



## Mapping of new HIV infections in Morocco and impact of select interventions



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### ABSTRACT

**Objectives:** The aim of this study was to assess HIV modes of exposure in Morocco at the national level and also for Souss-Massa-Drâa, the region most affected by HIV. Another aim was to assess the impact of different scenarios of select intervention packages.

**Methods:** The Modes of Transmission Model was adapted and used, and was parameterized using quality bio-behavioral surveillance data among key populations, routine data sources, and literature reviews.

**Results:** Nationally in 2013, the largest number of new infections occurred among clients of female sex workers (FSWs) (25%; 95% confidence interval (CI) 14–37%), followed by men who have sex with men (MSM) (22%; 95% CI 12–35%), HIV serodiscordant couples (22%; 95% CI 12–34%), FSWs (11%; 95% CI 6–18%), and people who inject drugs (5%; 95% CI 2–9%). A similar pattern of results was observed in Souss-Massa-Drâa, but the HIV incidence rate was four-fold that at the national level. Different scenarios of feasible intervention packages reduced HIV incidence by 8–44%.

**Conclusions:** Commercial heterosexual sex networks continue as the leading driver of the epidemic, with half of HIV incidence. A quarter of new infections occurred among MSM, a third of which in Souss-Massa-Drâa. Feasible expanded coverage of interventions could lead to large reductions in incidence.

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### Introduction

Although the HIV epidemic is receding globally, it appears to be expanding in the Middle East and North Africa (MENA) (UNAIDS, 2016). HIV epidemics in MENA, many of which are emerging, have been documented among people who inject drugs (PWID), men who have sex with men (MSM), and female sex workers (FSWs), with heterogeneity between countries on the relative role of each of these key populations (Abu-Raddad et al., 2010a,b; Mumtaz et al., 2011, 2014a,b).

Morocco is the most outstanding country in MENA in confronting the epidemic through an evidence-informed and comprehensive response (Mumtaz et al., 2013, 2018; Kouyoumjian et al., 2013; Bennani et al., 2014). As part of this effort, Morocco conducted a national HIV Modes of Transmission (MoT) analysis in

2010. This analysis highlighted the need to focus the HIV response on key populations through the development of proactive and sustainable HIV surveillance, as well as ensuring a wider coverage of condom use programming, voluntary counseling and testing (VCT) services, and harm reduction and treatment units.

Consequently, as part of national HIV surveillance expansion activities, Morocco conducted first rounds of integrated bio-behavioral surveillance surveys (IBBSS) among FSWs in Agadir, Fes, Rabat, and Tanger (Johnston, 2011a), MSM in Agadir and Marrakech (Johnston, 2011b), and PWID in Tanger and Nador (Johnston, 2012), using state-of-the-art sampling methodologies for hidden and hard-to-reach populations, such as respondent-driven sampling. This quality evidence facilitated an analysis of HIV exposure and incidence to inform policy and programming decisions through a framework of ‘know your epidemic, know your response’ (Wilson and Halperin, 2008).

Against this background, the objectives of the present study were (1) to update the 2010 Morocco National HIV MoT Model results factoring in the newly available IBBSS and other data up to 2013 (Mumtaz et al., 2013, 2018); (2) to analyze the distribution of

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new HIV infections by mode of exposure in the region of the country most affected by HIV, Souss-Massa-Drâa; (3) to assess the impact of several HIV prevention and treatment interventions, including increasing antiretroviral therapy (ART) coverage, condom use, and (for PWID) harm reduction (reducing current sharing of needles and syringes). This article summarizes the results and findings of the study, based on a detailed report of the results presented to the Morocco Ministry of Health and other HIV stakeholders in Morocco, to inform HIV policy and programming in this country (Bennani et al., 2014).

## Methods

### Sources of data

The IBBSS studies among FSWs (Johnston, 2011a), MSM (Johnston, 2011b), and PWID (Johnston, 2012), were provided by the Morocco Ministry of Health, in addition to sentinel surveillance, VCT, notified HIV/AIDS cases, and ART data, among others. Further data were retrieved from extensive state-of-the-art systematic reviews (Kouyoumjian et al., 2013; Mumtaz et al., 2010, 2014a) of HIV data and related outcomes in MENA that were conducted as informed by the Cochrane Collaboration handbook (The Cochrane Collaboration, 2008) and reported following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Moher et al., 2009), as well as from the MENA HIV/AIDS Epidemiology Synthesis Project database (Abu-Raddad et al., 2010a,b) and an updated literature search of data from Morocco.

### Model structure, model parameterization, and uncertainty analyses

A description of the MoT Model structure is provided in Section 1 of the Supplementary Material and in the 2010 MoT study (Mumtaz et al., 2013). The model parameters for both the National MoT Model study and the regional Souss-Massa-Drâa MoT Model study were primarily based on the IBBSS and other data from Morocco, as described above, in addition to regional and global HIV data, and consensus of national stakeholders (Section 2, Supplementary Material).

Table S1.1 in the Supplementary Material provides key definitions used to classify individuals by risk group in the model. Table S2.1 of the Supplementary Material summarizes the biological parameters of the model. Table S2.2 of the Supplementary Material (National) and Table S3.1 of the Supplementary Material (Souss-Massa-Drâa) provide the key demographic attributes. Table S2.3 of the Supplementary Material (National) and Table S3.2 of the Supplementary Material (Souss-Massa-Drâa) include the risk group size estimates for each HIV risk group. Table S2.4 of the Supplementary Material (National) and Table S3.3 of the Supplementary Material (Souss-Massa-Drâa) show HIV prevalence for each HIV risk group. Table S2.5 of the Supplementary Material (National) and Table S3.4 of the Supplementary Material (Souss-Massa-Drâa) tabulate the risk behavior parameters for each HIV risk group.

### Uncertainty analysis

The model parameters were varied simultaneously and randomly within a range of uncertainty of 25% around each parameter value (Table S4.1, Supplementary Material). The range of plausibility for the total annual incidence was determined by the range obtained from the UNAIDS SPECTRUM model (UNAIDS, 2013), as applied for Morocco in 2012 (Morocco Ministry of Health/National AIDS Program, 2013). The median of all selected plausible outputs was then calculated and the uncertainty was described by plausibility bounds defined as the 2.5 and 97.5 percentiles. Further details of the National and Souss-Massa-Drâa MoT Model uncertainty analyses are found in Section 4 of the Supplementary Material.

### Assessment of the impact of the select interventions on HIV incidence

The impact of several HIV prevention and treatment interventions targeted at people living with HIV (PLHIV), key populations, and stable heterosexual couples (i.e., HIV serodiscordant couples) were examined. The intervention packages were designed based on relevance to the National AIDS Program of Morocco, as well as what could be reasonable and feasible immediate targets given the 2013 ART coverage of only 20% among

**Table 1**  
Select HIV prevention and treatment intervention packages targeted at people living with HIV, key populations, and HIV serodiscordant couples in Morocco.

Intervention	Description
<b>ART intervention packages</b>	
Increasing ART coverage for PLHIV with different CD4 levels	80% ART coverage for PLHIV with CD4 <350 cells/ $\mu$ l 50% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l 60% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l 70% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l
Increasing ART coverage for PLHIV with different CD4 levels, key populations, and HIV serodiscordant couples	80% ART coverage for PLHIV with CD4 <350 cells/ $\mu$ l 50% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l, 50% coverage for key populations, and 30% for HIV serodiscordant couples 60% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l, 60% coverage for key populations, and 40% for HIV serodiscordant couples 70% ART coverage for PLHIV with CD4 <500 cells/ $\mu$ l, 70% coverage for key populations, and 50% for HIV serodiscordant couples
<b>Condom use intervention package</b>	
Increasing current condom use coverage among FSWs, clients of FSWs, and MSM	by 25% by 50% by 75% by 100%
<b>Harm reduction intervention package</b>	
Reducing current sharing of needles and syringes among PWID	by 25% by 50% by 75%

ART, antiretroviral therapy; PLHIV, people living with HIV; FSWs, female sex workers; MSM, men who have sex with men; PWID, people who inject drugs.

PLHIV. Specifically, these intervention packages have been designed based on consensus of national HIV stakeholders in Morocco and taking into account funding availability, experience in the field, and logistical considerations. The distributions of the PLHIV population by CD4 count and of ART coverage levels across these populations were determined based on the outputs of the Morocco SPECTRUM model 2012 (UNAIDS, 2013; Morocco Ministry of Health/National AIDS Program, 2013).

Table 1 summarizes the intervention packages examined. Different scenarios of four select intervention packages were specifically examined, including (1) expansion of ART coverage through two different intervention packages as informed by the adopted National Guidelines of 2013 and the National Strategic Plan of 2016; (2) increasing condom use coverage among FSWs, clients of FSWs, and MSM; and (3) increasing harm reduction coverage among PWID by reducing sharing of needles and syringes.

## Results

Risk group size estimates for each HIV risk group for both the National and Souss-Massa-Drâa MoT analyses are listed in Table 2. The distribution of new HIV infections by mode of exposure for both the National and Souss-Massa-Drâa MoT analyses are shown in Table 3. These are also schematized in Figure 1, along with the uncertainty around the model predictions. The results of the analyses on the MoT Model predictions for both the National and Souss-Massa-Drâa MoT Models are tabulated in Table 4.

### National Modes of Transmission analysis

Population groups engaged in commercial heterosexual sex were the largest of all key populations in Morocco, including an estimated 85 000 FSWs and 850 000 clients (Table 2). MSM came second with 55 319 individuals, and PWID third with 5000 individuals (Table 2). Just over 5% of the 15–49 years of age population (9.5% of males and 0.9% of females) engaged in high-risk behaviors, mostly as clients of FSWs (Table 4). Less than 2% of the 15–49 years of age population were in stable partnerships with partners engaging in high-risk behaviors, and were therefore at higher risk of being exposed to HIV; these were mostly women (Table 4).

The largest contribution to HIV incidence (number of new infections per year) was among clients of FSWs (25%; 95% confidence interval (CI) 14–37%), followed by MSM (22%; 95% CI 12–35%), stable heterosexual couples (corresponding to HIV serodiscordant couples; 22%; 95% CI 12–34%), and FSWs (11%; 95% CI 6–18%) (Table 3). The networks of these population groups, i.e., these groups along with their stable sexual partners, contributed at least 70% (95% CI 57–81%) of HIV incidence (Table 4). Specifically, commercial heterosexual sex networks contributed 41% (95% CI 27–56%) of incidence, followed by MSM networks (24%; 95% CI 13–37%) and PWID networks (6%; 95% CI 3–10%) (Table 4). The remaining one-third of incidence was among stable heterosexual couples (HIV serodiscordant couples) and people engaged in casual heterosexual sex (Table 4).

About half (44%) of HIV incidence in Morocco was among women, but 73% of all infections among women were transmitted by an infected spouse (Table 4). Most infections (92%) among men were due to high-risk practices (Table 4). The HIV incidence rate was highest among PWID at 3.4% per person-year, followed by MSM at 1.3% and FSWs at 0.4% (Table 3). If these incidence rates remain constant, HIV prevalence may reach, at endemic equilibrium, levels as high as 17% among PWID, 10% among MSM, and 3% among FSWs (Table 3). These estimates at endemic equilibrium were not generated using the MoT Model but using a complementary deterministic competing-hazards differential-equations model that included as an input the HIV force of infection (HIV incidence rate) generated by the MoT Model.

### Souss-Massa-Drâa Modes of Transmission analysis

Population groups engaged in commercial heterosexual sex were the largest of all key population groups in Souss-Massa-Drâa, including an estimated 11 363 FSWs and 113 630 clients (Table 2). MSM came second with 13 080 individuals, and PWID third with an estimate of only 100 individuals (Table 2). About 10% of the 15–49 years of age population (17.8% of men and 1.6% of women) engaged in high-risk behaviors, mostly as clients of FSWs (Table 4). Less than 4% of the 15–49 years of age population were in stable partnerships with partners engaging in high-risk behaviors, and were therefore at higher risk of being exposed to HIV; these were mostly women (Table 4).

**Table 2**  
Risk group size estimates for each HIV risk group in the National and Souss-Massa-Drâa Modes of Transmission Model analyses in Morocco, 2013.

Population	Prevalence of risk (%) (National)			Population size estimate (N) (National)			Prevalence of risk (%) (Souss-Massa-Drâa)			Population size estimate (N) (Souss-Massa-Drâa)		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
PWID	0.026	0.047	0.005	5000	4480	520	0.007	0.013	0.001	100	90	10
Stable sexual partners of PWID	0.015	0.003	0.027	2890	301	2589	0.004	0.001	0.007	58	6	52
FSWs	0.444	–	0.888	85 000	–	85 000	0.796	–	1.593	11 363	–	11 363
Clients of FSWs	4.439	8.877	–	850 000	850 000	–	7.965	15.929	–	113 630	113 630	–
Stable sexual partners of FSWs' clients	1.775	–	3.551	340 000	–	340 000	3.186	–	6.372	45 452	–	45 452
MSM	0.289	0.578	–	55 319	55 319	–	0.917	1.834	–	13 080	13 080	–
Stable female partners of MSM	0.122	–	0.243	23 278	–	23 278	0.386	–	0.772	5504	–	5504
People engaged in casual heterosexual sex	5.5	10.0	1.0	1 053 243	957 494	95 749	5.5	10.0	1.0	78 467	71 334	7133
Stable partners of people engaged in casual heterosexual sex	2.525	0.050	5.000	483 534	4787	478 747	2.525	0.050	5.0000	36 024	357	35 667
People engaged in stable heterosexual partnerships	57.365	60.445	54.286	10 985 397	5 787 570	5 197 827	51.214	52.174	50.255	730 665	372 176	358 489
People with no risk this year	27.50	20.00	35.00	5 266 216	1 914 988	3 351 228	27.50	20.00	35.00	392 337	142 668	249 669
Population at risk of medical injections	100	100	100	19 149 878	9 574 939	9 574 939	100	100	100	1 426 680	713 340	713 340
Population at risk of blood transfusions	0.364	0.364	0.364	69 750	34 875	34 875	0.364	0.364	0.364	9465	4732.5	4735.2

PWID, people who inject drugs; FSWs, female sex workers; MSM, men who have sex with men.

**Table 3**

Key predictions of the National and Souss-Massa-Drâa Modes of Transmission Model analyses in Morocco, 2013.

National MoT Model	HIV prevalence (%)	Number of PLHIV	HIV incidence	Percentage of total incidence (%)	Incidence among males	Incidence among females	Incidence of females/total (%)	HIV incidence per person-year (%)	Equilibrium prevalence (forecast) (%) <sup>a</sup>
Population									
PWID	9.00	450	153	4.84	137	16	10.4	3.37	16.81
Sexual partners of PWID	3.00	87	25	0.80	3	23	89.6	0.90	7.80
FSWs	2.04	1734	350	11.08	0	350	100.0	0.42	2.46
Clients	0.38	3230	780	24.65	780	0	0.0	0.09	0.55
Partners of clients	0.19	646	163	5.17	0	163	100.0	0.05	0.45
MSM	3.00	1660	708	22.39	708	0	0.0	1.32	10.16
Female partners of MSM	0.75	175	45	1.42	0	45	100.0	0.19	1.44
Casual heterosexual sex	0.28	2908	82	2.58	74	7	9.1	0.01	0.06
Partners of casual heterosexual sex	0.14	668	168	5.31	2	166	99.0	0.03	0.33
Stable heterosexual partnerships	0.07	7690	683	21.59	60	622	91.2	0.01	0.06
No risk	0.07	3686	0	0.00	–	–	–	–	–
Medical injections	0.14	–	4	0.13	2	2	50.0	0.00	–
Blood transfusions	0.02	–	1	0.03	0	0	50.0	0.00	–
Total adult population	0.12	22 933	3163	100.0	1767	1396	44.1	0.02	–
Souss-Massa-Drâa MoT Model									
Population									
PWID	2.30	2	1	0.09	1	0	10.4	0.87	4.95
Sexual partners of PWID	0.77	0	0	0.01	0	0	89.6	0.23	2.12
FSWs	5.10	580	185	19.39	0	185	100.0	1.71	9.32
Clients	1.58	1795	253	26.60	253	0	0.0	0.23	1.34
Partners of clients	0.79	359	90	9.48	0	90	100.0	0.20	1.84
MSM	4.75	621	243	25.52	243	0	0.0	1.95	14.33
Female partners of MSM	1.19	65	17	1.76	0	17	100.0	0.31	2.26
Casual heterosexual sex	0.70	549	15	1.61	14	1	9.1	0.02	0.15
Partners of casual heterosexual sex	0.35	126	32	3.32	0	31	99.0	0.09	0.82
Stable heterosexual couples	0.18	1279	115	12.08	10	105	91.5	0.02	0.15
No risk	0.18	706	0	0.00	–	–	–	–	–
Medical injections	0.40	–	1	0.11	1	1	50.0	0.00	–
Blood transfusions	0.05	–	0	0.04	0	0	50.0	0.00	–
Total adult population	0.43	6084	953	100.0	522	431	45.2	0.07	–

MoT, Modes of Transmission; PLHIV, people living with HIV; PWID, people who inject drugs; FSWs, female sex workers; MSM, men who have sex with men.

<sup>a</sup> Forecast assuming persistence of the current HIV incidence rate as predicted by the MoT Model.

The largest contribution to HIV incidence in Souss-Massa-Drâa was among clients of FSWs (27%; 95% CI 15–39%), followed by MSM (26%; 95% CI 13–41%), FSWs (19%; 95% CI 11–30%), and stable heterosexual couples (i.e., HIV serodiscordant couples; 12%; 95% CI 3–25%) (Table 3). The networks of these population groups contributed at least 83% (95% CI 69–92%) of HIV incidence (Table 4). Specifically, commercial heterosexual sex networks contributed 55% (95% CI 39–72%) of incidence, followed by MSM networks (27%; 95% CI 15–43%) and PWID networks (0.10%; 95% CI 0.05–0.20%) (Table 4). The remaining incidence was among stable heterosexual couples (HIV serodiscordant couples) and people engaged in casual heterosexual sex (Table 4).

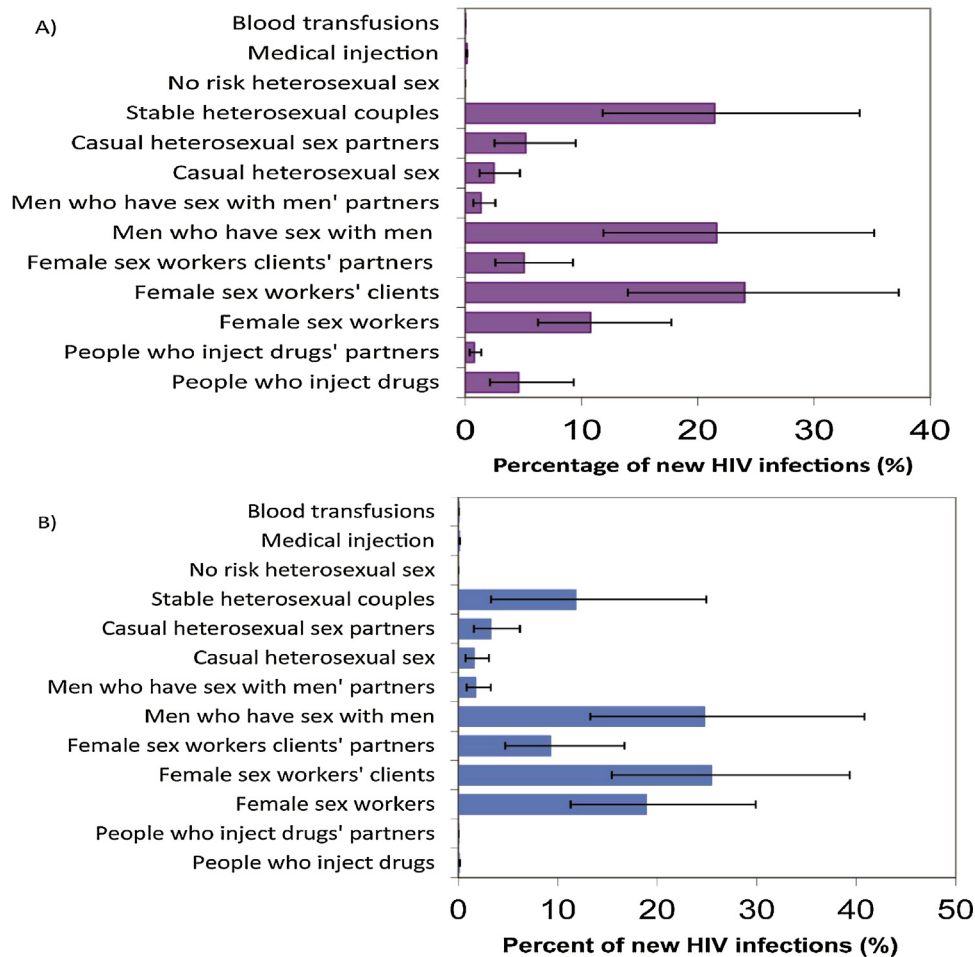
About half (45%) of HIV incidence in Souss-Massa-Drâa was among women, but 57% of all infections among women were transmitted by an infected spouse (Table 4). Most infections (95%) among men were due to high-risk practices (Table 4). The HIV incidence rate was highest among MSM at 2.0% per person-year, followed by FSWs at 1.7% and PWID at 0.9% (Table 3). If these incidence rates remain constant, HIV prevalence may reach, at

endemic equilibrium, levels as high as 14% among MSM, 9% among FSWs, and 5% among PWID (Table 3).

#### Impact of select interventions on HIV incidence

Figure 2A shows the impact of the four scenarios in the first ART intervention package in which ART coverage is scaled up to 80% among PLHIV with a CD4 count <350 cells/ $\mu$ l, or to 50%, 60%, and 70%, respectively, among PLHIV with a CD4 count <500 cells/ $\mu$ l. HIV incidence for 2013 was reduced through this package by 8–27%, thereby averting 247–855 new HIV infections.

Figure 2B shows the impact of the four scenarios in the second ART intervention package. This package compares an ART coverage of 80% among PLHIV with a CD4 count <350 cells/ $\mu$ l to three other scenarios where ART coverage is scaled up to 50%, 60%, and 70%, respectively, among both PLHIV with a CD4 count <500 cells/ $\mu$ l and key populations (FSWs, clients of FSWs, MSM, and PWID) while simultaneously expanding ART coverage to 30%, 40%, and 50%, respectively, among HIV serodiscordant couples. HIV



**Figure 1.** Distribution of new HIV infections by mode of exposure and the uncertainty in the Morocco Modes of Transmission Model predictions, 2013. (A) Morocco National MoT model predictions. (B) Souss-Massa-Drâa MoT Model predictions.

incidence for 2013 was reduced through this package by 8–44%, thereby averting 247–1403 new HIV infections.

Figure 2C shows the impact of the four scenarios of the condom intervention package that expands condom use coverage among FSWs, clients of FSWs, and MSM by 25%, 50%, 75%, and 100%, respectively. Relative to current condom use coverage, HIV incidence among these three population groups for 2013 was reduced through this package by 10–39%, thereby averting 177–711 new HIV infections.

Figure 2D shows the impact of the three scenarios of the harm reduction intervention package that reduces sharing of needles and syringes among PWID. By reducing sharing of needles and syringes by 25–75%, relative to the current level of sharing, HIV incidence among PWID for 2013 was reduced by 24–73%, thereby averting 36–112 new HIV infections.

## Discussion

This study provided a mapping of HIV exposures in Morocco at the national level, as well as for Souss-Massa-Drâa, the region most affected by the epidemic. The 2010 National MoT analysis (Mumtaz et al., 2013) was first updated based on quality IBBSS data that became available recently. It was found that commercial heterosexual sex networks continue to be the leading driver of the epidemic in this country, but that there is a growing contribution for MSM. Nearly a quarter of new HIV infections in 2013 occurred among MSM. While the pattern of HIV exposures in Souss-Massa-Drâa largely mirrored the national pattern, the HIV incidence rate

was four-fold higher. Nearly a third of new HIV infections in Morocco occurred in this region. Although Morocco has established an array of HIV prevention and treatment programs that reduced HIV transmission, further reductions are possible with feasible expansion of these programs to reach higher service coverage.

The HIV incidence in Morocco did not change appreciably over the years 2010–2013, but it seemed to be on a slow declining trend (Table 3 versus 2010 MoT Model analysis (Mumtaz et al., 2013)). The networks of FSWs and their clients, MSM, and PWID are the core drivers of the HIV epidemic in Morocco, contributing two-thirds of total HIV incidence (Table 4). Following a regional trend (Mumtaz et al., 2011, 2014b), HIV transmission among MSM is apparently becoming, or has just been recognized with the recent availability of quality data for this population, a key feature of the epidemic in Morocco. The epidemic in commercial heterosexual sex networks and MSM appears to be most intense in the south of Morocco, and especially in Souss-Massa-Drâa (Figure S5.1, Supplementary Material). For PWID, most transmission appears to be in the north of Morocco (Johnston, 2012) (Figure S5.1, Supplementary Material), although knowledge of this population group remains insufficient to reach conclusive findings.

The predictions of the National and Souss-Massa-Drâa MoT Models show that men and women contribute nearly equally to HIV incidence (Table 3), in agreement with the distribution among notified cases (Ministère de la Santé au Maroc and null, 2013). However, most women acquired the infection from their infected spouses (Table 4), highlighting the vulnerability of women in HIV

**Table 4**

Results of analyses on the predictions of the National and Souss-Massa-Drâa Modes of Transmission Model analyses in Morocco, 2013.

Finding	National MoT model	Souss-Massa-Drâa MoT model
Infections originating from:		
CHS networks	40.9%	55.5%
MSM networks	23.8%	27.3%
PWID networks	5.6%	0.1%
Three most at-risk networks (CHS, MSM, PWID)	70.4%	82.8%
Casual heterosexual sex networks	7.9%	4.9%
HIV serodiscordant partnerships among the stable heterosexual couples in the general population	21.6%	12.1%
Parenteral transmissions other than injecting drug use	0.2%	0.1%
Infections among:		
Women due to an infected spouse	73.0%	56.6%
Men due to high-risk behavior (CHS, MSM, PWID)	92.0%	95.2%
Partners of high-risk individuals	12.7%	14.6%
Population engaged in high-risk behavior (CHS, MSM, PWID):		
Males	9.5%	17.8%
Females	0.9%	1.6%
Adult population	5.2%	9.7%
Fraction of males among population engaged in high-risk behavior	91.4%	91.8%
Fraction of females among population engaged in high-risk behavior	8.6%	8.2%
Population engaged in high-risk behavior (CHS, MSM, PWID) or casual heterosexual sex:		
Males	19.5%	27.8%
Females	1.9%	2.6%
Population	10.7%	15.2%
Fraction of males among people engaged in high-risk behavior or casual heterosexual sex	91.2%	91.5%
Fraction of females among people engaged in high-risk behavior or casual heterosexual sex	8.8%	8.5%
Partners of persons engaged in high-risk behavior (CHS, MSM, PWID):		
Number	366 168	51 014
Fraction of adult population	1.9%	3.6%
Partners of persons engaged in high-risk behavior (CHS, MSM, PWID) or casual heterosexual sex:		
Number	849 703	87 038
Fraction of adult population	4.4%	6.1%

MoT, Modes of Transmission; CHS, commercial heterosexual sex; MSM, men who have sex with men; PWID, people who inject drugs.

serodiscordant couples as seen in other MENA countries (Abu-Raddad et al., 2010a).

The Souss-Massa-Drâa MoT Model analysis provided the first regional MoT application in MENA. The main features of its findings agreed with those of the National MoT Model analysis (Tables 3 and 4). Similarly, networks of FSWs and their clients, MSM, and PWID were the core drivers of the HIV epidemic in Souss-Massa-Drâa, contributing 83% of total HIV incidence (Table 4).

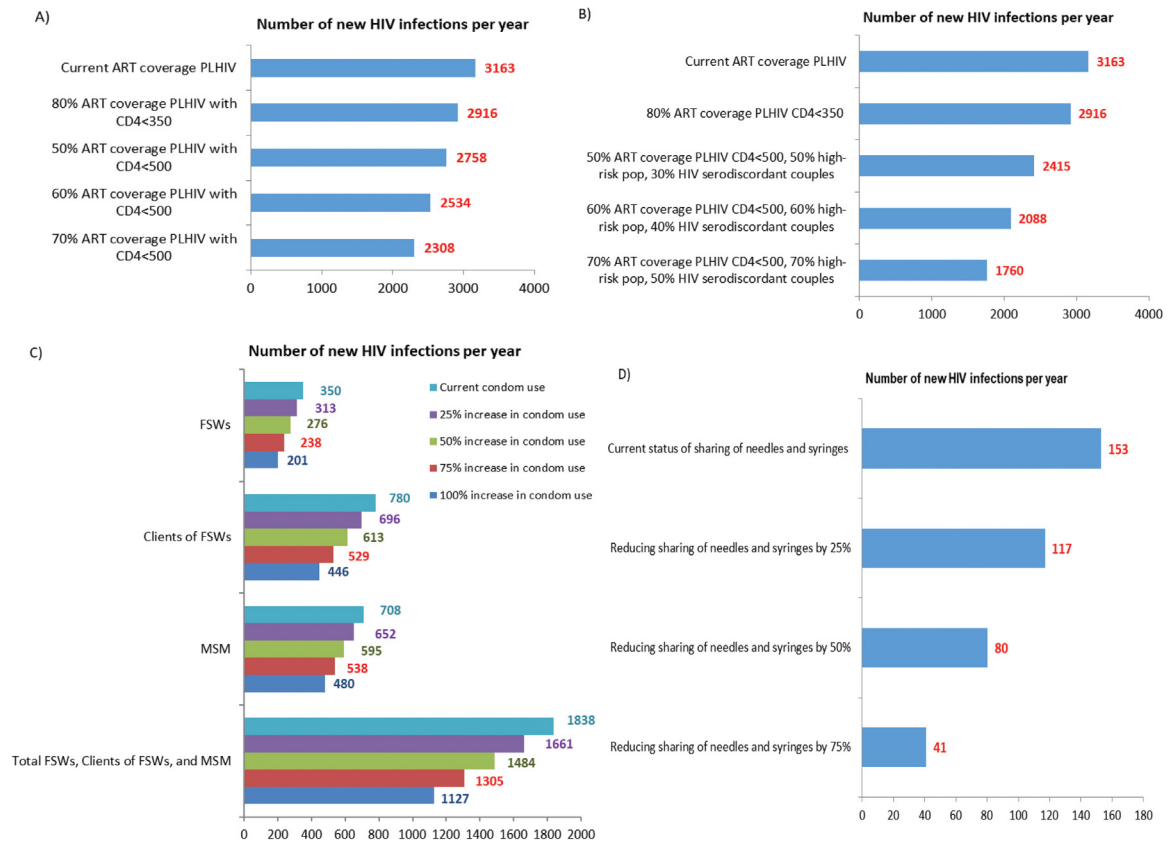
Although the pattern of HIV exposures in Souss-Massa-Drâa largely mirrored the national pattern, there are key features that distinguish the epidemic in Souss-Massa-Drâa (Tables 3 and 4). The HIV incidence rate in Souss-Massa-Drâa was four-fold that at the national level, affirming the disproportionate role of this region in the epidemic. Commercial heterosexual sex networks played a larger and dominant role in the Souss-Massa-Drâa epidemic, contributing two-thirds of total HIV incidence. MSM networks appeared also to play a larger role here than at the national level, contributing 27% of HIV incidence. Nonetheless, there is apparently limited injecting drug use in this part of Morocco, with minimal contribution of this mode of exposure to the epidemic.

The susceptibility of Souss-Massa-Drâa to a more intense HIV epidemic may relate to the high mobility characterizing this region. Indeed, Souss-Massa-Drâa is a primary tourism hub in Morocco and the center of an agricultural production area that attracts a large number of poor seasonal migrant laborers from different parts of the country.

Morocco accomplished significant strides in scaling-up HIV interventions among key populations, but there is much room for improvement for a better epidemic control. In 2012, there were 5301 HIV-infected people on ART out of an estimated 30 000 PLHIV

(Morocco Ministry of Health/National AIDS Program, 2013). Despite the achievement in establishing and expanding ART access and coverage, the coverage is still well below what is desired in light of current World Health Organization guidelines (World Health organization, 2015a,b). The present study results indicate that much can be gained in HIV incidence reduction by expanding ART coverage and other interventions such as condom use and harm reduction (Figure 2). The focus of these interventions should be among key groups, as their transmission networks are the main drivers of the epidemic.

The limitations of this study arise from the limitations of the MoT Model's structure and the data input used to parameterize the model, as described in detail previously (Mumtaz et al., 2013; Gouws et al., 2012; Case et al., 2012a). Briefly, the model, for instance, does not account for heterogeneity in the risk of exposure to HIV infection in the different population groups including, for example, among stable heterosexual couples (Case et al., 2012b; Borquez et al., 2016), across regions or subregions (Borquez et al., 2016), or by HIV infectiousness for different infection stages (Case et al., 2012b; Mishra et al., 2014). The static model structure also does not accommodate competing risks/multiple sources of exposure. Populations are classically classified based on the source of exposure that presents the highest risk for infection acquisition (Case et al., 2012b; Mishra et al., 2014). Long chains of secondary HIV transmissions initiated through high-risk behaviors among key populations are also not captured using this parsimonious model (Mishra et al., 2014). These limitations may introduce uncertainties in the quantitative predictions and may result in an underestimation of the contribution of key populations to HIV incidence (Case et al., 2012b; Borquez et al., 2016; Mishra et al.,



**Figure 2.** Impact of select prevention and treatment intervention packages among people living with HIV, key populations, and HIV serodiscordant couples on the predicted number of new HIV infections compared to the current National Modes of Transmission Model predictions for 2013 (ART, antiretroviral therapy; FSWs, female sex workers; MSM, men who have sex with men; PLHIV: people living with HIV).

2014). Despite these limitations, and until a new methodology of similar practical use is developed, the MoT Model remains a useful tool for informing HIV response, as it allows a systematic and straightforward application using available data.

The quantitative estimates may also have been affected by uncertainties in input data, particularly in relation to risk group size estimation and HIV prevalence in the different at-risk populations. Nevertheless, given the quality IBBSS data used in the present model application, it is likely that the qualitative findings regarding the drivers of HIV incidence are robust. The uncertainty analyses conducted on the model results support this conclusion (Figure 1). The predictions of the National and Souss-Massa-Drâa MoT Models also agree with our understanding of the HIV epidemic in Morocco based on the outcomes of different studies of different designs (Mumtaz et al., 2018; Kouyoumjian et al., 2013). For example, a recent systematic review of multiple sources of HIV data identified substantial HIV infection levels among key populations, with the largest share of new HIV infections occurring among FSWs and their clients (Kouyoumjian et al., 2013). The study findings are also consistent with those of the earlier 2010 MoT analysis for Morocco, which highlighted the contributions of high-risk networks, particularly commercial heterosexual sex networks, to HIV incidence.

This analysis was conducted using data up to the year 2013 and did not incorporate more recent data, which may have affected some of the quantitative estimations. However, recent data, in particular among key populations, suggest that the epidemic is rather stable and the findings are representative (Morocco Ministry of Health/National AIDS Program, 2017). High efficacy

for ART was assumed (based on findings of a clinical trial) (Cohen et al., 2011), and this may have slightly inflated the estimates for the impact of ART intervention packages. A ratio of 10 clients per FSW was also assumed, as informed by (indirect) findings of different studies conducted among FSWs in Morocco (Kouyoumjian et al., 2013; Johnston, 2011a), as well as field experiences of HIV stakeholders; however, there could be heterogeneity in risk behavior among FSWs that is difficult to capture using this parsimonious model.

## Conclusions and implications

HIV incidence in commercial heterosexual sex networks continues as the leading contributor to the epidemic in Morocco. However, a quarter of HIV incidence occurs among MSM, and this contribution may be increasing. HIV sexual transmission is most intense in the Souss-Massa-Drâa region of Morocco, where the HIV incidence rate is four-fold that at the national level and where one-third of new HIV infections are occurring.

These findings shed light on key features of the epidemic in this country, but several gaps remain. It appears that HIV transmission among PWID is less intense than that in other MENA countries (Mumtaz et al., 2014a,b), and mainly focused in the north of Morocco. Nonetheless, localized and hidden HIV epidemics among PWID, as well as MSM, might be present in different areas of Morocco, but are yet to be identified and characterized, which may affect their predicted role in the epidemic.

Morocco is recognized for its vigorous, evidence-informed, and multisectorial HIV response, including the presence of a highly

active civil society and non-governmental organizations working on HIV prevention and treatment and social support services (Kouyoumjian et al., 2013; Saba et al., 2013; Abu-Raddad et al., 2013). Most of the HIV incidence could be controlled by expanding existing services, such as ART and harm reduction, and focusing the HIV response on populations most in need of these services including FSWs and clients, MSM, and PWID. Such an opportunity to stop the HIV epidemic in Morocco distinguishes this country. Moreover, the successes of Morocco provide an example and an opportunity for other MENA countries to strengthen their routine surveillance, conduct local studies among key populations, and improve their HIV response, which remains mostly rudimentary. The HIV response in Morocco also demonstrates the possibility and feasibility of promoting a detailed and meaningful knowledge of HIV epidemiology, which remains lacking in other parts of MENA.

### Conflict of interest

The authors have no conflicts of interest to disclose.

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### Author contributions

LJA led the conduct of this study; the literature reviews and the collection, analysis, and interpretation of the data; and the drafting of the article. SPK conducted the literature reviews and the collection, analysis, and interpretation of the data, and wrote the first draft of the article. HC contributed to the revision of this article. All authors contributed to the conduct of the research, interpretation of the results, and drafting and revision of the article.

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### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.ijid.2017.12.013>.

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