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HIV Screening Scenarios and Targets to Achieve 90% Sero-Status Knowledge Over 2021-2025 in Morocco – Pioneer Use Case of the Goals HIV Testing Strategies Model in a Concentrated Epidemic

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Abstract

Introduction: Morocco aims for 90% of persons living with HIV (PLHIV) knowing their serostatus, by 2023.

Methods: Morocco applied the Goals testing model, projecting alternative testing scale-up scenarios, varying coverage targets for 13 adult populations. The model was calibrated using program service delivery, spending and surveillance data (2015-2019), integrated bio-behavioural surveys, and national HIV estimates. It projects annual diagnoses by target group from undiagnosed prevalence and testing coverage, allowing for HIV-infected people self-selecting for testing, retesting and transitions between groups. Scenarios were evaluated for knowledge status improvement and cost, focusing on 2023-2025.

Results: The model estimated 1,122 PVVIH were newly diagnosed in 2019, 0.3% of 390,200 tests, a yield well above population prevalence. Most diagnoses concerned Female Sex Workers (FSW), Men who have Sex with Men and migrants. Yield was highest among partners of index cases, migrants and persons who inject drugs. Realizing testing targets of Morocco's 2019 Strategic Plan Extension should improve knowledge from 72% at 2019 to 89%, leaving 2,469 PLVIH undiagnosed and costing 1.55 million tests (US$ 2.3 million) in 2023. Expanded testing including FSW clients, prisoners and patients with STI, TB or HIV/AIDS symptoms, could improve knowledge status to 93% in 2023, leaving 1,619 PLVIH undiagnosed. This would cost up to 2.1 million tests (US$ 3.1 million) in 2023 alone, if yield falls to 0.04% due to decreasing undiagnosed prevalence. If the program maintains yield above 0.09% by improved targeting, only 862,000 annual tests may be needed.

Conclusions: To achieve HIV knowledge targets affordably, Morocco must scale-up and rationalize testing, guided by undiagnosed prevalence, beyond identified target groups. Test need will depend on yield realized, which merits close monitoring and adaptive testing policies, possibly including risk score algorithms. The model presented can support Morocco and other HIV/AIDS programs to optimize the pathway toward universal treatment coverage.

Keywords: Testing; Cost-effectiveness; Linkage to care; Key and vulnerable populations; HIV epidemiology; Modelling

List of abbreviations: AIM: Spectrum AIDS Incidence Model; ANC: Antenatal Care; FSW: Female Sex Worker; MSM: Men who have Sex with Men; NAP: National AIDS Program; NSP: National Strategic Plan to fight HIV/AIDS; PITC: Provider-Initiated Testing and Counselling; PLHIV: People living with HIV/AIDS; PWID: Persons who Inject Drugs; STI: Sexually Transmitted Infections; TB: Tuberculosis; VCT: Voluntary Testing and Counselling

Introduction

UNAIDS has established the 90-90-90 goals which call for 90% of people living with HIV (PLHIV) knowing their status, 90% of

them on ART and 90% of them virally suppressed by 2020, as a cornerstone of the 'Fast Track' initiative to eliminate HIV as a public health problem by 2030 [1]. Many countries committed to these goals, including Morocco. In 2020, these cascade of care goals were renewed and updated by UNAIDS to become 95%, 95% and 95% within all subpopulations and age groups by 2025 [2]. The 'first 90' goal of 90% HIV serostatus knowledge (abbreviated: 90% knowledge status) hinges critically on scale-up of HIV testing, for which the World Health Organization issued several guidelines, addressing recommended target groups, testing algorithms and delivery modalities or approaches suitable to different epidemic contexts [3,4].

Morocco's Ministry of Health and partners, through its 2017-2021 National HIV Strategic Plan (NSP), adopted the 90% knowledge status target for the year 2021 (abbreviated: 90% knowledge status) [5]. A subsequent extension to this NSP, evaluating progress up to 2017, moved the 90% knowledge target to year 2023, to be achieved by scaling-up the annual tests to around 1.2 million tests annually [6].

In 2015 Morocco's National HIV/AIDS Program (NAP) had achieved a test positivity rate of 0.20% (1,343 new diagnoses out of 673,498 tests; Supplementary Information 1). This represents a good yield within this concentrated epidemic with national adult HIV prevalence of only 0.09% [7], indicating its effectively reaching higher-prevalence groups. By 2019, despite an estimated stable prevalence since 2015, yield had improved to be 0.35%, reflecting 1,385 new cases diagnosed among 390,363 tests, the latter being a temporarily lower annual service volume due to a stock-out in tests that year. The improved yield reflected increased testing among MSM and additional higher-risk or vulnerable populations, including workers in higher-risk occupations (e.g. truck drivers), and an accelerated roll-out of testing facilities and services in regions with higher prevalence, such as Sous Massa, Drâa and Southern Morocco [8]. Furthermore, testing yield had increased within the target groups of migrants, PWID and STI patients (Supplementary Information 1). In 2015, testing coverage, knowledge status and coverage of ART were much higher in women than in men; these inequalities had reduced by 2019 with an accelerated progress among men.

We used the epidemiological model *Goals HIV Testing model* [9,10] to estimate Morocco's progress in rolling-out HIV testing and strategies to reach the 90% knowledge target by 2023. The model calculates numbers of tests, new diagnoses and resulting change in knowledge status and ART coverage, from user-inputted testing coverage's, in turn for 13 possible testing program target groups, which are characterized by their population size, HIV prevalence, current knowledge status and testing and ART coverage.

As a first use case of this new model, this article describes the model calibration to Morocco's surveillance and program data for year 2019, and the results of alternative testing scale-up scenarios for the national HIV/AIDS program over 2021-2030, in terms of new diagnoses, testing yield, knowledge status, ART coverage and cost.

Methods

Goals Testing Model

The Goals HIV testing model [9,10] is a freely available web application, that calculates numbers of tests, new diagnoses and resulting change in knowledge status and ART coverage from user-set coverage targets, for 13 population groups that differ in population size, HIV prevalence, current knowledge of status and ART coverage. For each group, test coverage can be specified for up to 9 testing approaches (including facility-based testing, community-based testing, self-testing and partner testing), which may vary in the rate of linkage to ART and/or in test cost.

Calibration to Morocco

The model was calibrated for 2019 as the starting year, based on Morocco's survey and surveillance data, NAP-reported testing volumes, testing yield and ART numbers (Supplementary Information 1; [5,11-17]), and the program's latest national estimates of HIV prevalence [7,18]. Specific sources and assumptions for each parameter and group, based on data from 2015-2019, are detailed in Supplementary Information 2.

Starting from 13 groups distinguished by default in the model, three groups with very low HIV prevalence (partners of pregnant women in ANC, infants born to HIV-infected women and other children) and testing yield in Morocco were substituted by three groups of higher relevance to the national testing strategy and with existing program data and testing targets: migrants, prisoners, and male clients of FSW (considered to include most male STI patients; Table 1 and Supplementary Information 2). Having dropped infants and children, the model thus focused on the national population aged 15 years and above.

In order to fit Morocco's high yield of new diagnoses in women observed in 2019 (Supplementary Information 1) alongside program-recorded number already diagnosed and on ART (Supplementary Information 1), we assumed that in 2019 there were 10,000 women PLHIV, which is mid-way between the point estimate and upper-bound of the 2020 national estimation [7]. For men, the point estimate of the official estimation was retained.

This calibration was broadly coherent with the 2019 program data (1,385 newly diagnosed cases, i.e. 0.35% of 390,363 tests. In the model, 390,195 tests conducted in 2019 were estimated to have yielded 1,122 new cases, corresponding to a yield of 0.29% (Table 1). For men, this calibration estimated 612 new diagnoses in 2019, which represents 84% of the reported new male cases; for women the calibration estimated 510 new cases or 78% of the 654 female cases reported.

Table 1: Morocco's population and HIV-infected population, by target group, knowledge status, ART and testing coverage, in the calibrated model, 2019

Population group	Population	PLHIV	Diagnosed	On ART	HIV prevalence	Test yield	Coverage (persons of unknown status)	Tests	New diagnoses
Pregnant women in ANC	681,512	582	200	200	0.09%	0.06%	14%	97,230	55
Migrants	30,000	1,050	368	327	3.5%	3.9%	18%	5,809	227
Women STI patients	338,858	1,870	1,459	1,317	0.55%	0.12%	5%	15,249	19
Prisoners	86,384	195	68	61	0.23%	0.25%	32%	30,159	75
FSW	73,417	1,248	874	789	1.7%	0.88%	36%	28,700	252
MSM	42,826	1,400	672	598	3.3%	1.7%	35%	14,639	253
PWID	1,223	87	52	46	7.1%	3.0%	37%	434	13
TB patients	32,606	587	425	378	1.8%	0.50%	39%	12,597	63
Partners of new index cases	1,385	201	145	129	14.5%	7.6%	15%	208	16
Patients w. HIV symptoms	206,813	2,810	2,192	1,979	1.4%	0.51%	1.6%	3,650	19
FSW clients, with or without STI	734,178	4,052	2,743	2,445	0.55%	0.30%	5%	40,229	122
Other women	12,234,821	3,986	3,752	3,373	0.033%	0.003%	0.77%	103,231	3
Other men	12,179,334	3,953	2,990	2,647	0.032%	0.013%	0.28%	38,060	5
Women, 15+ years	**13,466,599**	**10,000**	**7,803**	**7,044**	**0.074%**	**0.20%**	**1.9%**	**257,738**	**510**
Men, 15+ years	**13,176,759**	**12,020**	**8,137**	**7,247**	**0.091%**	**0.46%**	**1.0%**	**132,457**	**612**
Total, 15+ years	**26,643,358**	**22,020**	**15,940**	**14,290**	**0.083%**	**0.29%**	**1.5%**	**390,195**	**1,122**
		Knowledge status		**Linked into ART**		**Coverage ART**			
Women, 15+ years			78%	90%		70%			
Men, 15+ years			68%	89%		60%			
Total, 15+ years			**72%**	**90%**		**65%**			

Legend of Table 1: See Supplementary Information 2 for explanation of group-specific data sources and assumptions. Other model parameters were set as follows:

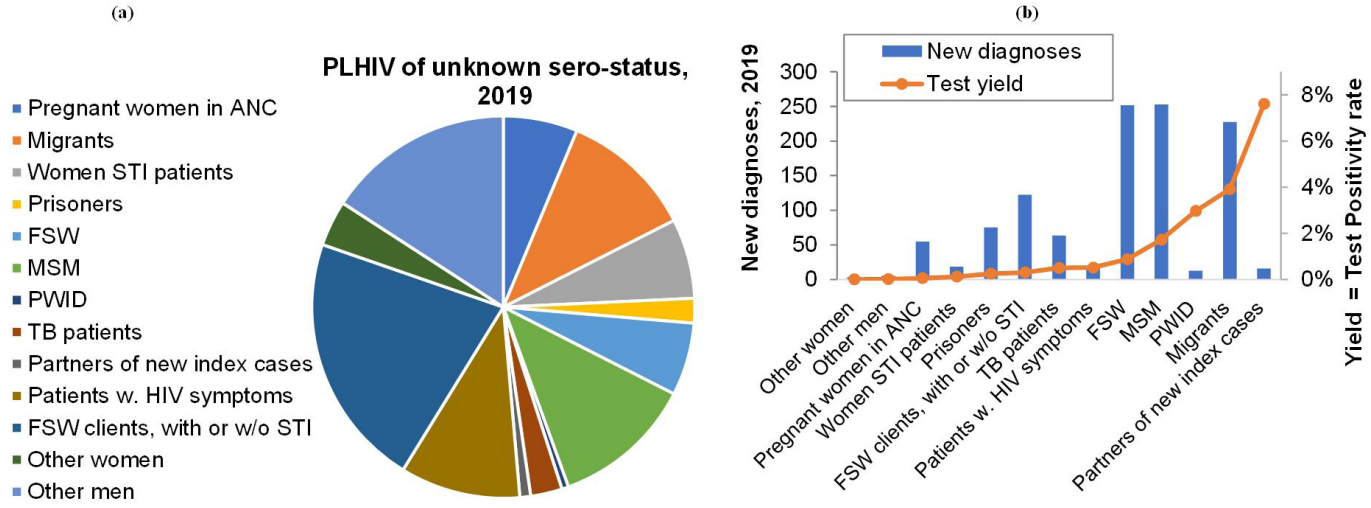
- Ratio of testing by HIV-infected relative to uninfected people of 1.7, applied to 8 groups, excepting pregnant women in ANC, and STI and TB patients (as their testing is initiated by the provider and universal) and MSM and PWID (so as to better calibrate the low yield reported 2019, compared to the group prevalence estimated in AIM 2020 [7]).
- Mortality rate among PLHIV, with or without ART 0.013 per year;
- Population growth 1.0% per year, as for the population of PLHIV between 2019 and 2023 in a Spectrum AIM projection that reaches 81% ART coverage from 2023 [7];
- Re-testing within the same year: factor 1.10, i.e. every 110 tests include 100 people tested (sum between HIV-infected and uninfected), of whom 10 tested twice (which increases the test volume compared to yield of new diagnoses), applied to testing modalities that involve client initiative to get tested, which in Morocco's calibration covered Migrants, FSW, Clients of FSW, Partners of newly diagnosed (index) cases, Patients with HIV symptoms and 'Other' women and men.
- 0 re-testing by known PLHIV not on ART.
- Annual transition from testing target groups to the group of Other women or Other men: 33% for pregnant women in ANC and female STI patients; 50% for TB patients and partners of newly diagnosed (index) cases; 10% (as in AIM 2020 [7]) for migrants, prisoners, PWID, FSW clients and Patients with HIV symptoms.
- Linkage to care and ART, as percentage of known PLHIV: 90.3% for women and 89.1% for men; 89.6% for all adults 15 years and above.

Possible reasons for the slightly lower yield and case volume in the model compared to data include that:

- Female prevalence may have been higher than assumed;
- Some reported diagnoses may have been not really new but duplicate/repeat diagnoses and/or duplicate recordings (which seems plausible especially for tests done among lower-risk populations, since as of 2019 Morocco's testing program used unique patient identifiers only for the key populations MSM, FSW and IDU);
- A possible over-stated number of PLHIV knowing their status, which had been estimated based on national HIV/AIDS case notifications since 1986, with a possibly too small adjustment for mortality, which had been based on cohort analysis among PLHIV notified within 2015-2019 only [19];
- A possible under-reporting of negative tests.

The calibrated model adequately reproduced the ranking of testing yield across target groups, yield being highest among partners of newly diagnosed (index) patients, migrants, PWID, FSW, MSM and patients with symptoms of HIV/AIDS (Figure 1b). Based on yield, the number of PLHIV undiagnosed (Figure 1a) and current testing coverage, the groups that contributed most new diagnoses in 2019 were MSM, migrants, and FSW and their clients (Figure 1b).

Figure 1: (a) Distribution between possible testing target groups of **(a)** PLHIV not knowing their status; **(b)** tests and testing yield, in the model calibrated to Morocco, 2019



Scale-up scenarios

We modelled three scenarios for the scale-up of HIV testing starting in 2020 (Table 2):

Table 2: Testing coverage targets and summary results of 3 scale-up scenarios, compared to 2019 baseline

Testing Coverage, 2023	2019 baseline	NSP Extension Plan	Maximum	Maximum + Yield maintained
Pregnant women in ANC	14%	95%	95%	20%
Migrants	18%	70%	85%	5%
Women STI patients	5%	70%	85%	85%
Prisoners	32%	70%	85%	5%
FSW	36%	70%	85%	11%
MSM	35%	70%	85%	7%
PWID	37%	85%	90%	9%
TB patients	39%	95%	95%	15%
Partners of new index cases	15%	70%	85%	13%
Patients with HIV symptoms	2%	50%	95%	17%
FSW clients, with or w/o STI	5%	20%	60%	26%
Other women	0.77%	0.77%	0.77%	0.77%
Other men	0.28%	0.28%	0.28%	0.28%
	2019:	**2023:**	**2023:**	
PLHIV	22,020	22,915	22,915	As in scenario Maximum
New cases diagnosed, 2020-23 total		6,381	8,402	
PLHIV remaining without diagnosis, 2019 or 2023	6,080	2,469	1,619	
Knowledge status, 2019 or 2023	72%	**89%**	**93%**	
ART coverage, 2019 or 2023	65%	80%	86%	
Knowledge status, 2025		**91%**	**93%**	
ART coverage, 2025		83%	87%	
Persons tested, 2019 or 2023	390,195	1,548,649	2,070,826	861,442
Test volume (incl. confirmatory tests), 2019 or 2023	391,317	1,549,679	2,071,617	862,232
Cost, 2019 or 2023 (US$)	513,352	2,324,131	3,068,376	1,277,096
Test yield, 2019 or 2023	0.29%	0.07%	0.04%	0.09%
Test yield, 2020-23 overall		0.14%	0.15%	0.20%

Legend of Table 2: Testing coverage is expressed as people tested divided by the sum of HIV-negative people + PLHIV not yet diagnosed in the given year.

NSP Extension: Testing coverage targets of the *2023 Extension to the National Strategic Plan [5]* to the 2017-2021 NSP, for all populations concerned. Additionally, similarly high coverage targets for patients of newly diagnosed (index) patients, clients of FSW and patients with symptoms of HIV, for whom the actual extension plan had not set targets.

Maximum: Coverage increased above those of the *NSP Extension* scenario, to target levels judged the maximum optimistically conceivable in Morocco's context.

Maximum + Yield maintained: As many new cases diagnosed in each group as in the Maximum scenario, but realized with a lower testing coverage and volume, thanks to an improved yield stipulated to never fall below 50% of the yield in 2019 in each group. This scenario thus assumes that efforts by HIV/AIDS programs to improve yields through index testing and risk assessment tools will more than compensate the effect of diminishing returns expected from increasing knowledge status and fewer HIV-positive undiagnosed cases remaining in the group being tested.

Costing

Costs of testing were calculated according to the annual test volume, multiplied by a test unit cost. Unit costs were based on procurement budgets and spending by the national HIV/AIDS program. We did not consider additional indirect costs (of personnel, distribution, infrastructure or program management), as these fall outside of the scope and budget of the NAP.

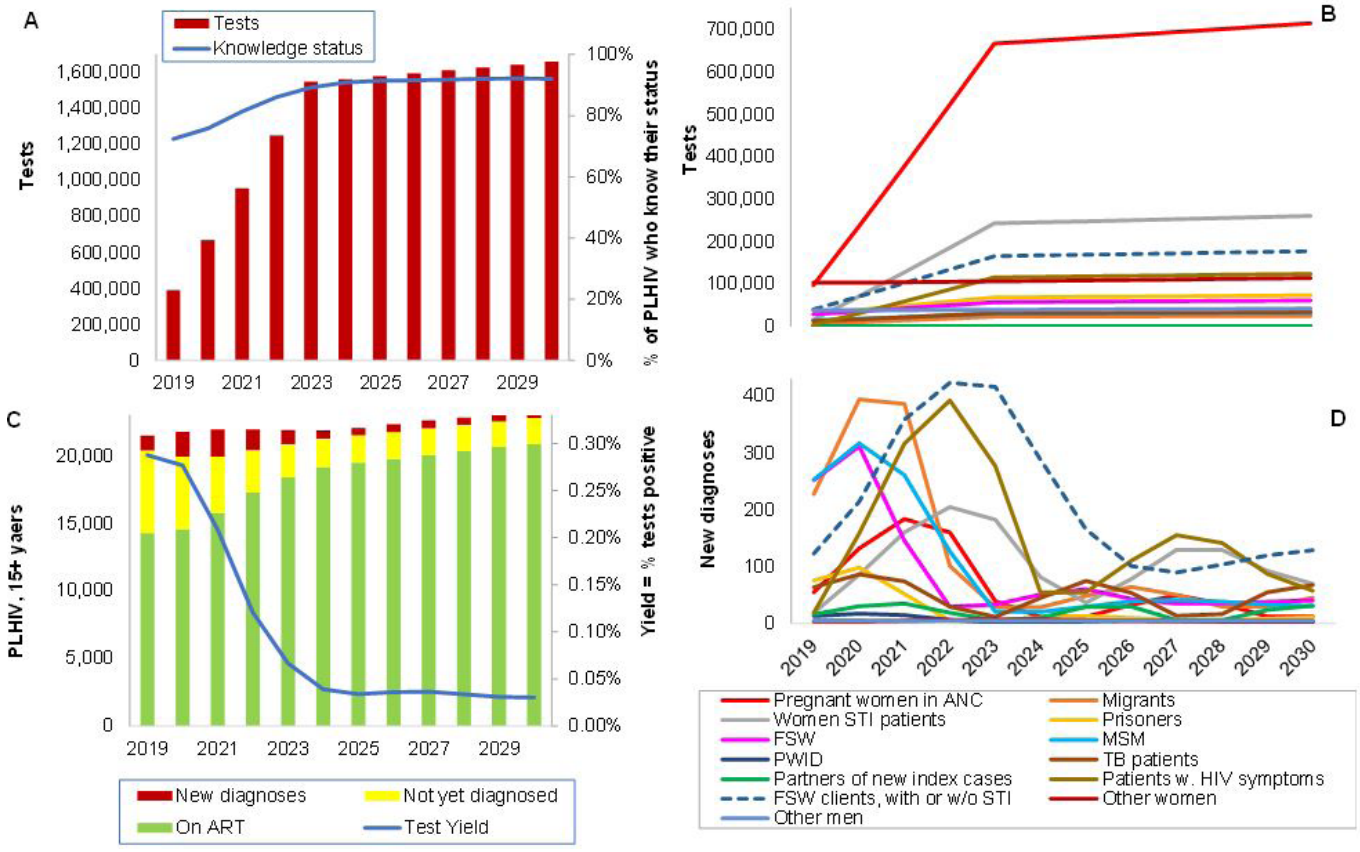
In 2020, the test procurement cost was US$ 0.79 for single HIV tests, US$ 1.71 for dual HIV/syphilis tests used in antenatal care, in STI clinics and for some tests among FSW and MSM and US$ 3.39 for HIV self-tests, used to test FSW, MSM and other higher-risk groups (Supplementary Information 3). In comparison, a National AIDS Spending Assessment covering the period 2016-2017 [20] had estimated the single-test cost at US$ 0.87.

Confirmatory tests were costed for each new diagnosis, at a unit cost of US$ 7.0 [21] – to represent the three-test strategy recommended by the WHO for low-prevalence settings [4].

Outcome measures

Comparison of scenario focused on the outcome measures: new diagnoses, proportion of PLHIV knowing their status, and tests needed (i.e. persons tested, and the total tests including confirmatory tests) and testing cost. Knowledge status was evaluated at 2023, the end-year of Morocco's current NSP Extension, and 2025, the end-year for the next NSP being drafted. Test need and cost were evaluated for the year 2023, as well as cumulated over 2020-2023.

Figure 2: Annual results of scenario 'NSP Extension', 2019-2030: **(A)** Total test need and knowledge of sero-status among PLHIV; **(B)** Tests by population group; **(C)** distribution of PLHIV by serostatus knowledge and ART status; **(D)** new diagnoses by population group



Legend of Figure 2: panels (b) and (d) share the same legend and x-axis values (years), shown below panel (d)

Additionally, we evaluated the cost-per-new-diagnosis, a validated indicator of the cost-effectiveness of HIV testing programs [22]. This indicator was evaluated averaged over 2020-2023, considering that the indicator will evolve within this period, as new diagnoses start to reduce undiagnosed prevalence and thus yield.

Ethics statement

The study did not involve new data collection on living subjects; no ethics approval was required.

Results

New cases diagnosed, knowledge status and tests required

In the model, the *NSP Extension* scenario would yield 6,381 new diagnoses between 2020-2023 (Table 2). Knowledge status increases from 72% at 2019 to 89% by 2023, and 91% by 2025 (Figure 2a). This scenario leaves 2,469 PLVIH undiagnosed in 2023 (Table 2 and Figure 2c). The result is achieved through a projected increase in the number of people tested annually from 669,000 in 2020 to 1.55 million in 2023 (Figure 2b). As new cases are detected, annual yield starts to fall (Figure 2d).

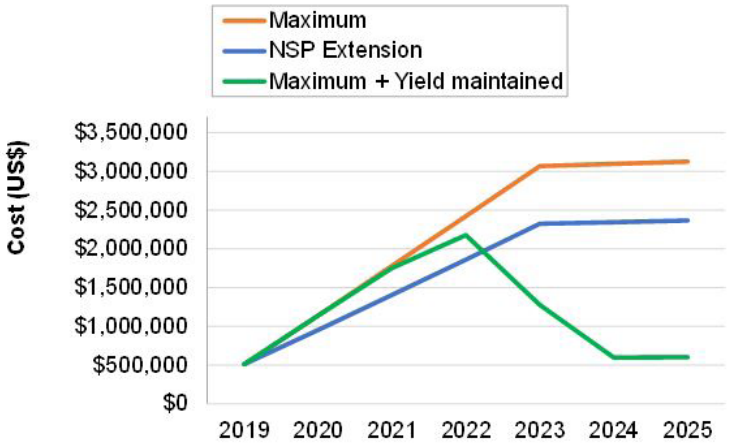
Scenario *Maximum* diagnoses 8,402 new cases and achieves 93% knowledge status by 2023 already. The increased coverage required for this implies an increase in numbers of people tested annually, reaching 2.07 million in 2023 alone.

Scenario *Maximum + Yield maintained* supposes that overall testing yield does not fall below 0.09% in 2023, which thus remains well above the (stable) national HIV prevalence. The yield in 2023 is 2.4-fold better than that under the *Maximum* scenario, with a corresponding reduction (saving) in tests needed: no more than 862,000 tests in 2023 (Table 2).

Costs

In the scenario *NSP Extension*, annual cost is US$ 1.64 million averaged over 2020-2023, and $ 2.32 million in 2023 alone. In descending order, the groups incurring the highest testing cost, cumulated over 2020-2023, are: pregnant women, women STI patients, FSW clients, and FSW. In scenario *Maximum*, the annual cost reaches US$ 3.07 million in 2023. Scenario *Maximum + Yield maintained* reduce this cost to US$ 1.28 million (Figure 3).

Figure 3: Annual testing cost, by scenario



Of this overall testing cost, in 2023 0.68%, 0.70% and 1.68% was for confirmatory tests in the three successive scenarios, in proportion to the respective testing yields.

Cost per new diagnosis

The cost per new diagnosis, averaged over 2020-2023 for the scenario *NSP Extension*, is low i.e. favorable for partners of newly diagnosed (index) patients, migrants, patients with HIV symptoms, HSH, TB patients and FSW and their clients (Table 3).

It is high for pregnant women tested in ANC, with low prevalence and undiagnosed prevalence. Cost per new diagnosis is highest for 'other' women and men, among whom in the model calibration the undiagnosed prevalence and numbers of new diagnoses are lowest (Table 1).

Table 3: Cost (US$) and cost per new diagnosis, 2020-2023 total, in the scenario *NSP Extension*, by population targeted

Population target group	Tests	Cost	New diagnoses	Yield	Cost per diagnosis	Rank order
Pregnant women in ANC	1,797,048	$ 3,080,915	514	0.029%	$ 5,999	11
Migrants	65,956	$ 58,554	909	1.38%	$ 64	2
Women STI patients	625,244	$ 1,075,120	633	0.10%	$ 1,697	10
Prisoners	214,825	$ 171,107	159	0.074%	$ 1,074	9
FSW	185,144	$ 413,928	519	0.28%	$ 798	8
MSM	96,405	$ 218,712	724	0.75%	$ 302	5
PWID	3,138	$ 2,754	39	1.23%	$ 71	3
TB patients	96,704	$ 77,926	201	0.21%	$ 389	6
Partners of new index cases	2,678	$ 2,739	89	3.31%	$ 31	1
Patients with HIV symptoms	292,324	$ 239,324	1,144	0.39%	$ 209	4
FSW clients, with or without STI	471,129	$ 750,173	1,412	0.30%	$ 531	7
Other women	419,164	$ 331,829	20	0.005%	$ 16,335	13
Other men	154,539	$ 122,416	18	0.012%	$ 6,680	12
All adults 15+ years	**4,424,300**	**$ 6,545,498**	**6,381**	**0.144%**	**$ 1,026**	

Legend of Table 3: The ranking by cost-effectiveness, in the right-most column, indicates the group with lowest, most favourable cost per new diagnoses as rank 1.

Discussion

Morocco's NAP achieved a good yield of HIV testing over 2015-2019, thanks to its effective targeting of groups with high prevalence and low historic testing access. In order to achieve 90% knowledge status by 2023 within an affordable testing budget, our modeled scenarios show a need to further improve targeting to groups and individuals with the highest undiagnosed prevalence, beyond known key groups and including for example clients of FSW, patients with symptoms of HIV, and partners of newly diagnosed (index) patients and possibly even additional new vulnerable groups.

While the scenarios presented consistently highlight which groups have most undiagnosed cases and highest undiagnosed prevalence, and the numbers of new diagnoses needed in each group, the two variants of scenario *Maximum* illustrated substantial uncertainty in numbers of tests required, as a function of the expected testing yield. Obeying the mathematical rule of diminishing returns, testing yield will fall as most cases get diagnosed. In programmatic practice, this need not always occur: Morocco's testing yield improved from 2015 to 2019 despite improving knowledge status, and certain programs in other countries also documented success in improving and maintaining high testing yield, thanks to smart targeting and triaging of tests. Scenario *Maximum + Yield maintained* illustrates the strong (2.4-fold) saving that maintaining high testing yield may make to the testing need and cost: from 2.3 million people tested at a yield of 0.04%, to 862,000 people tested at a yield of 0.09% (Table 2) in 2023.

Strategies recommended to maintain or improve test yield, according to WHO guidelines and experiences in countries, include establishing locally validated risk score algorithms that identify the highest-risk persons within a given testing setting, and promoting self-testing among groups known for a lesser uptake of provider-initiated testing or other public testing services, and social networking strategies that efficiently identify higher-risk contacts beyond direct, known sexual partners of newly diagnosed people [4,19].

Limitations

The model and its calibration revealed several limitations and uncertainties concerning optimal testing strategies and expected results, as well as about Morocco's epidemic situation.

The model calibration to national surveillance and NAP data assumed a higher female HIV prevalence than Morocco's latest official estimate. This illustrates an uncertainty in Morocco's burden and service coverage of HIV among women, which as of 2019 was based on only 18% screening coverage among pregnant women. Expanding HIV screening to all women attending ANC should make data more representative. Ideally, expanding surveillance beyond ANC would corroborate HIV prevalence trends for non-pregnant, non-key groups.

The related uncertainty in Morocco's current knowledge status and ART coverage (among all PLHIV and those knowing their status) invites scrutiny on earlier estimations on the country's cascade of HIV care. These relied on HIV/AIDS case notifications since 1986, with adjustment for mortality [19] – which, reflecting mortality observed among patients diagnosed after 2015 only, may have been insufficient. Compounding this possible bias, notifications-based estimates of PLHIV diagnosed and alive may have overlooked some duplicate diagnoses (repeat diagnoses and/or double-reporting) – as has been noted in notification databases in other settings.

Related, the incidence of new HIV infections within the projection period is inevitably uncertain. Annual new infections assumed for 2020-2025 followed the official 2020 estimation, with a progressive decline, in response to ART coverage reaching 85% by 2023. If in reality Morocco's incidence would be higher, more additional diagnoses and tests would be needed than projected, or alternatively the presented scenarios would reach a lower knowledge status. Conversely, an accelerated incidence reduction, for example thanks to progress in primary HIV prevention, another pillar of Morocco's HIV/AIDS strategy, would make testing and knowledge status targets easier to reach. Also social distancing practiced since 2020 as part of the response to the Coronavirus disease 2019 (COVID-19) pandemic may temporarily reduce HIV incidence, for example by reducing commercial sex – as long as such behavioural effects are not overridden by the adverse effect of HIV service disruption (e.g. condom distribution and ART dispensing).

In the model's structure, an inherent uncertainty is how much people move between groups, for example, a FSW returning to the population of 'Other women'. Such movement means that high testing rates in special populations with high turnover, such as pregnant women, will contribute to high knowledge of status among other men and women, even if testing in the latter groups is not scaled-up. The more transitioning among groups, the lesser the testing need to achieve a given overall knowledge status. However, transition parameters are difficult to estimate directly from available data, thus compounding uncertainty in predicted test volumes needed to achieve targeted new diagnoses and knowledge status.

Concerning Morocco's scale-up scenarios, a particular uncertainty concerns testing targets for patients with HIV/AIDS symptoms. While this group contributed little to testing yield recorded by Morocco's program in 2019 (Supplementary Information 1), the calibration assumed this is a large group with high prevalence (almost as high as FSW) but as yet low coverage. These assumptions were based on relatively little data from multiple sources [16,17], contrasting with more systematic, continuous surveillance and monitoring data used for established program target groups (Supplementary Information 2). The massive coverage increase stipulated for patients with symptoms, from 3,650 tests (1.8% of 209,470 persons) in 2019 to 50% in the *NSP Extension* and 95% in the *Maximum* scenario, was a large and critical contributor to projected impact across all scenarios (Figure 2b and d), but its feasibility remains to be demonstrated.

Projected costs per new case should be interpreted with at least two nuances. Firstly, this cost will evolve and increase rapidly with progress toward the 90% knowledge status target in a given group. For example, within 2020-2021 only, FSW are among the groups with lowest cost per new diagnosis (lower than for their clients), but by 2023 this pattern inverses, such that accumulated over 2020-2023 (Table 3) FSW clients, with a lower coverage target and so lesser decrease in yield, have an overall lower cost per new diagnosis. This implies that testing strategies must be dynamic, and evaluated and possibly adapted as knowledge status and the distribution of remaining undiagnosed cases evolve-probably within less than 4-5 years cycles. As knowledge status improves in a targeted group, complementary approaches are indicated to maintain high yield, such as notification of partners.

Secondly, the cost per new diagnosis cannot be the only basis for programmatic prioritization. Other important factors include: the demand for testing from the population, synergies between testing and other health services with benefits beyond HIV diagnoses, and social and ethical consideration. Notably, ANC-based testing had among highest cost per new diagnosis in our projections, however it is the cornerstone for eliminating Mother-to-Child-transmission of HIV, which is highly cost-effective in terms of averting future HIV infections, including in low-prevalence settings like Morocco [23], and a target of Morocco's NSP [5,6] – whereas our cost-effectiveness analysis ignored the benefits of diagnoses among infants. Moreover, while the cost of ANC-based HIV testing may be high compared to HIV program testing budgets, it is only modest in the context of overall ANC service costs, and may not necessarily be borne by the HIV program.

Similarly, cost-effectiveness results would change when focusing on new ART enrolments or even health gains among diagnosed HIV cases – and notably rank higher the group of patients with symptoms of HIV/AIDS, compared to testing target groups where HIV cases would on average be in earlier stages of disease.

Finally, the cost projections considered varying mixes of HIV test types used among different target groups, but not any costs beyond test procurement – which may vary with testing modality and target group. For example, overhead costs may be relatively low among prisoners, compared to groups whose testing incurs higher outreach costs.

As a follow-up to the current study, Morocco's national model calibration is being validated by a refined application at sub-national level, using province-level data, whose results are beyond the scope of this article but which will add insights into geographical variations in the national HIV epidemic, response and surveillance data.

Conclusions

In conclusion, this analysis documents the success and ongoing improvement of Morocco's national HIV/AIDS program in rolling-out HIV testing and ART coverage. With a view to achieving 90% serostatus knowledge status within an affordable testing budget, the new model's application shows a need to further improve targeting to groups and individuals with highest undiagnosed prevalence, beyond known key groups, and adapting strategies to ensure continued high yield.

Despite several uncertainties discussed, we believe the presented projections provide a valid semi-quantitative guide to optimizing Morocco's national testing program, notably in terms of key groups to target, and numbers of new diagnoses needed to achieve near-universal knowledge status and epidemic control. In this decade of concurrent pandemics and health sector challenges, the Goals HIV testing model is a useful tool to help Ministries of Health rationalize infection testing strategies and targets and optimize health outcomes.

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Supplementary Information

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