Somalia"[Text] OR "Somal*"[Text] OR "Sudan*"[Text] OR "Syria*"[Text] OR "Tunisia*"[Text] OR "United Arab Emirates"[Text] OR "Emirat*"[Text] OR "West Bank"[Text] OR "Ghaza*"[Text] OR "Gaza*"[Text] OR "Palestine"[Text] OR "Palestinian*"[Text] OR "Yemen*"[Text] OR "UAE"[Text] OR "KSA"[Text]

Women

"Female/analysis"[Mesh] OR "Female/statistics and numerical data"[Mesh] OR "Women/epidemiology"[Mesh] OR "Women/statistics and numerical data"[Mesh] OR Women[Text] OR Girl*[Text] OR Female*[Text]

FINAL PUBMED SEARCH
"Sexually transmitted infections" AND "Sex work" AND "MENA" AND "Women"

Embase (September 04, 2018)
Sexually transmitted infections
exp sexually transmitted disease/ or exp chlamydia/ or exp chlamydia trachomatis/ or exp pelvic inflammatory disease/ or exp genital tract infection/ or exp genital tract inflammation/ or chlamydia.mp. or chlamydia trachomatis.mp. or trachomatis.mp. or chlamydial.mp. or chlamydial infection.mp. or chlamydia infection.mp. or pelvic inflammatory disease.mp. or exp gonorrhea / or exp neisseria gonorrhoeae / or gonorrhea.mp. or neisseria gonorrhoeae.mp. or gonorrhoeae.mp. or gonococcus.mp. or gonococci.mp. or gonococcal.mp. or gonococcal infection.mp. or exp syphilis/ or exp treponema pallidum/ or syphilis.mp. or great pox.mp. or treponema pallidum.mp. or exp herpes simplex virus/ or exp herpes simplex/ or exp herpes simplex virus 1/ or exp simplexvirus/ or exp herpesvirus/ or exp herpesviridae/ or exp herpes simplex virus 2/ or (herpes simplex or herpes simplex virus or HSV type-1 or HSV type 1 or HSV1 or HSV-1 or HSV 1 or human herpes virus or herpes simplex virus type 1 or Herpes simplex virus type-1 or herpes simplex virus 1 or herpes simplex virus-1 or herpes simplex type 1 or herpes simplex type-1 or herpes simplex 1 or herpes simplex-1 or Herpesvirus type 1 or Herpesvirus type-1 or Herpesvirus 1 or Herpesvirus-1 or Herpes virus type 1 or Herpes virus type-1 or Herpes virus 1 or Herpes virus-1 or genital herpes or herpes genitalis or herpes labialis or herpetic stomatitis or HSV type-2 or HSV type 2 or HSV2 or HSV-2 or HSV 2 or herpes simplex virus type 2 or herpes simplex virus type-2 or herpes simplex virus 2 or herpes simplex virus-2 or herpes simplex type 2 or herpes simplex type-2 or herpes simplex 2 or herpes simplex-2 or herpesvirus type 2 or herpesvirus type-2 or herpesvirus 2 or herpesvirus-2 or herpes virus type 2 or herpes virus type-2 or herpes virus 2 or Herpes virus-2 or sexually transmitted or venereal or STI or STD or genital or infection or infections or infected).mp.
Sex work
exp prostitution/ or exp casual sex/ or exp transactional sex/ or exp group sex/ or exp sex tourism/ or exp sexual promiscuity/ or exp extramarital sex/ or exp premarital sex/ or exp sexual relation/ or exp sexual partners/ or ((exp sex trafficking/ or exp sexual exploitation/ or exp sexual coercion/) NOT Child) or (sex* work* or sexwork* or sex-work* or sex partner* or sexual partner* or sexual contact* or premarital sex or premarital sexual or premarital relation* or pre-marital sex or pre-marital sexual or pre-marital relation* or pre marital sex or pre marital sexual or pre marital relation* or extramarital sex or extramarital sexual or extramarital relation* or extra-marital sex or extra-marital sexual or extra-marital relation* or extra marital sex or extra marital sexual or extra marital relation* or illicit sex or illicit sexual or illicit relation* or illegal sex or illegal sexual or illegal relation* or (out* ADJ1 marriage) or illegal social behavio?r or adultery or prostitut* or promiscu* or FSW or FSWs or CSW or CSWs or SW or SWs or TSW or TSWs or TS or (women ADJ4 sex*) or (Travailleuse* ADJ1 sex*) or bar girl* or call girl* or callgirl* or escort* or masseuse* or hostess* or female entertain* or sex

entertain* or sexual entertain* or entertainment work* or sex industr* or sex establishment* or brothel* or red light or red-light or (red ADJ1 district*) or nightclub* or pimp or recreation* sex* or intergenerational sex* or cross-generation sex* or cross-generational sex* or commercial sex* or transactional sex* or sex* transaction* or casual sex* or informal sex* or group sex* or street sex* or (migra* ADJ4 sex*) or (sex* ADJ4 migra*) or survival sex* or occupational sex* or sex* tourism or sex seeking or sex-seeking or solicit* or (consum* ADJ4 sex*) or (sex* ADJ 4 consumer) or (sex* ADJ4 consumers) or (sex* ADJ4 provi*) or (provi* ADJ4 sex*) or (sell* ADJ4 sex*) or (sex* ADJ4 sell*) or sold sex* or (exchang* ADJ4 sex*) or (sex* ADJ4 exchange) or (trading ADJ4 sex*) or (trade* ADJ4 sex*) or sex* trade or sex* favor* or (commodi* ADJ4 sex*) or (sex* ADJ4 commodi*) or (paid ADJ4 sex*) or (pay* ADJ4 sex*) or (sex* ADJ4 pay*) or (buy* ADJ4 sex*) or (sex* ADJ4 buy*) or (charg* ADJ4 sex*) or (sex* ADJ4 charg*) or (engag* ADJ4 sex*) or (sex* ADJ4 engage*) or (sex* ADJ4 service*) or (service* ADJ4 sex*) or (money ADJ4 sex*) or (sex* ADJ4 money) or (cash ADJ4 sex*) or (sex* ADJ4 cash) or (sex* ADJ4 drug*) or (drug* ADJ4 sex*) or (sex* ADJ4 goods) or (goods ADJ4 sex*) or (sex* ADJ4 gift*) or (gift* ADJ4 sex*) or hidden population* or hard to reach population* or hard-to-reach population* or (core ADJ1 group*) or vulnerable women or vulnerable female*).mp. or ((vulnerable population* or most-at-risk population* or most at risk population* or high risk population* or high-risk population* or population* at high risk or population* at high-risk).mp. AND (sex* or infection* or STI or STIs or STD or STDs or human immunodeficiency virus or HIV* or AIDS* or acquired immune deficiency syndrome or acquired immunodeficiency syndrome).mp.) or ((sex trafficking or sexual trafficking or (traffick* ADJ4 sex*) or sex* slave* or sex* coerc* or sex* abduct* or sex* exploit* or sex* abuse* or sex* violence) NOT Child).mp. or ((women ADJ4 traffick*) or (girls ADJ4 traffick*) or (female* ADJ4 traffick*) or (traffick* ADJ4 women) or (traffick* ADJ4 girls) or (traffick* ADJ4 female*)).mp.

MENA

exp Middle East/ or exp North Africa/ or exp Arab/ or exp Afghanistan/ or exp Djibouti/ or exp Pakistan/ or exp Somalia/ or exp Sudan/ or exp South Sudan/ or Middle East.mp. or North Africa.mp. or EMRO.mp. or Eastern Mediterranean.mp. or Arab.mp. or Arabs.mp. or Arab World.mp. or Islam.mp. or Afghanistan.mp. or Afghan*.mp. or Algeria*.mp. or Bahrain*.mp. or Djibouti.mp. or Egypt*.mp. or Jordan*.mp. or Kuwait*.mp. or Leban*.mp. or Libya*.mp. or Iran*.mp. or Iraq*.mp. or Morocc*.mp. or Oman*.mp. or Pakistan*.mp. or Qatar*.mp. or Saudi*.mp. or Somal*.mp. or Sudan*.mp. or Syria*.mp. or Tunisia*.mp. or United Arab Emirates.mp. or Emirat*.mp. or West Bank.mp. or Ghaza*.mp. or Gaza*.mp. or Palestin*.mp. or Yemen*.mp. or UAE.mp. or KSA.mp.

Women

exp female/ or (women or girl* or female*).mp.

FINAL EMBASE SEARCH
"Sexually transmitted infections" AND "Sex work" AND "MENA" AND "Women"

Regional databases

Iran Scientific Information Database (September 11, 2018)
Keyword search for: "chlamydia", "gonorrhea", "gonorrhaeae", "gonococc", "trichomonas", "trichomoniasis", "syphilis", "treponema", "HSV", "herpes", "venereal", "sexually transmitted", "pelvic inflammatory disease", "reproductive tract infection", "urinary tract infection"

Iraq Academic Scientific Journals database (September 10, 2018)
Keyword search for: "chlamydia", "gonorrhea", "gonorrhaeae", "gonococc*", "trichomonas", "trichomoniasis", "syphilis", "treponema*", "HSV", "herpes", "venereal", "sexually transmitted", "pelvic inflammatory disease", "reproductive tract infection*", "urinary tract infection*"

MENA HIV/AIDS Epidemiology Synthesis Project database (September 01, 2018)
Hand search of all documents in the database

PakMediNet database (September 12, 2018)
Keyword search for: "chlamydia", "gonorrhea", "gonorrhaeae", "gonococcal", "gonococcus", "gonococci", "trichomonas", "trichomoniasis", "syphilis", "treponema", "HSV", "herpes", "venereal", "sexually transmitted", "pelvic inflammatory disease", "reproductive tract infection", "urinary tract infection"

World Health Organization Global Health Observatory data repository (September 16, 2018)

Search by category: "sexually transmitted infections"
World Health Organization African Index Medicus database (September 08, 2018) Keyword search for: "Algeria", "Algerie", "Djibouti", "Egypt", "Egypte", "Libya", "Libie", "Maroc", "Morocco", "Tunisia", "Tunisie", "Somalia", "Somalie", "Sudan", and "Soudan"
World Health Organization Index Medicus for the Eastern Mediterranean Region database (September 20, 2018) Keyword search for: "chlamydia", "gonorrhea", "gonorrhaeae", "gonococcal", "gonococcus", "gonococci", "trichomonas", "trichomoniasis", "syphilis", "treponema", "HSV", "herpes", "venereal", "sexually transmitted", "pelvic inflammatory disease", "reproductive tract", "urinary tract"
Abstract archives of the International AIDS Society conferences (July 28, 2018) Keyword search using each MENA country name

FSWs, female sex workers.

Box S2. List of extracted variables

Report characteristics
Author(s)
Year of publication
Full citation
Publication type
Data source
General study characteristics
Study population and its characteristics
Year(s) of data collection
Country of origin
Country of survey
City
Study site
Study design
Sampling methodology
Eligibility criteria
Participation rate
Sexually transmitted infection incidence
Number followed-up
Follow-up time
Seroconversion risk
Incidence rate
Specimen type (endocervical, urine, vaginal, serum)
Diagnostic method (polymerase chain reaction, culture, enzyme-linked immunoassay, rapid plasma reagin....)
Sexually transmitted infection prevalence
Number tested
Number positive
Specimen type (endocervical, urine, vaginal, serum)
Diagnostic method (polymerase chain reaction, culture, enzyme-linked immunoassay, rapid plasma reagin....)

Table S2. Definitions of types of infection and classification of results of diagnostic methods for *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and herpes simplex virus type 2 (HSV-2) in studies identified by the systematic review into current, recent, and ever infection.

Infection	Current infection	Recent infection	Ever infection[a] (seropositivity using antibody testing)
Definition	A state in which a person is currently a carrier of a pathogen responsible for causing the infection	A state in which a person has acquired the infection some time *recently*, but may or may not currently be a carrier of the pathogen	A state in which a person has acquired the infection some time in the past, but may or may not currently be a carrier of the pathogen
STI			
Treponema pallidum	Positive RPR test	Not applicable	Positive FTA-ABS test
	Positive VDRL test		Positive RDT test
	Positive RPR test or positive VRDL test with positive results confirmed through either positive FTA-ABS, or positive RDT, or positive TPHA tests		Positive TPHA test
Chlamydia trachomatis	Positive culture Positive NAAT test Positive immunofluorescence test on genital specimen (antigen detection)	Positive IgM serology Positive IgA serology Higher titers indicative of recent infection	Positive IgG serology
Neisseria gonorrhoeae	Positive culture Positive NAAT test Positive gram stain	Not applicable	Positive IgG serology
Trichomonas vaginalis	Positive culture Positive wet mount Positive NAAT test	Not applicable	Positive IgG serology
Herpes simplex virus type 2	Not applicable	Positive IgM serology Positive IgA serology Higher titers indicative of recent infection	Positive IgG serology

[a]Testing conducted for the total sample regardless of test results for current infection.
FTA-ABS, fluorescent treponemal antibody absorption test. IgG, immunoglobulin G. NAAT, nucleic acid amplification test. RDT, rapid diagnostic test. RPR, rapid plasma reagin. STI, sexually transmitted infection. TPHA, *Treponema pallidum* haemagglutination assay. VDRL, venereal disease research laboratory.

Table S3. Criteria for assessing the risk of bias (ROB) of *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, *Trichomonas vaginalis*, and herpes simplex virus type 2 (HSV-2) prevalence studies among FSWs in the Middle East and North Africa (MENA), as identified by the systematic review

Quality domain	ROB assessment	Criteria
1. Rigor of sampling methodology	Low ROB	Studies using probability-based sampling
	High ROB	Studies using non-probability sampling
	Unclear	Information not reported
2. Response rate	Low ROB	≥60% or ≥60% of target sample size reached in studies using respondent-driven or time-location sampling
	High ROB	<60% or <60% of target sample size reached in studies using respondent-driven or time-location sampling
	Unclear	Information not reported
3. Sexually transmitted infection ascertainment	Low ROB	Biological assay for infection ascertainment explicitly indicated
	High ROB	–
	Unclear	Biological assay for infection ascertainment not explicitly indicated

FSWs, female sex workers.

Table S4. Details of independent variables included in the meta-regression analyses for syphilis prevalence

Variable	Sub-categories
Country/subregion*	1. Eastern MENA: Afghanistan, Iran, and Pakistan 2. Egypt, Jordan, Yemen 3. North Africa: Algeria, Morocco, Sudan, and Tunisia 4. Horn of Africa: Djibouti, Somalia, and South Sudan
Year of data collection	Median
Infection type	1. Current 2. Ever (seropositivity using antibody testing) 3. Unclear
Diagnostic method	1. RPR/VDRL & TPHA/FTA-ABS/RDT 2. RPR/VDRL 3. TPHA 4. RDT 5. Not specified
STI ascertainment	1. Biological assay not explicitly reported 2. Biological assay explicitly indicated
Sampling methodology	1. Non-probability/unclear sampling 2. Probability-based sampling
Sample size	1. <100 participants 2. ≥100 participants
Sampling methodology	1. Non-probability/unclear sampling 2. Probability-based sampling such as respondent-driven sampling or systematic random sampling
Response rate	1. <60%/unclear 2. ≥60% or ≥60% of target sample size reached in studies using respondent-driven sampling or time-location sampling.

*Countries were grouped based on geography and similarity in prevalence levels.
FTA-ABS, fluorescent treponemal antibody absorption test. MENA, Middle East and North Africa. RDT, rapid diagnostic test. RPR, rapid plasma reagin. STI, sexually transmitted infection. TPHA, *Treponema pallidum* haemagglutination assay. VDRL, venereal disease research laboratory.

Table S5. Summary of the risk of bias (ROB) assessment for *Treponema pallidum* (syphilis), *Chlamydia trachomatis*, *Neisseria gonorrhea*, *Trichomonas vaginalis*, herpes simplex virus type 2 (HSV-2) prevalence studies among FSWs in the Middle East and North Africa (MENA)

ROB quality domains	Number of studies	%
Rigor of sampling methodology		
Low ROB	63	44.7
High ROB	65	46.1
Unclear	13	9.2
Response rate		
Low ROB	65	46.1
High ROB	3	2.1
Unclear	73	51.8
Sexually transmitted infection ascertainment		
Low ROB	111	78.7
High ROB	--	--
Unclear	30	21.3
Total number of studies	**141[*]**	**100.0**
Summary		
Low ROB		
At least 1 domain	120	85.1
At least 2 domains	80	56.7
All 3 domains	39	27.7
High ROB		
At least 1 domain	68	48.2
At least 2 domains	0	0
All 3 domains	0	0

[*]Three studies reported in the systematic review were excluded from further analyses, either because of the priority order followed for selecting studies applying the same assay to different biological specimens (2 studies), or because measures based on culture were superseded by measures based on polymerase chain reaction (1 study).
FSWs, female sex workers. NA, not applicable.

Table S6. Risk of bias (ROB) assessment for syphilis, *Chlamydia trachomatis*, *Neisseria gonorrhea*, *Trichomonas vaginalis*, herpes simplex virus type 2 (HSV-2) prevalence studies among FSWs in the Middle East and North Africa (MENA)

Country Short citation*	Year(s) of data collection	Tested (n)	Prevalence	Sampling method	Response rate	STI ascertainment
SYPHILIS CURRENT INFECTION						
Afghanistan						
Todd, 2010 [2]	2006-08	520	0	High ROB	Unclear	Low ROB
Egypt						
MOH, 2000 [3]	1999-00	52	5.8	High ROB	Unclear	Low ROB
Iran						
Kassaian, 2012 [4]	2009-10	91	0	High ROB	Low ROB	Low ROB
Navadeh, 2012 [5]	2010	139	7.2	Low ROB	Low ROB	Low ROB
Kazerooni, 2014 [6]	2010-11	278	0	Low ROB	Low ROB	Low ROB
Jahanbakhsh, 2017 [7]	2012	14	0	High ROB	Unclear	Low ROB
Morocco						
MOH, 2008 [8]	2007	141	13.5	High ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	362	21.4	Low ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	359	18.8	Low ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	392	13.9	Low ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	318	13.3	Low ROB	Low ROB	Low ROB
Pakistan						
Baqi, 1998 [10]	1993-94	81*	5.0	High ROB	Low ROB	Low ROB
Rehan, 2009 [11] & NACP, 2005 [12]	2004	421	3.6	High ROB	Low ROB	Low ROB
Rehan, 2009 [11] & NACP, 2005 [12]	2004	387	16.0	Low ROB	Low ROB	Low ROB
Shah, 2004 [13]	2004	157	11.5	High ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	107	2.8	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	1.2	Low ROB	Unclear	Low ROB
Khan, 2011 [15]	2007	730	4.5	Low ROB	Low ROB	Low ROB
Somalia						
Jama, 1987 [16]	1985-86	85	44.7	High ROB	Unclear	Low ROB
Jama Ahmed, 1991 [17]	1988-89	155	47.7	High ROB	Unclear	Low ROB
Scott, 1991 [18]	1989	57	50.8	High ROB	Unclear	Low ROB
Corwin, 1991 [19]	1990	302	35.4	High ROB	Unclear	Low ROB
Watts, 1994 [20]	1990	236	30.9	High ROB	Unclear	Low ROB
IOM, 2017 [21]	2014	96	2.4	Low ROB	High ROB	Low ROB
Sudan						
MOH, 2016 [22]	2015-16	832	7.3	Low ROB	Low ROB	Low ROB
Tunisia						
Bchir, 1988 [23]	1987	42	28.6	High ROB	Unclear	Low ROB
Ayachi, 1997 [24]	1992-94	79	24.1	High ROB	Unclear	Low ROB
Yemen						
Stulhofer, 2008 [25]	2008	244	4.9	Low ROB	Unclear	Low ROB
SYPHILIS EVER INFECTION†						
Afghanistan						
NACP, 2010 [26]	2009	368	5.4	Low ROB	Low ROB	Low ROB
NACP, 2012 [27]	2012	344	0.9	Low ROB	Low ROB	Low ROB
NACP, 2012 [27]	2012	333	0.0	Low ROB	Low ROB	Low ROB
NACP, 2012 [27]	2012	355	2.0	Low ROB	Low ROB	Low ROB
Algeria						
MOH, 2009 [28]	2004	185	11.9	High ROB	Unclear	Low ROB
MOH, 2009 [28]	2007	380	18.4	High ROB	Unclear	Low ROB
Iran						
Mirzazadeh, 2016 [29]	2015	1,337	0.4	High ROB	Unclear	Low ROB
Pakistan						
Hawkes, 2009 [14]	2007	107	2.8	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	1.6	Low ROB	Unclear	Low ROB
Bibi, 2010 [30]	2003	50	44.0	High ROB	Unclear	Low ROB
Raza, 2015 [31]	2014	NR	20.0	High ROB	Unclear	Low ROB
Somalia						

Jama, 1987 [16]	1985-86	85	57.6	High ROB	Unclear	Low ROB
Jama Ahmed, 1991 [17]	1988-89	155	69.0	High ROB	Unclear	Low ROB
Burans, 1990 [32]	NR	89	28.1	High ROB	Low ROB	Low ROB
IOM, 2017 [21]	2008	237	3.4	Low ROB	Low ROB	Low ROB
Sudan						
Sudan NACP, 2012 [33]	2011	305	1.5	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	279	3.4	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	282	3.4	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	296	5.4	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	288	4.3	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	287	1.7	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	303	5.2	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	296	4.1	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	293	8.9	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	291	1.9	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	303	5.3	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	299	1.8	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	284	1.8	Low ROB	Low ROB	Low ROB
Sudan NACP, 2012 [33]	2011	288	4.2	Low ROB	Low ROB	Low ROB
MOH, 2016 [22]	2015-16	832	12.0	Low ROB	Low ROB	Low ROB
Tunisia						
Bchir, 1988 [23]	1987	42	38.1	High ROB	Unclear	Low ROB
Ayachi, 1997 [24]	1992-94	79	36.7	High ROB	Unclear	Low ROB
Znazen, 2010 [34]	2007	183	2.7	High ROB	Low ROB	Low ROB
SYPHILIS UNCLEAR						
Afghanistan						
WHO, 2018 [35]	2010	NR	8.7	Unclear	Unclear	Unclear
MENA HIV ESP, 2013 [36]	2012	440	5.7	Unclear	Unclear	Unclear
WHO, 2018 [35]	2017	2,457	1.3	Unclear	Unclear	Unclear
Algeria						
WHO, 2018 [35]	2013	27	7.4	Unclear	Unclear	Unclear
WHO, 2018 [35]	2014	24	29.2	Unclear	Unclear	Unclear
WHO, 2018 [35]	2016	183	14.2	High ROB	Unclear	Unclear
WHO, 2018 [35]	2017	81	16.0	High ROB	Unclear	Unclear
Djibouti						
WHO, 2015 [37]	2014	361	5.0	Unclear	Unclear	Unclear
Iran						
WHO, 2018 [35]	2008	NR	1.6	Unclear	Unclear	Unclear
Moayedi-Nia, 2016 [38]	2012-13	161	0	Low ROB	Unclear	Unclear
Jordan						
WHO, 2015 [37]	2008	NR	6.7	Unclear	Unclear	Unclear
Morocco						
Khattabi, 2005 [39]	2004	332	9.6	High ROB	Unclear	Unclear
Khattabi, 2005 [39]	2004	272	12.1	High ROB	Unclear	Unclear
Khattabi, 2005 [39]	2004	143	9.0	High ROB	Unclear	Unclear
Bennani, 2006 [40]	2005	102	11.8	High ROB	Unclear	Unclear
Bennani, 2006 [40]	2005	143	13.3	High ROB	Unclear	Unclear
WHO, 2018 [35]	2008	NR	16.9	Unclear	Unclear	Unclear
Pakistan						
MENA HIV ESP, 2010 [41]	2007	NR	23.5	Unclear	Unclear	Unclear
Somalia						
WHO, 2018 [35]	2017	860	2.7	Low ROB	Unclear	Unclear
Sudan						
WHO, 2018 [35]	2016	4,123	4.1	Low ROB	Unclear	Unclear
WHO, 2018 [35]	2017	1,244	14.4	Unclear	Unclear	Unclear
Yemen						
WHO, 2018 [35]	2010	301	0	Low ROB	Unclear	Unclear
CHLAMYDIA TRACHOMATIS CURRENT INFECTION						
Algeria						
Kadi, 1989 [42]	NR	44	45.5	High ROB	Unclear	Low ROB
Egypt						
MOH, 2000 [3]	1999-00	52	7.7	High ROB	Unclear	Low ROB

Iran						
Darougar, 1983 [43]	NR	116	6.9	High ROB	Unclear	Low ROB
Kazerooni, 2014 [6]	2010-11	278	9.0	Low ROB	Low ROB	Low ROB
Mirzazadeh, 2016 [29]	2015	1,337	6.0	High ROB	Unclear	Low ROB
Morocco						
MOH, 2008 [8]	2007	141	22.7	High ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	368	22.4	Low ROB	Low ROB	Low ROB
Pakistan						
Rehan, 2009 [11]	2004	348	5.2	High ROB	Low ROB	Low ROB
Rehan, 2009 [11]	2004	383	11.0	Low ROB	Low ROB	Low ROB
Hawkes, 2009 [14]	2007	107	0.9	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	1.7	Low ROB	Unclear	Low ROB
Khan, 2011 [15]	2007	730	7.7	Low ROB	Low ROB	Low ROB
Somalia						
IOM, 2017 [21]	2014	90	0.7	Low ROB	High ROB	Low ROB
Tunisia						
Znazen, 2010 [34]	2007	188	72.9	Low ROB	High ROB	Low ROB
CHLAMYDIA TRACHOMATIS RECENT INFECTION						
Algeria						
Kadi, 1989 [42]	NR	44	95.0	High ROB	Unclear	Low ROB
Iran						
Darougar, 1983 [43]	NR	154	29.2	High ROB	Unclear	Low ROB
CHLAMYDIA TRACHOMATIS EVER INFECTION†						
Algeria						
Kadi, 1989 [42]	NR	44	100	High ROB	Unclear	Low ROB
Iran						
Darougar, 1983 [43]	NR	154	94.2	High ROB	Unclear	Low ROB
Kassaian, 2012 [4]	2009-10	91	19.8	High ROB	Low ROB	Low ROB
Tunisia						
Bchir, 1988 [23]	1987	42	73.8	High ROB	Unclear	Low ROB
Znazen, 2010 [34]	2007	183	85.8	High ROB	Low ROB	Low ROB
CHLAMYDIA TRACHOMATIS UNCLEAR						
Iran						
Navadeh, 2012 [5] & WHO, 2011 [44]	2010	144	2.9	Low ROB	Low ROB	Unclear
Morocco						
MENA HIV ESP, 2010 [41]	NR	NR	19.1	Unclear	Unclear	Unclear
NEISSERIA GONORRHOEAE CURRENT INFECTION						
Egypt						
MOH, 2000 [3]	1999-00	52	7.7	High ROB	Unclear	Low ROB
Iran						
Kazerooni, 2014 [6]	2010-11	278	1.4	Low ROB	Low ROB	Low ROB
Navadeh, 2012 [5] & WHO, 2011 [44]	2010	144	0	Low ROB	Low ROB	Unclear
Nasirian, 2017 [45]	2013-14	99	9.1	High ROB	Low ROB	Low ROB
Taghizadeh, 2015 [46]	2014	117	1.0	High ROB	Low ROB	Unclear
Mirzazadeh, 2016 [29]	2015	1,337	1.3	High ROB	Unclear	Low ROB
Morocco						
MOH, 2008 [8]	2007	141	10.6	High ROB	Low ROB	Low ROB
MENA HIV ESP, 2010 [41]	NR	NR	3.5	Unclear	Unclear	Unclear
MOH, 2012 [9]	2011-12	368	11.7	Low ROB	Low ROB	Low ROB
Pakistan						
Rehan, 2009 [11]	2004	348	9.8	High ROB	Low ROB	Low ROB
Rehan, 2009 [11]	2004	383	12.3	Low ROB	Low ROB	Low ROB
Hawkes, 2009 [14]	2007	107	1.9	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	2.0	Low ROB	Unclear	Low ROB
Khan, 2011 [15]	2007	730	7.5	Low ROB	Low ROB	Low ROB
Somalia						
Burans, 1990 [32]	NR	89	11.2	High ROB	Low ROB	Low ROB
IOM, 2017 [21]	2014	91	0.4	Low ROB	High ROB	Low ROB
Tunisia						
NACP, 2005 [47]	2005	NR	12.0-17.0‡	High ROB	Unclear	Unclear
Znazen, 2010 [34]	2007	188	11.2	High ROB	Low ROB	Low ROB

TRICHOMONAS VAGINALIS CURRENT INFECTION						
Egypt						
MOH, 2000 [3]	1999-00	52	19.2	High ROB	Unclear	Low ROB
Iran						
Vafaei, 2015 [48]	2009-11	85	8.2	High ROB	Low ROB	Low ROB
Navadeh, 2012 [5] & WHO, 2011 [44]	2010	144	1.4	Low ROB	Low ROB	Unclear
Nasirian, 2017 [45]	2013-14	99	0.0	High ROB	Low ROB	Low ROB
Mirzazadeh, 2016 [29]	2015	1,337	11.9	High ROB	Unclear	Low ROB
Morocco						
MOH, 2008 [8]	2007	141	14.9	High ROB	Low ROB	Low ROB
MOH, 2012 [9]	2011-12	367	11.8	Low ROB	Low ROB	Low ROB
Pakistan						
Rehan, 2009 [11]	2004	386	5.2	High ROB	Low ROB	Low ROB
Rehan, 2009 [11]	2004	384	19.3	Low ROB	Low ROB	Low ROB
Hawkes, 2009 [14]	2007	107	5.7	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	4.3	Low ROB	Unclear	Low ROB
Khan, 2011 [15]	2007	730	5.1	Low ROB	Low ROB	Low ROB
HSV-2 EVER INFECTION[†]						
Pakistan						
Hawkes, 2009 [14]	2007	107	4.7	Low ROB	Unclear	Low ROB
Hawkes, 2009 [14]	2007	426	8.0	Low ROB	Unclear	Low ROB
Syria						
Ibrahim, 2000 [49]	1995-98	101	22.8	High ROB	Unclear	Low ROB
Ibrahim, 2000 [49]	1995-98	125	20.0	High ROB	Unclear	Low ROB
Tunisia						
Znazen, 2010 [34]	2007	183	55.5	High ROB	Low ROB	Low ROB

The table is sorted, for each country, by data collection year(s) then city/province.
[*]Three studies reported in the systematic review were excluded from further analyses, either because of the priority order followed for selecting studies applying the same assay to different biological specimens (2 studies), or because measures based on culture were superseded by measures based on polymerase chain reaction (1 study).
[†]Ever infection indicates seropositivity using antibody testing.
[‡]Range reported based on several studies whose abstracts or full-texts could not be retrieved (mid-point: 14.5%).
IOM, International Organization for Migration. MENA HIV ESP, MENA HIV/AIDS Epidemiology Synthesis Project database. MOH, Ministry of Health. NACP, National AIDS Control Program. NR, not reported. STI, sexually transmitted infection. WHO, World Health Organization.

Table S7. Results of meta-analyses stratified by subregion on prevalence studies for current and ever infection with *Treponema pallidum* (syphilis) among FSWs in the Middle East and North Africa

Sexually transmitted infection	Studies	Samples		Reported prevalence		Pooled mean prevalence		Heterogeneity measures		
	N	Tested	Positive	Median* (%)	Range* (%)	Estimate (%)	95% CI	Q† (p-value)	I^2‡ (%; 95% CI)	Prediction interval§ (95%)
Subregion										
Current infection										
Eastern MENA	13	3,351	150	3.6	0-16.0	3.0	0.9-9.2	203.7 (p<0.0001)	94.1 (91.5-95.9)	0.0-20.9
Egypt, Jordan, and Yemen	2¶	296	15	5.4	4.9-5.8	--	--	--	--	--
North Africa	7	1,693	293	18.8	13.3-28.6	17.6	14.2-21.3	19.1 (p=0.004)	68.6 (30.7-85.8)	8.3-29.5
Horn of Africa	12	1,763	384	32.9	2.4-62.0	27.8	15.2-42.4	350.1 (p<0.0001)	96.9 (95.7-97.7)	0.0-84.4
Ever infection¥										
Eastern MENA	9	3,604	125	2.0	0-44.0	4.6	1.3-9.7	250.5 (p<0.0001)	96.8 (95.4-97.8)	0.0-30.3
Egypt, Jordan, and Yemen	0	--	--	--	--	--	--	--	--	--
North Africa	30	4,963	297	5.3	0-38.1	7.7	5.4-10.4	267.2 (p<0.0001)	89.1 (85.6-91.8)	0.0-25.0
Horn of Africa	11	1,401	288	52.5	3.1-92.3	46.8	26.6-67.4	388.5 (p<0.0001)	97.4 (96.5-98.1)	0.0-67.4

The same population may have contributed different measures for both current infection and ever (seropositivity using antibody testing) infection.
*Medians and ranges were calculated based on the stratified prevalence measures.
†Q: the Cochran's Q statistic is a measure assessing the existence of heterogeneity in effect size (here, prevalence) across studies.
‡I^2: a measure assessing the magnitude of between-study variation that is due to differences in effect size (here, prevalence) across studies rather than chance.
§Prediction interval: a measure estimating the 95% interval of the distribution of true effect sizes (here, prevalence measures).
¶Meta-analyses were performed if at least three studies were available.
¥Ever infection indicates seropositivity using antibody testing.
CI, confidence interval. FSWs, female sex workers.

Table S8. Results of stratified meta-analyses by year of data collection on prevalence studies for current and ever infection with *Treponema pallidum* (syphilis) and current infection with *Chlamydia trachomatis*, *Neisseria gonorrhoeae*, and *Trichomonas vaginalis* among FSWs in the Middle East and North Africa

Sexually transmitted infection	**Studies**	**Samples**		**Reported prevalence**		**Pooled mean prevalence**		**Heterogeneity measures**		
	N	Tested	Positive	Median* (%)	Range* (%)	Estimate (%)	95% CI	Q† (p-value)	I^2‡ (%; 95% CI)	Prediction interval§ (95%)
***Treponema pallidum* (syphilis)**										
Current infection										
<2010	25	4,313	526	11.5	0-62.0	15.0	8.8-22.3	855.1 (p<0.0001)	97.2 (96.6-97.7)	0.0-60.0
≥2010	9	2,790	316	7.3	0-21.4	8.0	3.4-14.1	187.3 (p<0.0001)	95.7 (93.6-97.1)	0.0-35.8
Ever infectionǁ										
<2010	30	2,386	382	29.2	0-92.3	24.6	16.1-34.2	693.4 (p<0.0001)	95.8 (94.8-96.6)	0.0-80.2
≥2010	20	7,582	328	3.4	0-20.0	3.6	2.0-5.6	342.2 (p<0.0001)	94.4 (92.6-95.8)	0.0-16.9
Chlamydia trachomatis										
Current infection										
<2010	12	2,535	325	8.8	0.9-76.2	17.1	7.9-28.8	526.1 (p<0.0001)	97.9 (97.3-98.4)	0.0-69.9
≥2010	4	2,073	187	7.5	0.7-22.4	8.4	2.4-17.3	80.6 (p<0.0001)	96.3 (93.1-98.0)	0.0-65.1
Neisseria gonorrhoeae										
Current infection										
<2010	13	2,796	227	9.7	1.9-17.5	8.1	5.6-10.9	73.2 (p<0.0001)	83.6 (73.4-89.9)	0.9-20.6
≥2010	7	2,434	74	1.3	0-11.7	2.2	0.2-5.8	88.0 (p<0.0001)	93.2 (88.4-96.0)	0.0-20.6
Trichomonas vaginalis										
Current infection										
<2010	8	2,226	186	6.4	1.2-19.3	8.2	4.2-13.3	100.9 (p<0.0001)	93.1 (88.6-95.8)	0.0-30.6
≥2010	5	2,032	211	8.2	0-11.9	5.5	1.6-11.2	56.8 (p<0.0001)	93.0 (86.5-96.3)	0.0-35.0

The same population may have contributed different measures for both current infection and ever (seropositivity using antibody testing) infection.

*Medians and ranges were calculated based on the stratified prevalence measures.

†Q: the Cochran's Q statistic is a measure assessing the existence of heterogeneity in effect size (here, prevalence) across studies.

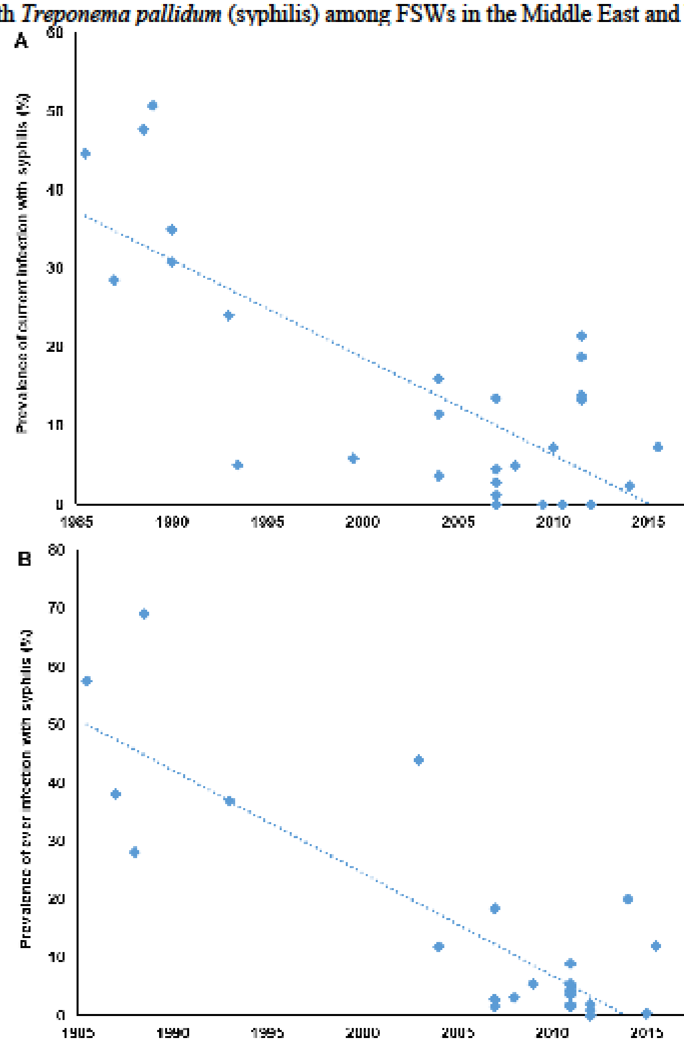
‡I^2: a measure assessing the magnitude of between-study variation that is due to differences in effect size (here, prevalence) across studies rather than chance.

§Prediction interval: a measure estimating the 95% interval of the distribution of true effect sizes (here, prevalence measures).

ǁEver infection indicates seropositivity using antibody testing.

CI, confidence interval. FSWs, female sex workers.

Figure S1. Scatter plots showing the time trend for the prevalence of A) current and B) ever infection with *Treponema pallidum* (syphilis) among FSWs in the Middle East and North Africa



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Appendix VII

Supplementary material for Research paper 3-

HSV-2 as a biomarker of HIV epidemic potential among FSWs

Supplementary Information

HSV-2 as a biomarker of HIV epidemic potential in female sex workers: meta-analysis, global epidemiology and implications

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Table S1. Paired HSV-2 and HIV prevalence measures among female sex workers identified in the systematic review.

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
AFRO (n=42)											
Burkina Faso	Low, 2011[1]	2003-05	Professional FSWs	Community	689	62.4	765	35.7	9.5	64.0	--
Burkina Faso	Nagot, 2003[2]	1998-02	FSWs in Bobo-Dioulasso	Community	540	66.0	562	34.0	--	--	--
Burkina Faso	Nagot, 2007[3]	2002-03	FSWs in Bobo-Dioulasso	STI clinic	273	70.1	273	31.5	--	100.0	--
Congo	Nzila, 1991[4]	1988	Hotel/home/street-based FSWs in Kinshasa	Community	265	82.3	1226	35.0	--	8.0	--
Congo	Vandepitte, 2007[5]	2002	Hotel-based FSWs	STI clinic	17	76.5	17	11.8	--	--	--
Congo	Vandepitte, 2007[5]	2002	Home-based FSWs	STI clinic	146	74.7	146	24.0	--	--	--
Congo	Vandepitte, 2007[5]	2002	Street-based FSWs	STI clinic	10	50.0	10	20.0	--	--	--
Congo	Vandepitte, 2007[5]	2002	Homeless FSWs	STI clinic	40	52.5	40	10.0	--	--	--
Congo	Vandepitte, 2007[5]	2002	Clandestine FSWs	STI clinic	289	50.2	289	6.6	--	--	--
Eritrea	Ghebrekidan, 1999[6]	1995	Registered FSWs in Massawa	Health center	107	80.0	107	29.0	--	--	--
Ethiopia	Holt, 2003[7]	1992	FSWs from Fandinka and Amon	Community	203	65.0	209	40.0	--	--	--
Guinea	Aho, 2014[8]	2005-06	FSWs in Conakry	Health center	201	84.1	223	35.3	--	98.7	--
Guinea	Diakite, 2006[9]	--	FSWs in Conakry	Unclear	416	72.1	417	38.1	--	--	--
Kenya	Vandenhoudt, 2013[10]	1997	FSWs recruited at workplace in Kisumu	Community	286	93.4	296	74.7	--	49.8	--
Kenya	Vandenhoudt, 2013[10]	2008	FSWs recruited through RDS in Kisumu	Community	479	83.8	479	56.5	--	75.5	--
Mozambique	Lafort, 2008[11]	--	FSWs at a reproductive health clinic in Tete	Health center	350	83.1	350	49.7	--	92.5	--
Nigeria	Dada, 1998[12]	1990-91	Low class FSWs (low fee)	Community	84	64.3	84	17.0	--	0.0[c]	--
Nigeria	Dada, 1998[12]	1990-91	Middle class FSWs (medium fee)	Community	624	58.7	624	12.0	--	0.0[c]	--
Nigeria	Dada, 1998[12]	1990-91	Upper class FSWs (hotels/clubs)	Community	88	56.8	88	8.0	--	0.0[c]	--
Nigeria	Eltom, 2002[13]	1991-94	FSWs from brothels or hotels in Lagos	Brothel/hotel	863	60.60	863	15.6	--	--	--
Rwanda	Braunstein, 2011[14]	--	FSWs in Kigali	Community	800	59.80	800	24.0	--	74.0	--
Senegal	Kane, 2009[15]	2006	FSWs in Dakar aged <20 years	Unclear	12	25.0	12	0.0[b]	--	--	--
Senegal	Kane, 2009[15]	2006	FSWs in Dakar aged 20-24 years	Unclear	54	61.1	54	11.1	--	--	--
Senegal	Kane, 2009[15]	2006	FSWs in Dakar aged 25-29 years	Unclear	88	85.2	88	13.6	--	--	--
Senegal	Kane, 2009[15]	2006	FSWs in Dakar aged ≥30 years	Unclear	450	94.0	450	23.1	--	--	--
South Africa	Malope, 2008[16]	2001	FSWs in a mining town in Carletonville	Community	95	95.8	95	76.8	--	--	--
South Africa	Ramjee, 2005[17]	--	FSWs near truck stops in Kwazulu Natal	Health center	416	84.0	416	50.0	--	11.2	--
Tanzania	Riedner, 2007[18]	2000	FSWs in entertainment venues in Mbeya	Community	753	88.8	753	66.9	--	--	--
Tanzania	Vu, 2018[19]	2013	FSWs in Dar es Salaam, Tanzania	Community	324	53.1	324	32.0	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Iringa, Tanzania	Community	220	21.8	220	32.9	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Mbeya, Tanzania	Community	244	53.7	244	29.2	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Mwanza, Tanzania	Community	350	51.7	350	19.0	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Shinyanga, Tanzania	Community	320	70.0	320	37.5	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Tabora, Tanzania	Community	228	61.4	228	14.0	--	30.0[c]	--
Tanzania	Vu, 2018[19]	2013	FSWs in Mara, Tanzania	Community	205	61.5	205	17.8	--	30.0[c]	--
Uganda	Vandepitte, 2011[20]	2009	FSWs from red-light district in Kampala	Red-light district	1026	80.0	1027	37.0	--	60.0	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged ≤20 years near mines & farms	Community	54	46.3	54	33.3	--	--	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged 21-25 years near mines & farms	Community	90	78.9	90	56.7	--	--	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged 26-30 years near mines & farms	Community	85	82.4	85	62.4	--	--	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged 31-35 years near mines & farms	Community	47	97.9	47	70.2	--	--	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged 36-40 years near mines & farms	Community	50	96.0	50	58.0	--	--	--
Zimbabwe	Cowan, 2005[21]	--	FSWs aged 41-45 years near mines & farms	Community	30	100.0	30	50.0	--	--	--

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
AMRO (n=57)											
Belize	Alvarez Rodriguez, 2013[22]	--	FSWs in Belize	Community	220	51.8	220	0.9	--	81.3	--
Domin. Rep.	Koenig, 2007[23]	2004-05	FSWs in Santo Domingo	Community	482	76.3	482	3.9	--	14.0	--
El Salvador	Creswell, 2010[24]	2008	FSWs in San Salvadore	Community	663	82.6	663	5.7	--	74.5	--
El Salvador	Soto, 2007[25]	2001-02	Brothel & mobile FSWs	Community	130	95.7	484	3.2	--	72.9	0.5
Guatemala	Soto, 2007[25]	2001-02	Brothel & mobile FSWs	Community	522	88.6	511	4.3	--	82.5	1.3
Honduras	Morales-Miranda[26]	2006	FSWs in 4 cities	Community	808	61.4	811	2.3	--	80.0	--
Honduras	Soto, 2007[25]	2001-02	Brothel & mobile FSWs	Community	416	91.1	493	9.6	--	93.8	3.3
Mexico	Uribe-Salas, 1999[27]	1993	FSWs working in massage parlors	Community	72	44.4	76	0.0[b]	--	80.6[c]	--
Mexico	Uribe-Salas, 1999[27]	1993	FSWs working in bars	Community	339	55.5	364	0.3	--	80.6[c]	--
Mexico	Uribe-Salas, 1999[27]	1993	Street-based FSWs	Community	346	78.9	362	1.1	--	80.6[c]	--
Mexico	Uribe-Salas, 2003[28]	1998	FSWs working in bars from Guatemala	Community	191	89.5	195	1.0	--	--	0.8[de]
Mexico	Uribe-Salas, 2003[28]	1998	FSWs working in bars from El Salvador	Community	75	90.7	76	0.0[b]	--	--	0.8[de]
Mexico	Uribe-Salas, 2003[28]	1998	FSWs working in bars from Honduras	Community	85	70.6	86	0.0[b]	--	--	0.8[de]
Mexico	Uribe-Salas, 2003[28]	1998	FSWs working in bars from Mexico	Community	109	88.1	121	0.8	--	--	0.8[de]
Nicaragua	Delgado, 2011[29]	2001-09	FSWs in Managua	Community	613	75.7	613	1.8	--	89.9[c]	--
Nicaragua	Delgado, 2011[29]	2001-09	FSWs in Chinandega	Community	212	83.5	211	2.4	--	89.9[c]	--
Nicaragua	Soto, 2007[25]	2001-02	Brothel & mobile FSWs	Community	454	82.1	460	0.2	--	56.6	1.2
Panama	Hakre, 2013[30]	2009-10	FSWs in Panama (≥50% registered)	Community	455	71.2	455	0.70	--	95.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Cocle (≥50% registered)	Community	64	84.4	64	0.0[b]	--	95.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Colon (≥50% registered)	Community	150	76.7	150	1.30	--	95.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Chiriqui (≥50% registered)	Community	155	72.3	155	0.0[b]	--	95.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Herrera & Los Santos (≥50% reg.)	Community	52	75.0	52	0.0[b]	--	95.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Bocas del Toro (≥50% unregistered)	Community	95	77.9	95	2.10	--	80.0[c]	--
Panama	Hakre, 2013[30]	2009-10	FSWs in Veraguas (≥50% unregistered)	Community	28	82.1	28	0.0[b]	--	80.0[c]	--
Panama	Soto, 2007[25]	2001-02	Brothel & mobile FSWs	Community	409	73.0	418	0.2	--	94.1	5.7
Peru	Caceres, 2006[31]	2003-05	Low income FSWs in 3 cities	Community	295	48.8	295	0.30	--	62.7	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Barranca	Community	18	77.8	168	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Chimbote	Community	36	88.9	199	1.0	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Chincha and Ica	Community	15	73.3	399	1.0	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Ilo and Pisco	Community	18	44.4	348	0.3	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Piura	Community	11	72.7	193	2.1	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Sullana	Community	27	51.9	200	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Tacna	Community	10	60.0	205	0.5	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Talara	Community	12	41.7	143	1.4	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Tumbes	Community	12	83.3	74	2.7	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Arequipa	Community	10	40.0	201	0.5	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Ayacucho	Community	15	60.0	147	0.7	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Cajamarca	Community	12	75.0	184	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Cerro de Pasco	Community	17	17.7	199	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Cusco	Community	17	58.8	208	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Huancayo	Community	10	50.0	196	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Huaraz	Community	11	72.7	140	0.7	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Juliaca	Community	11	9.1	197	0.0[b]	--	--	--

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
Peru	Carcamo, 2012[32]	2002-03	FSWs in Puno	Community	14	28.6	201	0.0[b]	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Huanuco	Community	21	76.2	202	0.5	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Iquitos	Community	26	100.0	200	1.5	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Pucallpa	Community	32	96.9	200	1.5	--	--	--
Peru	Carcamo, 2012[32]	2002-03	FSWs in Tarapoto	Community	26	88.5	159	1.9	--	--	--
Peru	Golenbock, 1988[33]	1986	FSWs in Callao	Community	140	91.0	140	0.0[b]	--	1.4	--
Peru	Gotuzzo, 1994[34]	1991-92	FSWs at governmental health clinic	STI clinic	399	82.20	400	0.8	--	54.1	--
Peru	Perla, 2012[35]	2002-03	Clandestine FSWs in Lima	Community	211	80.10	211	2.4	--	73.0	--
Peru	Sanchez, 1998[36]	1991-92	Registered FSWs attending an STI clinic	STI clinic	283	82.0	284	0.7	--	77.0	--
Peru	Sanchez, 1998[36]	1991-92	Unregistered FSWs attending an STI clinic	STI clinic	116	82.8	116	0.9	--	81.4	--
USA	Cohan, 2005[37]	1996-98	Women with sex work history in California	Community	226	72.9	226	0.3	--	--	19.7[d]
USA	Jones, 1998[38]	1991-92	FSWs who are cocaine users (non-injecting)	Community	303	73.4	303	25.4	--	46.0[c]	--
USA	Jones, 1998[38]	1991-92	FSWs who are cocaine users (injecting)	Community	34	65.4	34	23.5	--	46.0[c]	--
USA	Lutnick, 2008[39]	--	FSWs in San Francisco	Community	250	82.0	250	4.1	--	48.6	51.6
EURO (n=6)											
Greece	Papadogeorgaki, 2006[40]	2005	Greek FSWs	Health center	240	74.6	240	0.0[b]	--	--	--
Greece	Papadogeorgaki, 2006[40]	2005	Non-Greek FSWs	Health center	59	49.2	59	0.0[b]	--	--	--
Israel	Linhart, 2008[41]	--	Brothel-based FSWs	Brothel	300	60.0	300	0.3	--	90.70	--
Russia	Khromova, 2002[42]	--	Juvenile and homeless detainee FSWs	Prison	400	29.2	400	2.8	--	--	--
Slovakia	Bystricka, 2003[43]	--	FSWs attending a health center in Bratislava	Health center	18	50.0	18	5.6	--	--	--
Turkey	Gul, 2008[44]	2005	Brothel-based FSWs in Ankara	Brothel	130	80.0	130	0.0[b]	--	70.0	0.0
EMRO (n=4)											
Pakistan	Hawkes, 2009[45]	2007	FSWs in Rawalpindi	Community	426	8.0	426	0.0[b]	--	38.0[c]	3.0[e]
Pakistan	Hawkes, 2009[45]	2007	FSWs in Abbottabad	Community	107	4.7	107	0.0[b]	--	38.0[c]	3.0[e]
Tunisia	Znazen, 2010[46]	2007	FSWs engaged in sex work for <5years	Health center	63	47.6	63	0.0[b]	--	73.0	--
Tunisia	Znazen, 2010[46]	2007	FSWs engaged in sex work for ≥5years	Health center	120	59.2	125	0.0[b]	--	54.4	--
SEARO (n=71)											
Bangladesh	Qutub, 2003[47]	--	Brothel-based FSWs in Bangladesh	Brothel	463	94.6	463	0.0[b]	--	0.0	--
East Timor	Pisani, 2006[48]	2003	East Timorese & Indonesian FSWs in Dili	Community	98	60.2	100	3.0	--	36.0	--
India	Mishra, 2009[49]	2004	FSWs in Mysore, Karnataka	Community	393	64.4	393	25.2	--	--	--
India	National Rep., 2011[50]	2006	FSWs in Chittoor, Round 1	Community	40	80.0	401	8.0	--	85.0	--
India	National Rep., 2011[50]	2009	FSWs in Chittoor, Round 2	Community	40	52.5	398	10.5	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in East Godavari, Round 1	Community	42	81.4	422	26.3	--	93.0	--
India	National Rep., 2011[50]	2009	FSWs in East Godavari, Round 2	Community	40	78.0	401	23.3	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Guntur, Round 1	Community	41	82.9	405	21.3	--	95.0	--
India	National Rep., 2011[50]	2009	FSWs in Guntur, Round 2	Community	41	70.7	405	8.4	--	100.0	--
India	National Rep., 2011[50]	2006	FSWs in Hyderabad, Round 1	Community	40	77.5	399	14.3	--	95.0	--
India	National Rep., 2011[50]	2009	FSWs in Hyderabad, Round 2	Community	40	87.8	401	9.6	--	96.0	--
India	National Rep., 2011[50]	2005	FSWs in Karimnagar, Round 1	Community	41	65.1	412	21.1	--	91.0	--
India	National Rep., 2011[50]	2009	FSWs in Karimnagar, Round 2	Community	40	65.9	402	6.5	--	95.0	--
India	National Rep., 2011[50]	2006	FSWs in Prakasham, Round 1	Community	40	53.7	404	11.1	--	81.0	--
India	National Rep., 2011[50]	2009	FSWs in Prakasham, Round 2	Community	41	61.0	408	13.4	--	96.0	--
India	National Rep., 2011[50]	2006	FSWs in Visakhapatnam, Round 1	Community	41	57.1	411	14.2	--	94.0	--
India	National Rep., 2011[50]	2009	FSWs in Visakhapatnam, Round 2	Community	41	58.5	409	18.2	--	97.0	--
India	National Rep., 2011[50]	2006	FSWs in Warangal, Round 1	Community	42	61.9	417	10.8	--	89.0	--

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
India	National Rep., 2011[50]	2009	FSWs in Warangal, Round 2	Community	40	39.0	401	15.0	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Bangalore, Round 1	Community	67	68.6	673	12.7	--	92.0	--
India	National Rep., 2011[50]	2005	FSWs in Belgaum, Round 1	Community	36	83.8	360	33.9	--	96.0	--
India	National Rep., 2011[50]	2005	FSWs in Bellary, Round 1	Community	42	70.8	420	15.7	--	83.0	--
India	National Rep., 2011[50]	2005	FSWs in Shimoga, Round 1	Community	39	59.7	390	9.7	--	75.0	--
India	National Rep., 2011[50]	2006	FSWs in Kolhapur, Round 1	Community	12	83.3	115	33.0	--	88.0	--
India	National Rep., 2011[50]	2009	FSWs in Kolhapur, Round 2	Community	19	75.0	190	27.4	--	100.0	--
India	National Rep., 2011[50]	2006	FSWs bar girls in Mumbai, Round 1	Community	34	50.0	338	5.9	--	93.0	--
India	National Rep., 2011[50]	2009	FSWs bar girls in Mumbai, Round 2	Community	41	63.0	405	3.1	--	96.3	--
India	National Rep., 2011[50]	2006	Brothel-based FSWs in Mumbai, Round 1	Community	41	87.8	407	28.1	--	97.0	--
India	National Rep., 2011[50]	2009	Brothel-based FSWs in Mumbai, Round 2	Community	40	86.6	395	34.9	--	100.0	--
India	National Rep., 2011[50]	2006	Street-based FSWs in Mumbai, Round 1	Community	39	70.2	394	19.2	--	97.0	--
India	National Rep., 2011[50]	2009	Street-based FSWs in Mumbai, Round 2	Community	39	85.0	385	32.3	--	100.0	--
India	National Rep., 2011[50]	2006	FSWs in Parbhani, Round 1	Community	37	52.2	367	16.1	--	93.0	--
India	National Rep., 2011[50]	2009	FSWs in Parbhani, Round 2	Community	30	80.6	303	14.9	--	99.0	--
India	National Rep., 2011[50]	2006	Brothel-based FSWs in Pune, Round 1	Community	40	80.9	404	38.7	--	98.0	--
India	National Rep., 2011[50]	2009	Brothel-based FSWs in Pune, Round 2	Community	40	65.8	403	20.3	--	100.0	--
India	National Rep., 2011[50]	2006	Non-brothel-based FSWs in Pune, Round 1	Community	26	96.2	257	37.0	--	97.0	--
India	National Rep., 2011[50]	2009	Non-brothel-based FSWs in Pune, Round 2	Community	27	88.9	266	21.8	--	98.0	--
India	National Rep., 2011[50]	2006	Brothel-based FSWs in Thane, Round 1	Community	40	35.9	401	18.6	--	99.0	--
India	National Rep., 2011[50]	2009	Brothel-based FSWs in Thane, Round 2	Community	38	81.5	384	33.1	--	100.0	--
India	National Rep., 2011[50]	2006	Street-based FSWs in Thane, Round 1	Community	39	58.3	394	7.0	--	98.0	--
India	National Rep., 2011[50]	2009	Street-based FSWs in Thane, Round 2	Community	40	74.4	395	11.8	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Yevatmal, Round 1	Community	15	100.0	153	37.3	--	96.0	--
India	National Rep., 2011[50]	2009	FSWs in Yevatmal, Round 2	Community	16	87.5	157	26.8	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Chennai, Round 1	Community	41	31.7	410	2.2	--	96.0	--
India	National Rep., 2011[50]	2009	FSWs in Chennai, Round 2	Community	40	37.5	397	2.4	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Coimbatore, Round 1	Community	41	56.1	410	6.3	--	93.0	--
India	National Rep., 2011[50]	2009	FSWs in Coimbatore, Round 2	Community	40	58.9	400	6.3	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Dharmapuri, Round 1	Community	41	75.6	408	12.4	--	95.0	--
India	National Rep., 2011[50]	2009	FSWs in Dharmapuri , Round 2	Community	41	48.2	406	8.8	--	91.0	--
India	National Rep., 2011[50]	2006	FSWs in Madurai, Round 1	Community	40	48.8	402	4.3	--	84.0	--
India	National Rep., 2011[50]	2009	FSWs in Madurai, Round 2	Community	40	58.2	396	8.3	--	100.0	--
India	National Rep., 2011[50]	2006	FSWs in Salem, Round 1	Community	40	72.5	402	12.5	--	93.0	--
India	National Rep., 2011[50]	2009	FSWs in Salem, Round 2	Community	41	53.6	407	6.7	--	99.0	--
India	National Rep., 2011[50]	2006	FSWs in Dimapur, Round 1	Community	43	52.6	426	11.6	--	36.0	--
India	National Rep., 2011[50]	2009	FSWs in Dimapur, Round 2	Community	42	44.7	417	11.4	--	72.0	--
India	Sarna, 2013[51]	2010	FSWs in Nellore	Community	529	60.7	529	5.3	--	47.2	--
India	Shahmanesh, 2009[52]	2004-05	FSWs in Goa	Community	326	57.2	326	25.7	--	74.4	--
India	Uma, 2005[53]	2004	FSWs bacterial vaginosis positive	Community	260	73.5	260	5.3	--	--	--
India	Uma, 2005[53]	2004	FSWs bacterial vaginosis intermediate	Community	92	67.4	92	11.0	--	--	--
India	Uma, 2005[53]	2004	FSWs bacterial vaginosis negative	Community	230	56.1	230	1.3	--	--	--
Indonesia	Davies, 2007[54]	1999-00	FSWs in Kupang	STI clinic	176	86.9	176	0.0[b]	--	4.0	--
Thailand	Limpakarnjanarat, 1999[55]	1991-94	Brothel-based FSWs at Chiang province	STI clinic	280	78.2	280	47.1	--	32.8[c]	--
Thailand	Limpakarnjanarat, 1999[55]	1991-94	Non-brothel-based FSWs at Chiang province	STI clinic	220	72.3	220	12.7	--	32.8[c]	--

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
Vietnam	Vu Thuong, 2007[56]	2002	FSWs in Lai Chau	Community	100	5.0	100	2.0	--	45.3[c]	3.9[de]
Vietnam	Vu Thuong, 2007[56]	2002	FSWs in Quang Tri	Community	101	20.8	101	1.0	--	45.3[c]	3.9[de]
Vietnam	Vu Thuong, 2007[56]	2002	FSWs in Dong Thap	Community	149	32.2	149	4.7	--	45.3[c]	3.9[de]
Vietnam	Vu Thuong, 2007[56]	2002	FSWs in An Giang	Community	300	33.3	300	7.0	--	45.3[c]	3.9[de]
Vietnam	Vu Thuong, 2007[56]	2002	FSWs in Kien Giang	Community	253	30.0	253	4.0	--	45.3[c]	3.9[de]
Vietnam	Vu Thuong, 2007[56]	2004	FSWs in Lai Chau	Community	99	20.2	99	2.0	--	52.8[c]	3.1[d]
Vietnam	Vu Thuong, 2007[56]	2004	FSWs in Quang Tri	Community	100	33.0	100	1.0	--	52.8[c]	2.0[d]
Vietnam	Vu Thuong, 2007[56]	2004	FSWs in Dong Thap	Community	199	25.1	199	2.6	--	52.8[c]	0.0[d]
Vietnam	Vu Thuong, 2007[56]	2004	FSWs in An Giang	Community	285	23.5	285	5.3	--	52.8[c]	2.1[d]
Vietnam	Vu Thuong, 2007[56]	2004	FSWs in Kien Giang	Community	298	24.2	298	4.1	--	52.8[c]	2.7[d]
WPRO (n=49)											
Cambodia	Saphonn, 2006[57]	2000-02	FSWs first-time STI clinic attendees	STI clinic	938	38.8	938	27.4	--	--	--
China	Chen, 1998[58]	1993-94	FSWs in massage parlors in Taiwan	Mass. parlors	206	2.9	287	0.0[b]	--	94.0[c]	--
China	Chen, 1998[58]	1994-96	FSWs in massage parlors in Taiwan	Mass. parlors	81	1.2	242	0.0[b]	--	94.0[c]	--
China	Chen, 1998[58]	1993-94	FSWs in karaoke bars in Taiwan	Karaoke bars	557	7.5	557	0.4	--	--	--
China	Chen, 1998[58]	1993-94	Brothel-based FSWs in Taiwan	Brothel	159	1.3	159	0.0[b]	--	45.2[c]	--
China	Chen, 1998[58]	1994-96	Brothel-based FSWs in Taiwan	Brothel	142	4.9	156	0.0[b]	--	45.2[c]	--
China	Chen, 2005[59]	1999-00	FSWs aged 15-19 years in Kunming	STI clinic	70	4.3	70	84.3	--	45.2[c]	--
China	Chen, 2005[59]	1999-00	FSWs aged 20-24 years in Kunming	STI clinic	204	9.8	204	86.8	--	45.2[c]	--
China	Chen, 2005[59]	1999-00	FSWs aged 25-29 years in Kunming	STI clinic	144	13.2	144	79.9	--	45.2[c]	--
China	Chen, 2005[59]	1999-00	FSWs aged 30-34 years in Kunming	STI clinic	62	9.7	62	85.5	--	45.2[c]	--
China	Chen, 2005[59]	1999-00	FSWs aged 35-39 years in Kunming	STI clinic	25	16.0	25	88.0	--	45.2[c]	--
China	Chen, 2013[60]	2009	FSWs in Wuzhou and Hezhou in Guangxi	Community	2453	54.9	2,453	0.7	--	79.2	--
China	Fu, 2014[61]	--	Low fee FSWs in Guangdong	Community	196	57.1	196	1.0	--	21.1	--
China	Fu, 2014[61]	--	Medium fee FSWs in Guangdong	Community	379	16.9	379	0.0[b]	--	9.6	--
China	Han, 2016[62]	2012	Low fee FSWs	Community	417	31.7	417	0.7	--	42.3	4.8
China	Han, 2016[62]	2012	Medium fee FSWs	Community	1,070	26.4	1,070	0.3	--	55.5	1.3
China	Jing, 2017[63]	1994	Vietnamese FSWs in Hekou (June 2014)	Community	219	57.1	219	3.2	--	--	--
China	Jing, 2017[63]	1994	Vietnamese FSWs in Hekou (Dec 2014)	Community	245	58.4	245	2.0	--	--	--
China	Jing, 2017[63]	1995	Vietnamese FSWs in Hekou (May 2015)	Community	265	38.1	265	1.9	--	--	--
China	Jing, 2017[63]	1995	Vietnamese FSWs in Hekou (Nov 2015)	Community	329	51.1	329	1.8	--	--	--
China	Li, 2014[64]	2013	FSWs from multiple venues	Community	460	43.0	460	0.2	--	--	--
China	Luo, 2015[65]	2012	FSWs not using vaginal douching in Yunnan	Community	134	56.0	134	5.2	--	71.9	6.7
China	Luo, 2015[65]	2012	FSWs using vaginal douching in Yunnan	Community	699	70.8	699	11.0	--	78.9	9.6
China	Ngo, 2008[66]	2004	FSWs in Kunming	STI clinic	310	45.2	310	3.9	--	11.6	--
China	Remis, 2010[67]	2009	FSWs in Shanghai	Community	750	3.1	750	0.1	--	--	--
China	Wang, 2006[68]	2005	FSWs in a mining township	Community	327	63.7	237	20.7	--	--	--
China	Wang, 2012[69]	2006	FSWs in Kaiyuan (Fall 2006)	Community	741	67.3	741	10.2	--	--	--
China	Wang, 2012[69]	2006	FSWs from Kaiyuan (Spring 2006)	Community	748	67.9	748	11.9	--	--	--
China	Wang, 2012[69]	2007	FSWs from Kaiyuan (Fall 2007)	Community	705	70.8	705	13.1	--	--	--
China	Wang, 2012[69]	2007	FSWs from Kaiyuan (Spring 2007)	Community	440	62.7	440	11.4	--	--	--
China	Wang, 2012[69]	2008	FSWs from Kaiyuan (Fall 2008)	Community	587	68.1	587	11.2	--	--	--
China	Wang, 2012[69]	2008	FSWs from Kaiyuan (Spring 2008)	Community	558	71.2	558	12.2	--	--	--
China	Wang, 2012[69]	2009	FSWs from Kaiyuan (Fall 2009)	Community	548	71.3	548	16.2	--	--	--
China	Wang, 2012[69]	2009	FSWs from Kaiyuan (Spring 2009)	Community	548	70.4	548	15.5	--	--	--

Country	Short citation	Data collect. year(s)	Population characteristics	Site	Tested HSV-2 (n)	HSV-2 prev (%)	Tested HIV (n)	HIV prev (%)	ART cov (%)	Consistent condom use[a] (%)	Prop who inject drugs (%)
China	Wang, 2015[70]	2009	Vietnamese FSWs in China	Community	233	60.9	233	7.7	--	90.1	--
China	Wang, 2015[70]	2009	Chinese FSWs	Community	112	52.7	112	0.9	--	100.0	--
China	Wei, 2004[71]	1999	Sex- hospitality girls in Wuhan	Community	101	29.7	147	0.0[b]	--	51.7	8.2
China	Xu, 2008[72]	2006	FSWs from entertainment venues	Community	96	70.8	96	8.3	--	54.2	7.3
China	Xu, 2012[73]	2007	FSWs drug users (Mar-Jul 2007)	Community	150	86.7	150	43.3	--	84.7	--
China	Xu, 2012[73]	2007	FSWs non-drug users (Mar-Jul 2007)	Community	555	66.8	555	4.9	--	86.7	--
China	Xu, 2013[74]	2006-07	FSWs drug users (Mar 2006-Apr 2007)	Community	261	86.6	261	39.1	--	84.7	7.4[e]
China	Xu, 2013[74]	2006-07	FSWs non-drug users (Mar 2006-Apr 2007)	Community	1,381	66.8	1,381	4.8	--	86.7	7.4[e]
China	Yang, 2011[75]	2008	FSWs in entertainment establishments	Community	411	45.5	411	0.0[b]	--	78.7	--
China	Yang, 2011[75]	2009	FSWs in entertainment establishments	Community	411	50.1	411	0.0[b]	--	82.0	--
China	Yao, 2012[76]	2007	FSWs drug users (Sep-Oct 2007)	Community	94	92.6	94	38.3	--	--	81.9[f]
China	Yao, 2012[76]	2007	FSWs non-drug users (Sep-Oct 2007)	Community	305	59.7	305	4.0	--	--	--
China	Zhang, 2014[77]	2011	FSWs aged 18-25 years in Shanghai	Community	336	46.4	336	0.0[b]	--	49.3[c]	--
China	Zhang, 2014[77]	2011	FSWs aged 26-35 years in Shanghai	Community	196	59.2	196	0.0[b]	--	49.3[c]	--
China	Zhang, 2014[77]	2011	FSWs aged ≥36 years in Shanghai	Community	68	60.3	68	0.0[b]	--	49.3[c]	--

AFRO, African Region; AMRO, Region of the Americas; ART, antiretroviral therapy; Collect, collection; Cov, coverage; Domin Rep, Dominican Republic; EMRO, Eastern Mediterranean Region; EURO, European Region; FSWs, female sex workers; HIV, human immunodeficiency virus; HSV-2, herpes simplex virus type 2; Mass, massage; National Rep, National Report; Prev, prevalence; Prop, proportion; RDS, respondent-driven sampling; Reg, registered; SEARO, South-East Asia Region; STI, sexually transmitted infection; USA, United States of America; WPRO, Western Pacific Region.

[a]Consistent condom use measures were based on self-reported condom use at last sex with client, or alternatively on self-reported “consistent/regular” condom use, or condom use “all the time” during commercial sex acts.

[b]Studies reporting zero HIV prevalence were excluded from subsequent analysis.

[c]Strata were considered to have the same level of consistent condom use as the overall sample.

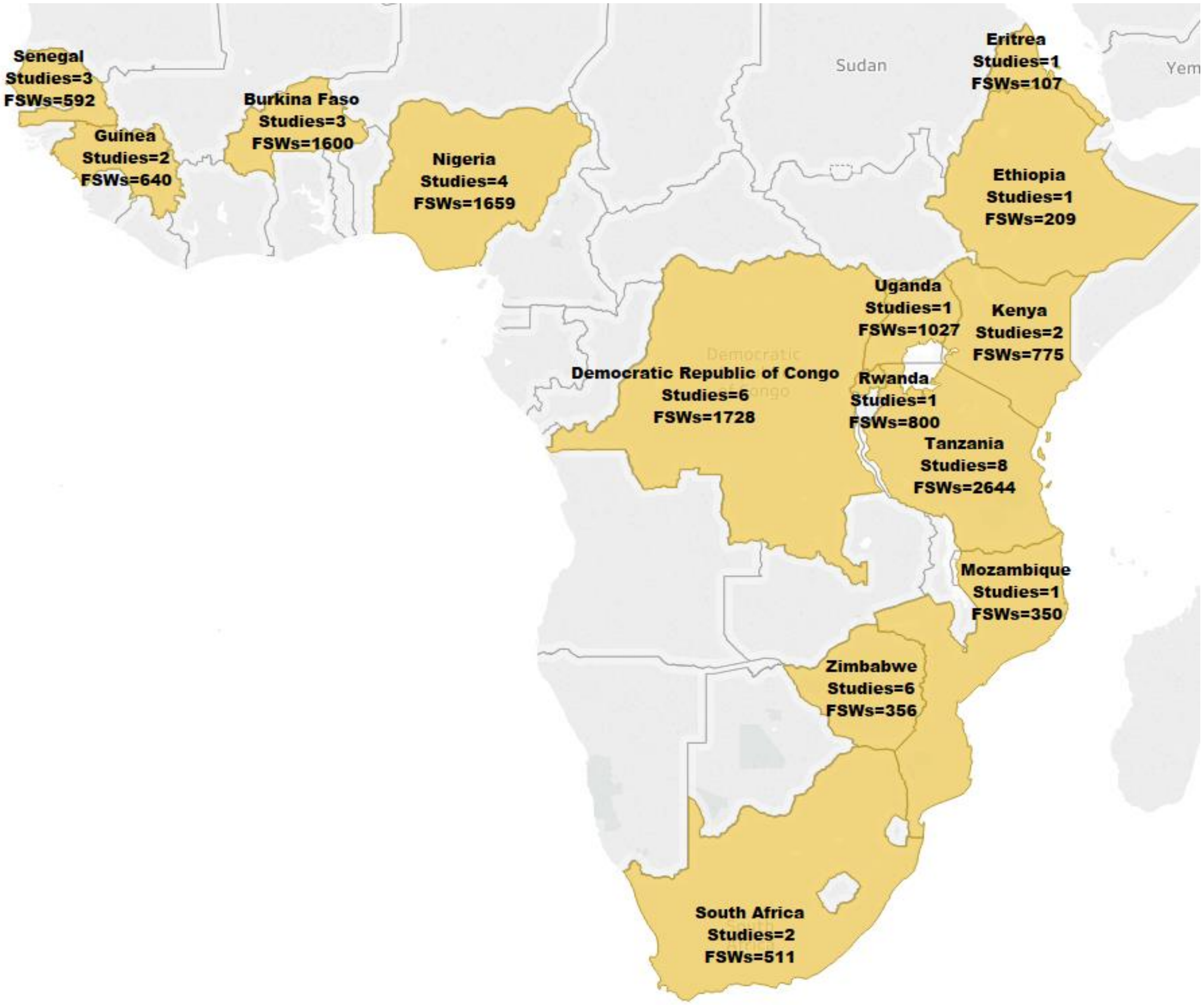
[d]Proportion of FSWs who reported ever injecting drugs.

[e]Strata were considered to have the same level of injecting drug use as the overall sample.

[f]Proportion of drug-using FSWs who reported injecting drug use.

Figure S1. Regional maps illustrating countries' data contribution in terms of the total number of studies and the total number of FSWs participating in those studies. Map showing data contribution from A) Africa, B) Americas, and C) Other world regions. Maps were created using Tableau Desktop v.10.1[78].

A) Africa



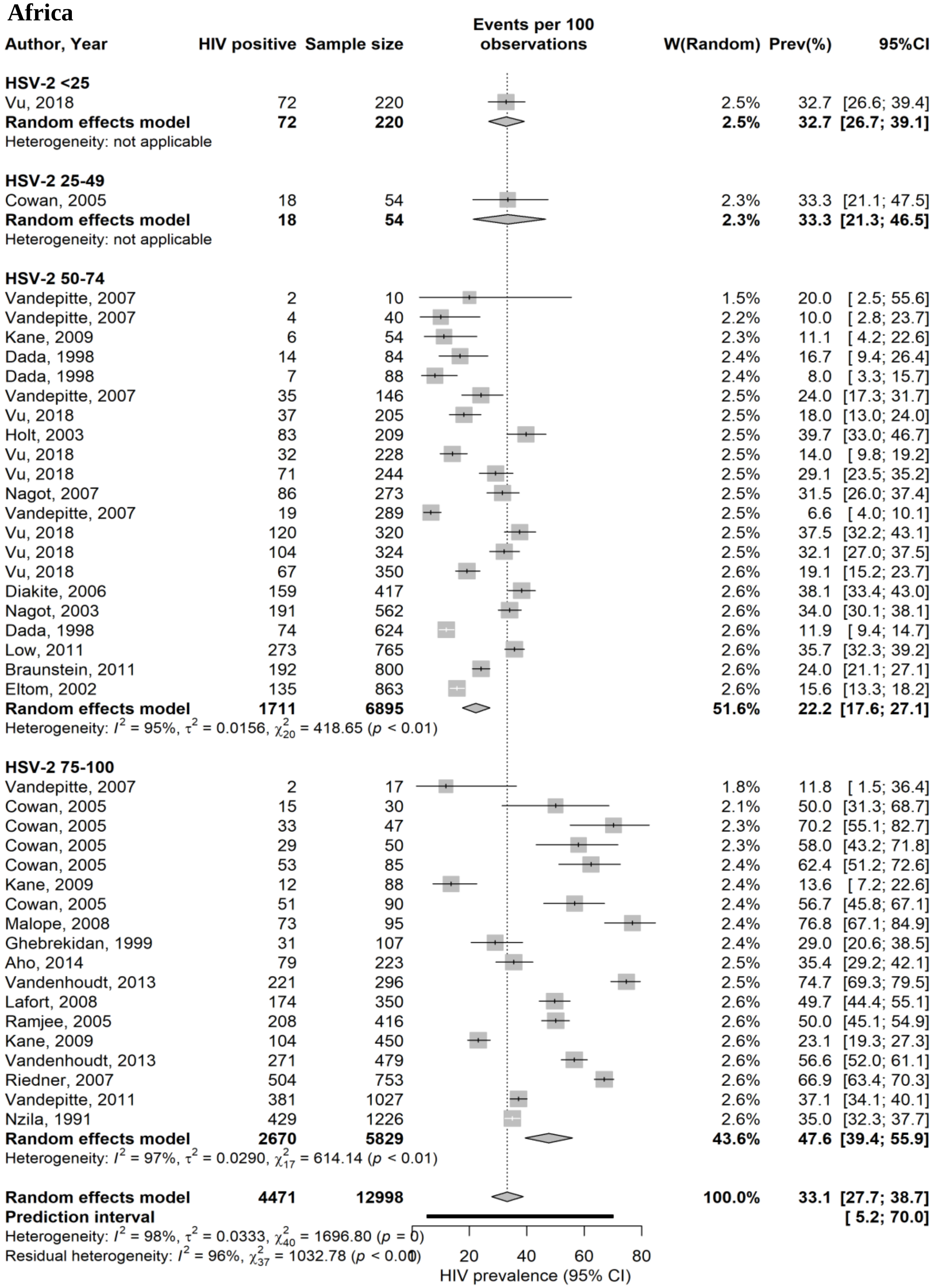
B) Americas

USA
Studies=4
FSWs=813
Mexico
Studies=4
FSWs=1042
Belize
Studies=1
FSWs=220
Honduras
Studies=2
FSWs=1304
Dominican Republic
Studies=1
FSWs=482
Guatemala
Studies=1
FSWs=511
Nicaragua
Studies=3
FSWs=1284
El Salvador
Studies=2
FSWs=1147
Panama
Studies=4
FSWs=1118
Peru
Studies=19
FSWs=4116

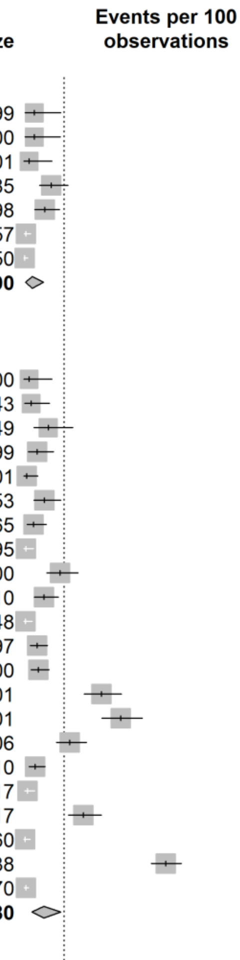
C) Other world regions

Figure S2. Forest plot showing the results of meta-analyses on studies reporting HIV prevalence among female sex workers stratified by HSV-2 prevalence level in A) Africa, B) other world regions, and C) globally. Forest plots were generated using R v.3.4.2[79].

A) Africa

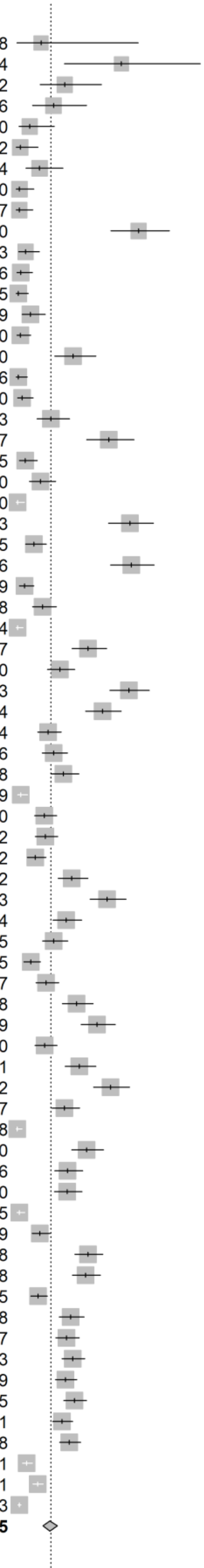


A) Other world regions



Author, Year	HIV positive	Sample size	W(Random)	Prev(%)	95%CI
HSV-2 <25					
Vu Thuong, 2007	2	99	0.6%	2.0	[0.2; 7.1]
Vu Thuong, 2007	2	100	0.6%	2.0	[0.2; 7.0]
Vu Thuong, 2007	1	101	0.6%	1.0	[0.0; 5.4]
Vu Thuong, 2007	15	285	0.7%	5.3	[3.0; 8.5]
Vu Thuong, 2007	12	298	0.7%	4.0	[2.1; 6.9]
Chen, 1998	2	557	0.7%	0.4	[0.0; 1.3]
Remis, 2010	1	750	0.7%	0.1	[0.0; 0.7]
Random effects model	**35**	**2190**	**4.5%**	**1.6**	**[0.3; 3.8]**
Heterogeneity: $I^2 = 87\%$, $\tau^2 = 0.0061$, $\chi^2_6 = 47.89$ ($p < 0.01$)					
HSV-2 25-49					
Vu Thuong, 2007	1	100	0.6%	1.0	[0.0; 5.4]
Carcamo, 2012	2	143	0.6%	1.4	[0.2; 5.0]
Vu Thuong, 2007	7	149	0.6%	4.7	[1.9; 9.4]
Vu Thuong, 2007	5	199	0.7%	2.5	[0.8; 5.8]
Carcamo, 2012	1	201	0.7%	0.5	[0.0; 2.7]
Vu Thuong, 2007	10	253	0.7%	4.0	[1.9; 7.1]
Jing, 2017	5	265	0.7%	1.9	[0.6; 4.3]
Caceres, 2006	1	295	0.7%	0.3	[0.0; 1.9]
Vu Thuong, 2007	21	300	0.7%	7.0	[4.4; 10.5]
Ngo, 2008	12	310	0.7%	3.9	[2.0; 6.7]
Carcamo, 2012	1	348	0.7%	0.3	[0.0; 1.6]
National Summary Report-India, 2011	10	397	0.7%	2.5	[1.2; 4.6]
Khromova, 2002	11	400	0.7%	2.8	[1.4; 4.9]
National Summary Report-India, 2011	60	401	0.7%	15.0	[11.6; 18.8]
National Summary Report-India, 2011	75	401	0.7%	18.7	[15.0; 22.9]
National Summary Report-India, 2011	36	406	0.7%	8.9	[6.3; 12.1]
National Summary Report-India, 2011	9	410	0.7%	2.2	[1.0; 4.1]
Han, 2016	3	417	0.7%	0.7	[0.1; 2.1]
National Summary Report-India, 2011	48	417	0.7%	11.5	[8.6; 15.0]
Li, 2014	1	460	0.7%	0.2	[0.0; 1.2]
Saphonn, 2006	257	938	0.7%	27.4	[24.6; 30.4]
Han, 2016	4	1070	0.7%	0.4	[0.1; 1.0]
Random effects model	**580**	**8280**	**14.5%**	**3.9**	**[1.6; 7.1]**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0275$, $\chi^2_{21} = 877.1$ ($p < 0.01$)					

HSV-2 50-74



Bystricka, 2003	1	18	0.5%	5.6 [0.1; 27.3]
Jones, 1998	8	34	0.5%	23.5 [10.7; 41.2]
Uma, 2005	10	92	0.6%	10.9 [5.3; 19.1]
Xu, 2008	8	96	0.6%	8.3 [3.7; 15.8]
Pisani, 2006	3	100	0.6%	3.0 [0.6; 8.5]
Wang, 2015	1	112	0.6%	0.9 [0.0; 4.9]
Luo, 2015	7	134	0.6%	5.2 [2.1; 10.5]
Carcamo, 2012	1	140	0.6%	0.7 [0.0; 3.9]
Carcamo, 2012	1	147	0.6%	0.7 [0.0; 3.7]
National Summary Report-India, 2011	52	190	0.6%	27.4 [21.2; 34.3]
Carcamo, 2012	4	193	0.6%	2.1 [0.6; 5.2]
Fu, 2014	2	196	0.7%	1.0 [0.1; 3.6]
Carcamo, 2012	1	205	0.7%	0.5 [0.0; 2.7]
Jing, 2017	7	219	0.7%	3.2 [1.3; 6.5]
Alvarez Rodriguez, 2013	2	220	0.7%	0.9 [0.1; 3.2]
Limpakarnjanarat, 1999	28	220	0.7%	12.7 [8.6; 17.9]
Cohan, 2005	1	226	0.7%	0.4 [0.0; 2.4]
Uma, 2005	3	230	0.7%	1.3 [0.3; 3.8]
Wang, 2015	18	233	0.7%	7.7 [4.6; 11.9]
Wang, 2006	49	237	0.7%	20.7 [15.7; 26.4]
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Uma, 2005	14	260	0.7%	5.4 [3.0; 8.9]
Linhart, 2008	1	300	0.7%	0.3 [0.0; 1.8]
Jones, 1998	77	303	0.7%	25.4 [20.6; 30.7]
Yao, 2012	12	305	0.7%	3.9 [2.0; 6.8]
Shahmanesh, 2009	84	326	0.7%	25.8 [21.1; 30.9]
Jing, 2017	6	329	0.7%	1.8 [0.7; 3.9]
National Summary Report-India, 2011	20	338	0.7%	5.9 [3.7; 9.0]
Uribe-Salas, 1999	1	364	0.7%	0.3 [0.0; 1.5]
National Summary Report-India, 2011	59	367	0.7%	16.1 [12.5; 20.2]
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National Summary Report-India, 2011	25	400	0.7%	6.2 [4.1; 9.1]
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National Summary Report-India, 2011	74	409	0.7%	18.1 [14.5; 22.2]
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Luo, 2015	77	699	0.7%	11.0 [8.8; 13.6]
Wang, 2012	92	705	0.7%	13.0 [10.7; 15.8]
Wang, 2012	76	741	0.7%	10.3 [8.2; 12.7]
Wang, 2012	89	748	0.7%	11.9 [9.7; 14.4]
Morales-Miranda	19	811	0.7%	2.3 [1.4; 3.6]
Xu, 2013	66	1381	0.7%	4.8 [3.7; 6.0]
Chen, 2013	16	2453	0.7%	0.7 [0.4; 1.1]
Random effects model	**2521**	**28935**	**46.5%**	**7.5 [5.9; 9.2]**

Heterogeneity: $I^2 = 96\%$, $\tau^2 = 0.0166$, $\chi^2_{70} = 1954.24$ ($p = 0$)

HSV-2 75-100

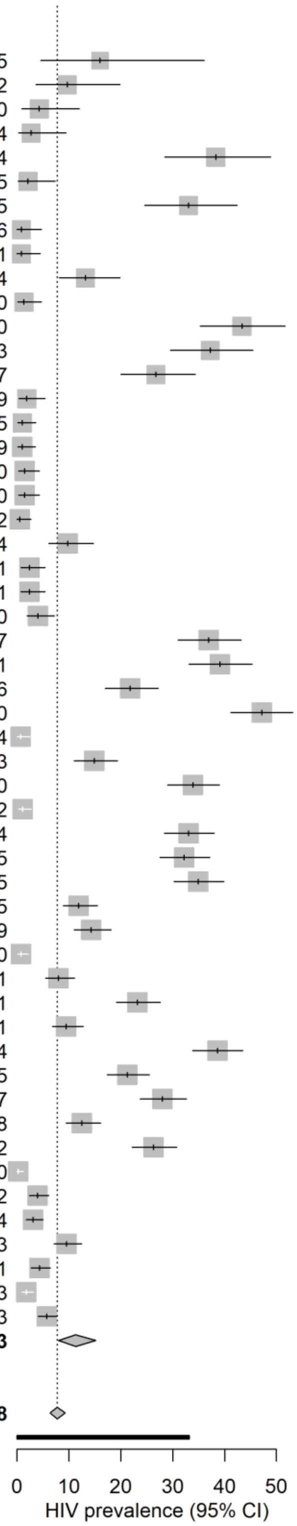
Study	Events	Total	Weight	Prevalence [95% CI]
Chen, 2005	4	25	0.5%	16.0 [4.5; 36.1]
Chen, 2005	6	62	0.6%	9.7 [3.6; 19.9]
Chen, 2005	3	70	0.6%	4.3 [0.9; 12.0]
Carcamo, 2012	2	74	0.6%	2.7 [0.3; 9.4]
Yao, 2012	36	94	0.6%	38.3 [28.5; 48.9]
Hakre, 2013	2	95	0.6%	2.1 [0.3; 7.4]
National Summary Report-India, 2011	38	115	0.6%	33.0 [24.6; 42.4]
Sanchez, 1998	1	116	0.6%	0.9 [0.0; 4.7]
Uribe-Salas, 2003	1	121	0.6%	0.8 [0.0; 4.5]
Chen, 2005	19	144	0.6%	13.2 [8.1; 19.8]
Hakre, 2013	2	150	0.6%	1.3 [0.2; 4.7]
Xu, 2012	65	150	0.6%	43.3 [35.3; 51.7]
National Summary Report-India, 2011	57	153	0.6%	37.3 [29.6; 45.4]
National Summary Report-India, 2011	42	157	0.6%	26.8 [20.0; 34.4]
Carcamo, 2012	3	159	0.6%	1.9 [0.4; 5.4]
Uribe-Salas, 2003	2	195	0.6%	1.0 [0.1; 3.7]
Carcamo, 2012	2	199	0.7%	1.0 [0.1; 3.6]
Carcamo, 2012	3	200	0.7%	1.5 [0.3; 4.3]
Carcamo, 2012	3	200	0.7%	1.5 [0.3; 4.3]
Carcamo, 2012	1	202	0.7%	0.5 [0.0; 2.7]
Chen, 2005	20	204	0.7%	9.8 [6.1; 14.7]
Delgado, 2011	5	211	0.7%	2.4 [0.8; 5.4]
Perla, 2012	5	211	0.7%	2.4 [0.8; 5.4]
Lutnick, 2008	10	250	0.7%	4.0 [1.9; 7.2]
National Summary Report-India, 2011	95	257	0.7%	37.0 [31.0; 43.2]
Xu, 2013	102	261	0.7%	39.1 [33.1; 45.3]
National Summary Report-India, 2011	58	266	0.7%	21.8 [17.0; 27.3]
Limpakarnjanarat, 1999	132	280	0.7%	47.1 [41.2; 53.2]
Sanchez, 1998	2	284	0.7%	0.7 [0.1; 2.5]
National Summary Report-India, 2011	45	303	0.7%	14.9 [11.0; 19.4]
National Summary Report-India, 2011	122	360	0.7%	33.9 [29.0; 39.0]
Uribe-Salas, 1999	4	362	0.7%	1.1 [0.3; 2.8]
National Summary Report-India, 2011	127	384	0.7%	33.1 [28.4; 38.0]
National Summary Report-India, 2011	124	385	0.7%	32.2 [27.6; 37.1]
National Summary Report-India, 2011	138	395	0.7%	34.9 [30.2; 39.9]
National Summary Report-India, 2011	47	395	0.7%	11.9 [8.9; 15.5]
National Summary Report-India, 2011	57	399	0.7%	14.3 [11.0; 18.1]
Gotuzzo, 1994	3	400	0.7%	0.8 [0.2; 2.2]
National Summary Report-India, 2011	32	401	0.7%	8.0 [5.5; 11.1]
National Summary Report-India, 2011	93	401	0.7%	23.2 [19.1; 27.6]
National Summary Report-India, 2011	38	401	0.7%	9.5 [6.8; 12.8]
National Summary Report-India, 2011	156	404	0.7%	38.6 [33.8; 43.6]
National Summary Report-India, 2011	86	405	0.7%	21.2 [17.4; 25.5]
National Summary Report-India, 2011	114	407	0.7%	28.0 [23.7; 32.6]
National Summary Report-India, 2011	51	408	0.7%	12.5 [9.5; 16.1]
National Summary Report-India, 2011	111	422	0.7%	26.3 [22.2; 30.8]
Soto, 2007	1	460	0.7%	0.2 [0.0; 1.2]
Koenig, 2007	19	482	0.7%	3.9 [2.4; 6.1]
Soto, 2007	15	484	0.7%	3.1 [1.7; 5.1]
Soto, 2007	47	493	0.7%	9.5 [7.1; 12.5]
Soto, 2007	22	511	0.7%	4.3 [2.7; 6.4]
Delgado, 2011	11	613	0.7%	1.8 [0.9; 3.2]
Creswell, 2010	38	663	0.7%	5.7 [4.1; 7.8]
Random effects model	**2222**	**15243**	**34.4%**	**11.3 [8.0; 15.2]**

Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0429$, $\chi^2_{52} = 2606.99$ ($p = 0$)

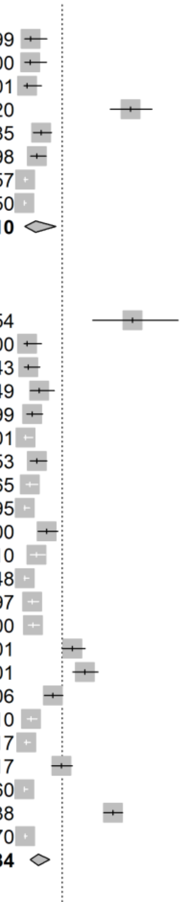
Random effects model	**5358**	**54648**	**100.0%**	**7.7 [6.4; 9.3]**
Prediction interval				**[0.0; 33.2]**

Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0276$, $\chi^2_{152} = 6130.79$ ($p = 0$)

Residual heterogeneity: $I^2 = 97\%$, $\chi^2_{149} = 5486.22$ ($p = 0$)

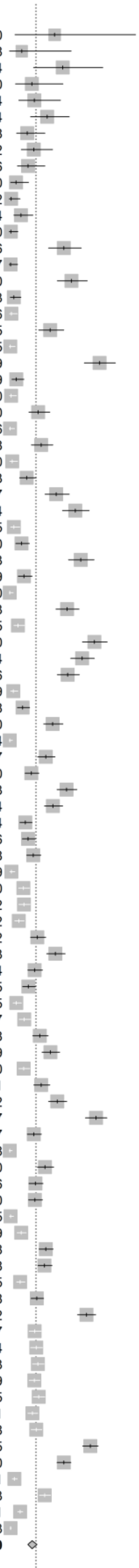


C) Global



Author, Year	HIV positive	Sample size	Events per 100 observations	W(Random)	Prev(%)	95%CI
HSV-2 <25						
Vu Thuong, 2007	2	99		0.5%	2.0	[0.2; 7.1]
Vu Thuong, 2007	2	100		0.5%	2.0	[0.2; 7.0]
Vu Thuong, 2007	1	101		0.5%	1.0	[0.0; 5.4]
Vu, 2018	72	220		0.5%	32.7	[26.6; 39.4]
Vu Thuong, 2007	15	285		0.5%	5.3	[3.0; 8.5]
Vu Thuong, 2007	12	298		0.5%	4.0	[2.1; 6.9]
Chen, 1998	2	557		0.5%	0.4	[0.0; 1.3]
Remis, 2010	1	750		0.5%	0.1	[0.0; 0.7]
Random effects model	**107**	**2410**		**4.1%**	**3.7**	**[0.3; 9.9]**
Heterogeneity: $I^2 = 97\%$, $\tau^2 = 0.0309$, $\chi^2_7 = 247.72$ ($p < 0.01$)						
HSV-2 25-49						
Cowan, 2005	18	54		0.5%	33.3	[21.1; 47.5]
Vu Thuong, 2007	1	100		0.5%	1.0	[0.0; 5.4]
Carcamo, 2012	2	143		0.5%	1.4	[0.2; 5.0]
Vu Thuong, 2007	7	149		0.5%	4.7	[1.9; 9.4]
Vu Thuong, 2007	5	199		0.5%	2.5	[0.8; 5.8]
Carcamo, 2012	1	201		0.5%	0.5	[0.0; 2.7]
Vu Thuong, 2007	10	253		0.5%	4.0	[1.9; 7.1]
Jing, 2017	5	265		0.5%	1.9	[0.6; 4.3]
Caceres, 2006	1	295		0.5%	0.3	[0.0; 1.9]
Vu Thuong, 2007	21	300		0.5%	7.0	[4.4; 10.5]
Ngo, 2008	12	310		0.5%	3.9	[2.0; 6.7]
Carcamo, 2012	1	348		0.5%	0.3	[0.0; 1.6]
National Summary Report-India, 2011	10	397		0.5%	2.5	[1.2; 4.6]
Khromova, 2002	11	400		0.5%	2.8	[1.4; 4.9]
National Summary Report-India, 2011	60	401		0.5%	15.0	[11.6; 18.8]
National Summary Report-India, 2011	75	401		0.5%	18.7	[15.0; 22.9]
National Summary Report-India, 2011	36	406		0.5%	8.9	[6.3; 12.1]
National Summary Report-India, 2011	9	410		0.5%	2.2	[1.0; 4.1]
Han, 2016	3	417		0.5%	0.7	[0.1; 2.1]
National Summary Report-India, 2011	48	417		0.5%	11.5	[8.6; 15.0]
Li, 2014	1	460		0.5%	0.2	[0.0; 1.2]
Saphonn, 2006	257	938		0.5%	27.4	[24.6; 30.4]
Han, 2016	4	1070		0.5%	0.4	[0.1; 1.0]
Random effects model	**598**	**8334**		**11.9%**	**4.5**	**[2.0; 7.9]**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0284$, $\chi^2_{22} = 911.04$ ($p < 0.01$)						

HSV-2 50-74



Vandepitte, 2007	2	10	0.4%	20.0	[2.5; 55.6]
Bystricka, 2003	1	18	0.4%	5.6	[0.1; 27.3]
Jones, 1998	8	34	0.5%	23.5	[10.7; 41.2]
Vandepitte, 2007	4	40	0.5%	10.0	[2.8; 23.7]
Kane, 2009	6	54	0.5%	11.1	[4.2; 22.6]
Dada, 1998	14	84	0.5%	16.7	[9.4; 26.4]
Dada, 1998	7	88	0.5%	8.0	[3.3; 15.7]
Uma, 2005	10	92	0.5%	10.9	[5.3; 19.1]
Xu, 2008	8	96	0.5%	8.3	[3.7; 15.8]
Pisani, 2006	3	100	0.5%	3.0	[0.6; 8.5]
Wang, 2015	1	112	0.5%	0.9	[0.0; 4.9]
Luo, 2015	7	134	0.5%	5.2	[2.1; 10.5]
Carcamo, 2012	1	140	0.5%	0.7	[0.0; 3.9]
Vandepitte, 2007	35	146	0.5%	24.0	[17.3; 31.7]
Carcamo, 2012	1	147	0.5%	0.7	[0.0; 3.7]
National Summary Report-India, 2011	52	190	0.5%	27.4	[21.2; 34.3]
Carcamo, 2012	4	193	0.5%	2.1	[0.6; 5.2]
Fu, 2014	2	196	0.5%	1.0	[0.1; 3.6]
Vu, 2018	37	205	0.5%	18.0	[13.0; 24.0]
Carcamo, 2012	1	205	0.5%	0.5	[0.0; 2.7]
Holt, 2003	83	209	0.5%	39.7	[33.0; 46.7]
Jing, 2017	7	219	0.5%	3.2	[1.3; 6.5]
Alvarez Rodriguez, 2013	2	220	0.5%	0.9	[0.1; 3.2]
Limpakarnjanarat, 1999	28	220	0.5%	12.7	[8.6; 17.9]
Cohan, 2005	1	226	0.5%	0.4	[0.0; 2.4]
Vu, 2018	32	228	0.5%	14.0	[9.8; 19.2]
Uma, 2005	3	230	0.5%	1.3	[0.3; 3.8]
Wang, 2015	18	233	0.5%	7.7	[4.6; 11.9]
Wang, 2006	49	237	0.5%	20.7	[15.7; 26.4]
Vu, 2018	71	244	0.5%	29.1	[23.5; 35.2]
Jing, 2017	5	245	0.5%	2.0	[0.7; 4.7]
Uma, 2005	14	260	0.5%	5.4	[3.0; 8.9]
Nagot, 2007	86	273	0.5%	31.5	[26.0; 37.4]
Vandepitte, 2007	19	289	0.5%	6.6	[4.0; 10.1]
Linhart, 2008	1	300	0.5%	0.3	[0.0; 1.8]
Jones, 1998	77	303	0.5%	25.4	[20.6; 30.7]
Yao, 2012	12	305	0.5%	3.9	[2.0; 6.8]
Vu, 2018	120	320	0.5%	37.5	[32.2; 43.1]
Vu, 2018	104	324	0.5%	32.1	[27.0; 37.5]
Shahmanesh, 2009	84	326	0.5%	25.8	[21.1; 30.9]
Jing, 2017	6	329	0.5%	1.8	[0.7; 3.9]
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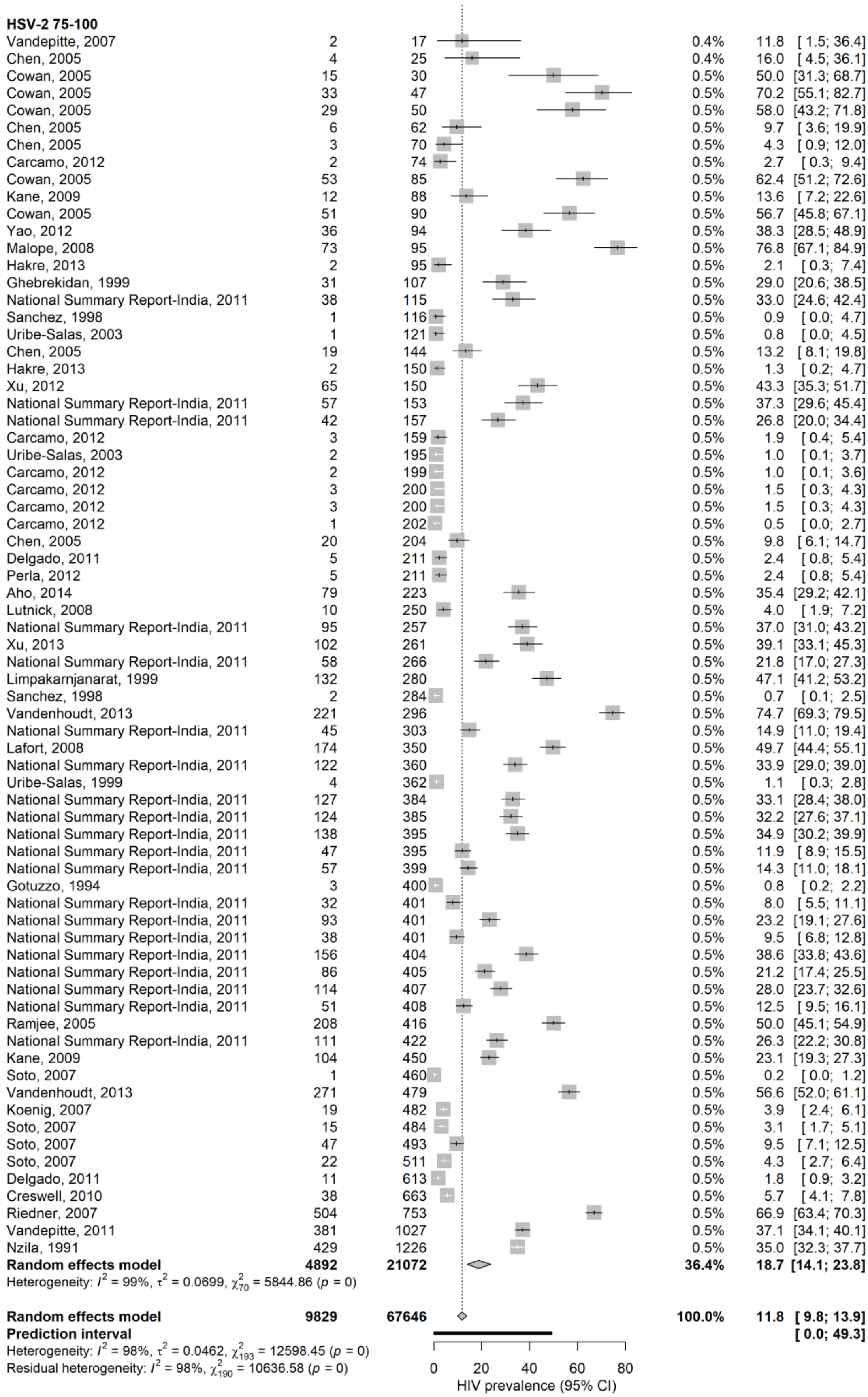
Xu, 2012	27	555	0.5%	4.9	[3.2; 7.0]
Wang, 2012	68	558	0.5%	12.2	[9.6; 15.2]
Nagot, 2003	191	562	0.5%	34.0	[30.1; 38.1]
Wang, 2012	66	587	0.5%	11.2	[8.8; 14.1]
Dada, 1998	74	624	0.5%	11.9	[9.4; 14.7]
National Summary Report-India, 2011	85	673	0.5%	12.6	[10.2; 15.4]
Luo, 2015	77	699	0.5%	11.0	[8.8; 13.6]
Wang, 2012	92	705	0.5%	13.0	[10.7; 15.8]
Wang, 2012	76	741	0.5%	10.3	[8.2; 12.7]
Wang, 2012	89	748	0.5%	11.9	[9.7; 14.4]
Low, 2011	273	765	0.5%	35.7	[32.3; 39.2]
Braunstein, 2011	192	800	0.5%	24.0	[21.1; 27.1]
Morales-Miranda	19	811	0.5%	2.3	[1.4; 3.6]
Eltom, 2002	135	863	0.5%	15.6	[13.3; 18.2]
Xu, 2013	66	1381	0.5%	4.8	[3.7; 6.0]
Chen, 2013	16	2453	0.5%	0.7	[0.4; 1.1]
Random effects model	**4232**	**35830**	**47.5%**	**10.1**	**[8.2; 12.3]**

Heterogeneity: $I^2 = 97\%$, $\tau^2 = 0.0251$, $\chi^2_{91} = 3632.96$ ($p = 0$)



HSV-2 75-100
Vandepitte, 2007 2 17 0.4% 11.8 [1.5; 36.4]
Chen, 2005 4 25 0.4% 16.0 [4.5; 36.1]
Cowan, 2005 15 30 0.5% 50.0 [31.3; 68.7]
Cowan, 2005 33 47 0.5% 70.2 [55.1; 82.7]
Cowan, 2005 29 50 0.5% 58.0 [43.2; 71.8]
Chen, 2005 6 62 0.5% 9.7 [3.6; 19.9]
Chen, 2005 3 70 0.5% 4.3 [0.9; 12.0]
Carcamo, 2012 2 74 0.5% 2.7 [0.3; 9.4]
Cowan, 2005 53 85 0.5% 62.4 [51.2; 72.6]
Kane, 2009 12 88 0.5% 13.6 [7.2; 22.6]
Cowan, 2005 51 90 0.5% 56.7 [45.8; 67.1]
Yao, 2012 36 94 0.5% 38.3 [28.5; 48.9]
Malope, 2008 73 95 0.5% 76.8 [67.1; 84.9]
Hakre, 2013 2 95 0.5% 2.1 [0.3; 7.4]
Ghebrekidan, 1999 31 107 0.5% 29.0 [20.6; 38.5]
National Summary Report-India, 2011 38 115 0.5% 33.0 [24.6; 42.4]
Sanchez, 1998 1 116 0.5% 0.9 [0.0; 4.7]
Uribe-Salas, 2003 1 121 0.5% 0.8 [0.0; 4.5]
Chen, 2005 19 144 0.5% 13.2 [8.1; 19.8]
Hakre, 2013 2 150 0.5% 1.3 [0.2; 4.7]
Xu, 2012 65 150 0.5% 43.3 [35.3; 51.7]
National Summary Report-India, 2011 57 153 0.5% 37.3 [29.6; 45.4]
National Summary Report-India, 2011 42 157 0.5% 26.8 [20.0; 34.4]
Carcamo, 2012 3 159 0.5% 1.9 [0.4; 5.4]
Uribe-Salas, 2003 2 195 0.5% 1.0 [0.1; 3.7]
Carcamo, 2012 2 199 0.5% 1.0 [0.1; 3.6]
Carcamo, 2012 3 200 0.5% 1.5 [0.3; 4.3]
Carcamo, 2012 3 200 0.5% 1.5 [0.3; 4.3]
Carcamo, 2012 1 202 0.5% 0.5 [0.0; 2.7]
Chen, 2005 20 204 0.5% 9.8 [6.1; 14.7]
Delgado, 2011 5 211 0.5% 2.4 [0.8; 5.4]
Perla, 2012 5 211 0.5% 2.4 [0.8; 5.4]
Aho, 2014 79 223 0.5% 35.4 [29.2; 42.1]
Lutnick, 2008 10 250 0.5% 4.0 [1.9; 7.2]
National Summary Report-India, 2011 95 257 0.5% 37.0 [31.0; 43.2]
Xu, 2013 102 261 0.5% 39.1 [33.1; 45.3]
National Summary Report-India, 2011 58 266 0.5% 21.8 [17.0; 27.3]
Limpakarnjanarat, 1999 132 280 0.5% 47.1 [41.2; 53.2]
Sanchez, 1998 2 284 0.5% 0.7 [0.1; 2.5]
Vandenhoudt, 2013 221 296 0.5% 74.7 [69.3; 79.5]
National Summary Report-India, 2011 45 303 0.5% 14.9 [11.0; 19.4]
Lafort, 2008 174 350 0.5% 49.7 [44.4; 55.1]
National Summary Report-India, 2011 122 360 0.5% 33.9 [29.0; 39.0]
Uribe-Salas, 1999 4 362 0.5% 1.1 [0.3; 2.8]
National Summary Report-India, 2011 127 384 0.5% 33.1 [28.4; 38.0]
National Summary Report-India, 2011 124 385 0.5% 32.2 [27.6; 37.1]
National Summary Report-India, 2011 138 395 0.5% 34.9 [30.2; 39.9]
National Summary Report-India, 2011 47 395 0.5% 11.9 [8.9; 15.5]
National Summary Report-India, 2011 57 399 0.5% 14.3 [11.0; 18.1]
Gotuzzo, 1994 3 400 0.5% 0.8 [0.2; 2.2]
National Summary Report-India, 2011 32 401 0.5% 8.0 [5.5; 11.1]
National Summary Report-India, 2011 93 401 0.5% 23.2 [19.1; 27.6]
National Summary Report-India, 2011 38 401 0.5% 9.5 [6.8; 12.8]
National Summary Report-India, 2011 156 404 0.5% 38.6 [33.8; 43.6]
National Summary Report-India, 2011 86 405 0.5% 21.2 [17.4; 25.5]
National Summary Report-India, 2011 114 407 0.5% 28.0 [23.7; 32.6]
National Summary Report-India, 2011 51 408 0.5% 12.5 [9.5; 16.1]
Ramjee, 2005 208 416 0.5% 50.0 [45.1; 54.9]
National Summary Report-India, 2011 111 422 0.5% 26.3 [22.2; 30.8]
Kane, 2009 104 450 0.5% 23.1 [19.3; 27.3]
Soto, 2007 1 460 0.5% 0.2 [0.0; 1.2]
Vandenhoudt, 2013 271 479 0.5% 56.6 [52.0; 61.1]
Koenig, 2007 19 482 0.5% 3.9 [2.4; 6.1]
Soto, 2007 15 484 0.5% 3.1 [1.7; 5.1]
Soto, 2007 47 493 0.5% 9.5 [7.1; 12.5]
Soto, 2007 22 511 0.5% 4.3 [2.7; 6.4]
Delgado, 2011 11 613 0.5% 1.8 [0.9; 3.2]
Creswell, 2010 38 663 0.5% 5.7 [4.1; 7.8]
Riedner, 2007 504 753 0.5% 66.9 [63.4; 70.3]
Vandepitte, 2011 381 1027 0.5% 37.1 [34.1; 40.1]
Nzila, 1991 429 1226 0.5% 35.0 [32.3; 37.7]
Random effects model 4892 21072 36.4% 18.7 [14.1; 23.8]
Heterogeneity: $I^2 = 99\%$, $\tau^2 = 0.0699$, $\chi^2_{70} = 5844.86$ ($p = 0$)
Random effects model 9829 67646 100.0% 11.8 [9.8; 13.9]
Prediction interval [0.0; 49.3]
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0462$, $\chi^2_{193} = 12598.45$ ($p = 0$)
Residual heterogeneity: $I^2 = 98\%$, $\chi^2_{190} = 10636.58$ ($p = 0$)
0 20 40 60 80
HIV prevalence (95% CI)

Box S1. Search criteria for the systematic review of the global association of herpes simplex virus type 2 (HSV-2) and HIV prevalence measures among female sex workers.

PubMed (September 3rd, 2019)

Sex work

"Extramarital Relations"[Mesh] OR "Sex Work*"[Mesh] OR "Sex/analysis"[Mesh] OR "Sex/statistics and numerical data"[Mesh] OR "Sexual partners"[Mesh] OR "Sex Trafficking/epidemiology"[Mesh] OR "Sex Trafficking/statistics and numerical data"[Mesh] OR Sex work*[Text] OR Sexual work*[Text] OR Sexwork*[Text] OR Sex-work*[Text] OR Sexual partner*[Text] OR Sex partner*[Text] OR Sexual contact*[Text] OR FSW[Text] OR FSWs[Text] OR CSW[Text] OR CSWs[Text] OR SW[Text] OR SWs[Text] OR TSW[Text] OR TSWs[Text] OR TS[Text] OR Travailleuse* sexe[Text] OR Travailleuse* sex[Text] OR Bar girl*[Text] OR Callgirl*[Text] OR Call girl*[Text] OR Escort*[Text] OR Masseuse*[Text] OR Hostess*[Text] OR ((Premarital[Text] OR Pre-marital[Text] OR Pre marital[Text] OR Extramarital[Text] OR Extra-marital[Text] OR Extra marital[Text] OR Illicit[Text] OR Illegal[Text]) AND (Sex[Text] OR Sexual[Text] OR Relation*[Text])) OR Outside marriage[Text] OR Out of marriage[Text] OR "Illegal social behavior"[Text] OR "Illegal social behaviour"[Text] OR Adultery[Text] OR Prostitut*[Text] OR Promiscu*[Text] OR Female entertain*[Text] OR Sex entertain*[Text] OR Sexual* entertain*[Text] OR Entertainment work*[Text] OR Sex industr*[Text] OR Sex establishment*[Text] OR Brothel*[Text] OR Red light[Text] OR Red-light[Text] OR Red district*[Text] OR Nightclub*[Text] OR Pimp[Text] OR ((Intergenerational[Text] OR Cross-generation*[Text] OR Cross-generational[Text] OR Recreational[Text] OR Commercial[Text] OR Transaction*[Text] OR Casual[Text] OR Group[Text] OR Informal[Text] OR Street[Text] OR Migrant*[Text] OR Survival[Text] OR Occupational[Text] OR Tourism[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Sex seeking[Text] OR Sex-seeking[Text] OR Solicit*[Text] OR ((Provision*[Text] OR Provider*[Text] OR Provid*[Text] OR Sell*[Text] OR Sold[Text] OR Exchang*[Text] OR Trad*[Text] OR Favor*[Text] OR Consum*[Text] OR Commodi*[Text] OR Paid[Text] OR Paying[Text] OR Pay[Text] OR Payer*[Text] OR Buying[Text] OR Buy[Text] OR Buyer*[Text] OR Charg*[Text] OR Engag*[Text] OR Service*[Text] OR Money[Text] OR Cash[Text] OR Drug*[Text] OR Goods[Text] OR Gift*[Text]) AND (Sex[Text] OR Sexual*[Text])) OR Hidden population*[Text] OR Hard to reach population*[Text] OR Hard-to-reach population*[Text] OR Core group*[Text] OR Core risk group*[Text] OR Vulnerable women[Text] OR Vulnerable population*[Text] OR Vulnerable female*[Text] OR Most-at-risk population*[Text] OR Most at risk population*[Text] OR High risk population*[Text] OR High-risk population*[Text] OR Population* at high risk[Text] OR Population* at high-risk[Text] OR ((Traffick*[Text] OR Slave*[Text] OR Coerc*[Text] OR Abduct*[Text] OR Exploit*[Text] OR Abuse*[Text] OR Violence[Text]) AND (Sex[Text] OR Sexual*[Text]))

Herpes simplex virus-2

(Simplexvirus[MeSH] OR Herpes Simplex[MeSH] OR Herpes Hominis[Text] OR HSV type-2[Text] OR HSV type 2[Text] OR HSV2[Text] OR HSV-2[Text] OR HSV 2[Text] OR HHV2[Text] OR HHV-2[Text] OR HHV 2[Text] OR Herpes simplex virus type 2[Text] OR Herpes simplex virus type-2[Text] OR herpes simplex virus 2[Text] OR herpes simplex virus-2[Text] OR herpes simplex type 2[Text] OR herpes simplex type-2[Text] OR herpes simplex 2[Text] OR herpes simplex-2[Text] OR Herpesvirus type 2[Text] OR Herpesvirus type-2[Text] OR Herpesvirus 2[Text] OR Herpesvirus-2[Text] OR Herpes virus type 2[Text] OR Herpes virus type-2[Text] OR Herpes virus 2[Text] OR Herpes virus-2[Text] OR genital herpes[Text] OR Human herpes virus[Text] OR Herpes virus[Text] OR Herpes Genitalis[Text] OR Herpes Labialis[Text])

HIV

("HIV"[Mesh] OR "HIV Seropositivity"[Mesh] OR "HIV Antibodies"[Mesh] OR "HIV Infections"[Mesh] OR "HIV Seroprevalence"[Mesh] OR HIV[Text] or "Human immunodeficiency virus"[Text])

Women

"Female/analysis"[Mesh] OR "Female/statistics and numerical data"[Mesh] OR "Women/epidemiology"[Mesh] OR "Women/statistics and numerical data"[Mesh] OR Women[Text] OR Girl*[Text] OR Female*[Text]

FINAL PUBMED SEARCH
("Sex work" AND "Herpes simplex virus-2" AND "HIV" AND "Women")
Total citations: 748

Embase (September 3rd, 2019)

Sex work

exp prostitution/ or exp casual sex/ or exp transactional sex/ or exp group sex/ or exp sex tourism/ or exp sexual promiscuity/ or exp extramarital sex/ or exp premarital sex/ or exp sexual relation/ or exp sexual partners/ or ((exp sex trafficking/ or exp sexual exploitation/ or exp sexual coercion/) NOT Child) or (sex* work* or sexwork* or sex-work* or sex partner* or sexual partner* or sexual contact* or premarital sex or premarital sexual or premarital relation* or pre-marital sex or pre-marital sexual or pre-marital relation* or pre marital sex or pre marital sexual or pre marital relation* or extramarital sex or extramarital sexual or extramarital relation* or extra-marital sex or extra-marital sexual or extra-marital relation* or extra marital sex or extra marital sexual or extra marital relation* or illicit sex or illicit sexual or illicit relation* or illegal sex or illegal sexual or illegal relation* or (out* ADJ1 marriage) or illegal social behavio?r or adultery or prostitut* or promiscu* or FSW or FSWs or CSW or CSWs or SW or SWs or TSW or TSWs or TS or (women ADJ4 sex*) or (Travailleuse* ADJ1 sex*) or bar girl* or call girl* or callgirl* or escort* or masseuse* or hostess* or female entertain* or sex entertain* or sexual entertain* or entertainment work* or sex industr* or sex establishment* or brothel* or red light or red-light or (red ADJ1 district*) or nightclub* or pimp or recreation* sex* or intergenerational sex* or cross-generation sex* or cross-generational sex* or commercial sex* or transactional sex* or sex* transaction* or casual sex* or informal sex* or group sex* or street sex* or (migra* ADJ4 sex*) or (sex* ADJ4 migra*) or survival sex* or occupational sex* or sex* tourism or sex seeking or sex-seeking or solicit* or (consum* ADJ4 sex*) or (sex* ADJ 4 consumer) or (sex* ADJ4 consumers) or (sex* ADJ4 provi*) or (provi* ADJ4 sex*) or (sell* ADJ4 sex*) or (sex* ADJ4 sell*) or sold sex* or (exchang* ADJ4 sex*) or (sex* ADJ4 exchange) or (trading ADJ4 sex*) or (trade* ADJ4 sex*) or sex* trade or sex* favor* or (commodi* ADJ4 sex*) or (sex* ADJ4 commodi*) or (paid ADJ4 sex*) or (pay* ADJ4 sex*) or (sex* ADJ4 pay*) or (buy* ADJ4 sex*) or (sex* ADJ4 buy*) or (charg* ADJ4 sex*) or (sex* ADJ4 charg*) or (engag* ADJ4 sex*) or (sex* ADJ4 engage*) or (sex* ADJ4 service*) or (service* ADJ4 sex*) or (money ADJ4 sex*) or (sex* ADJ4 money) or (cash ADJ4 sex*) or (sex* ADJ4 cash) or (sex* ADJ4 drug*) or (drug* ADJ4 sex*) or (sex* ADJ4 goods) or (goods ADJ4 sex*) or (sex* ADJ4 gift*) or (gift* ADJ4 sex*) or hidden population* or hard to reach population* or hard-to-reach population* or (core ADJ1 group*) or vulnerable women or vulnerable female*).mp. or ((vulnerable population* or most-at-risk population* or most at risk population* or high risk population* or high-risk population* or population* at high risk or population* at high-risk).mp. AND (sex* or infection* or STI or STIs or STD or STDs or human immunodeficiency virus or HIV* or AIDS* or acquired immune deficiency syndrome or acquired immunodeficiency syndrome).mp.) or ((sex trafficking or sexual trafficking or (traffick* ADJ4 sex*) or sex* slave* or sex* coerc* or sex* abduct* or sex* exploit* or sex* abuse* or sex* violence) NOT Child).mp. or ((women ADJ4 traffick*) or (girls ADJ4 traffick*) or (female* ADJ4 traffick*) or (traffick* ADJ4 women) or (traffick* ADJ4 girls) or (traffick* ADJ4 female*)).mp.

Herpes simplex virus-2

(exp Herpes simplex virus/ or exp herpes simplex/ or exp Simplexvirus/ or exp Herpesvirus/ or exp Herpesviridae/ or exp Herpes simplex virus 2/) OR (Herpes simplex or Herpes simplex virus or HSV type-2 or HSV type 2 or HSV2 or HSV-2 or HSV 2 or HHV2 or HHV-2 or HHV 2 or human herpes virus or herpes virus or Herpes simplex virus type 2 or Herpes simplex virus type-2 or herpes simplex virus 2 or herpes simplex virus-2 or herpes simplex type 2 or herpes simplex type-2 or herpes simplex 2 or herpes simplex-2 or Herpesvirus type 2 or Herpesvirus type-2 or Herpesvirus 2 or Herpesvirus-2 or Herpes virus type 2 or Herpes virus type-2 or Herpes virus 2 or Herpes virus-2 or genital herpes or Herpes Genitalis or Herpes Labialis).mp.

HIV

(exp Human immunodeficiency virus/ or Human immunodeficiency virus.mp. or HIV.mp.)

Women

exp female/ or (women or girl* or female*).mp.

FINAL EMBASE SEARCH
("Sex work" AND "Herpes simplex virus-2" AND "HIV" AND "Women")
Total citations: 1512

Abstract archives of the International AIDS Society conferences (October 27, 2019)

"HIV" AND "HSV"
Total citations: 63

"HSV"
Total citations: 496

"Herpes"
Total citations: 567

Box S2. List of extracted variables.

Report characteristics
Author(s)
Year of publication
Full citation
Publication type
Data source
General study characteristics
Study population and its characteristics
Year(s) of data collection
Region
Country of origin
Country of survey
City
Study site
Study design
Sampling methodology
Eligibility criteria
HIV prevalence
Number tested for HIV antibody
Number positive for HIV antibody
Reported HIV antibody prevalence
Diagnostic test used for HIV infection ascertainment
Herpes simplex virus type 2 (HSV-2) prevalence
Number tested for HSV-2 antibody
Number positive for HSV-2 antibody
Reported HSV-2 antibody prevalence
Diagnostic test used for HSV-2 infection ascertainment
Population characteristics
Proportion who inject drugs
Proportion on antiretroviral therapy
Proportion reporting consistent condom use

Box S3. Countries covered under the different World Health Organization regions[80].

World Health Organization region	Countries
African Region (AFRO)	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, South Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.
Region of the Americas (AMRO)	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia (Plurinational State of), Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, United States of America, Uruguay, Venezuela (Bolivarian Republic of).
Eastern Mediterranean Region (EMRO)	Afghanistan, Bahrain, Djibouti, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, Yemen.
European Region (EURO)	Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, The former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan.
South-East Asia Region (SEARO)	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, Timor-Leste.
Western Pacific Region (WPRO)	Australia, Brunei Darussalam, Cambodia, China, Cook Islands, Fiji, Japan, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam.

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Appendix VIII

Supplementary material for Research paper 4-

HIV incidence and impact of interventions among FSWs and clients in MENA

Supplementary Material

HIV incidence and impact of interventions among female sex workers and their clients in the Middle East and North Africa: Mathematical modeling analysis

Section S1. Estimation of HIV incidence in stable partners (spouses) of clients of female sex workers.

We modelled HIV sexual transmission from clients of female sex workers (FSWs) to their stable partners (spouses) using a deterministic modelling component the input of which was provided by the output of the individual-based model of FSWs and clients. All incidence in spouses was assumed to arise from HIV transmission from the HIV-positive client/husband to the spouse. This is supported by empirical evidence, specifically in the context of the Middle East and North Africa, indicating limited risk of HIV acquisition for women in marital partnerships from a source outside this partnership.[1-7]

The probability of HIV transmission from an HIV-positive client (not on antiretroviral therapy (ART)) to a susceptible spouse over the course of one year is given by

$$t_{Spouse} = 1 - \left(1 - \beta_{Spouse}\right)^{n_{Spouse}\left(1 - f_{condom}\right)\tau_{Spouse}} \left(1 - \left(1 - e_{condom}\right)\beta_{Spouse}\right)^{n_{Spouse} f_{condom} \tau_{Spouse}}$$

Here, β_{Spouse} is the weighted average for the probability of HIV transmission per unprotected coital act across the different HIV infection stages (the weighted average is given by the sum of the product of HIV transmission probability per unprotected coital act in a specific HIV infection stage by the duration spent in that stage relative to the total duration of infection), n_{Spouse} is the number of coital acts in the spousal partnership over the course of a year, f_{condom} is the fraction of acts protected by condom use, e_{condom} is the effectiveness of condom use in reducing HIV transmission, and τ_{Spouse} is the duration of follow-up (here, assumed to be one year).

The number of HIV sero-discordant spousal partnerships for each of regular and non-regular clients is given by

$$N_{disc} = NF_{Marital}P_{Client}\left(1 - P_{Spouse}\right)$$

Here, N is the total number of regular or non-regular clients of FSWs, $F_{Marital}$ is the fraction of clients in spousal partnerships (assumed to be the same for regular and non-regular clients), P_{Client} is HIV prevalence among regular or non-regular clients of FSWs, and P_{Spouse} is HIV prevalence among spouses (assumed to be one third of that among clients of FSWs[4,5,8]).

For spouses of each of regular or non-regular clients of FSWs, HIV incidence is hence given by

$$I_{Spouse} = N_{disc}t_{Spouse}\left(1 - e_{ART}Coverage_{ART}\right)$$

Here, e_{ART} is the effectiveness of ART in reducing HIV transmission from an HIV-positive client to the spouse and $Coverage_{ART}$ is the coverage of ART among clients.

HIV incidence rate is thus given by:

$$IR = \frac{I_{Spouse}}{(1 - P_{Spouse})NF_{Marital}}.$$

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