# Scaling up of HIV treatment for men who have sex with men in Bangkok: a modelling and costing study

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## Summary

**Background** **Despite the high prevalence of HIV in men who have sex with men (MSM) in Bangkok, little investment in HIV prevention for MSM has been made. HIV testing and treatment coverage remains low. Through a pragmatic programme-planning approach, we assess possible service linkage and provision of HIV testing and antiretroviral treatment (ART) to MSM in Bangkok, and the most cost-effective scale-up strategy.**

**Methods** **We obtained epidemiological and service capacity data from the Thai National Health Security Office database for 2011. We surveyed 13 representative medical facilities for detailed operational costs of HIV-related services for sexually active MSM (defined as having sex with men in the past 12 months) in metropolitan Bangkok. We estimated the costs of various ART scale-up scenarios, accounting for geographical accessibility across Bangkok. We used an HIV transmission population-based model to assess the cost-effectiveness of the scenarios.**

**Findings** **For present HIV testing (23% [95% CI 17–36] of MSM at high risk in 2011) and ART provision (20% of treatment-eligible MSM at high risk on ART in 2011) to be sustained, a US$73·8 million ($51·0 million to $97·0 million) investment during the next decade would be needed, which would link an extra 43 000 (27 900–58 000) MSM at high risk to HIV testing and 5100 (3500–6700) to ART, achieving an ART coverage of 44% for MSM at high risk in 2022. An additional $55·3 million investment would link an extra 46 700 (30 300–63 200) MSM to HIV testing and 12 600 (8800–16 600) to ART, achieving universal ART coverage of this population by 2022. This increased investment is achievable within present infrastructure capacity. Consequently, an estimated 5100 (3600–6700) HIV-related deaths and 3700 (2600–4900) new infections could be averted in MSM by 2022, corresponding to a 53% reduction in deaths and a 35% reduction in infections from 2012 levels. The expansion would cost an estimated $10 809 (9071–13 274) for each HIV-related death, $14 783 (12 389–17 960) per new infection averted, and $351 (290–424) per disability-adjusted life-year averted.**

**Interpretation** **Spare capacity in Bangkok's medical facilities can be used to expand ART access for MSM with large epidemiological benefits. The expansion needs increased funding directed to MSM services, but given the epidemiological trends, is probably cost effective. Our modelling approach and outcomes are likely to be applicable to other settings.**

**Funding** **World Bank Group and Australian National Health and Medical Research Council.**

*Lancet HIV* 2015

Published Online
March 30, 2015
http://dx.doi.org/10.1016/S2352-3018(15)00020-X

See Online/Comment
http://dx.doi.org/10.1016/S2352-3018(15)00036-3

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## Introduction

Thailand is one of the Asian countries most severely affected by HIV. The country has a population of more than 67 million, 440 000 of whom have HIV. 70% of people with HIV live in 33 of 76 Thai provinces.[1] HIV transmission is predominantly by commercial sex, injecting drug use, and unprotected anal intercourse in men who have sex with men (MSM). Although intervention programmes have effectively targeted female sex workers and people who inject drugs, the Thai national response to HIV in MSM has been largely neglected and, consequently, HIV prevalence in MSM was 20–30% in 2011, and has been increasing.[2] Transmission by unprotected anal intercourse in MSM accounts for about 60% of 43 040 new HIV infections predicted in Thailand from 2012 to 2016 according to the Asian Epidemic Model.[3] The long-term health and economic costs of this epidemic, if allowed to continue, will be substantial. Despite this prediction, investment in prevention for MSM accounted for only 1·3% of the total budget in the 10th National HIV Plan.[4] The Thai Government invested more than US$270 million in its HIV response in 2013 and has committed to increase its domestic expenditure by $75 million in 2015–17, and by $100 million between 2013 and 2022.[1] Optimisation of these resources to maximise population health benefits is therefore a top priority. Findings from an independent allocative efficiency study based on epidemiology and the cost of programmes suggested that at least 12% of the planned government budget for the Thai national HIV response during 2013–22 should be allocated to MSM to minimise the number of new infections (Zhang L and colleagues, unpublished).

In view of the need to prioritise geographical areas, population groups, and programmes for greatest effect,[5] we examine what is pragmatically needed in infrastructure and what is the most cost-efficient expansion pathway for the scaling up of testing and treatment to MSM in Bangkok, Thailand. About a third of the total population of MSM in Bangkok are at high risk of HIV,[6] characterised by their young age, many partnerships, inconsistent condom use, and high-risk sexual activities in MSM hotspots.[7] In

metropolitan Bangkok, HIV prevalence in MSM at high risk reportedly increased from 21% to 28% in the past decade,[8,9] and incidence has been as high as 7·7 per 100 person-years.[8] The Bangkok Metropolitan Administration (BMA) has responded to the HIV epidemic in MSM with the *Bangkok: getting to zero* initiative.[10] MSM are encouraged to take up free HIV testing at public and research clinics twice a year. Antiretroviral treatment (ART) is free to eligible patients (during the study period, patients were eligible if they had a CD4 count of less than 350 cells per µL; however, from Oct 1, 2014, ART eligibility is irrespective of CD4 count). Despite these initiatives, societal stigma and discrimination against MSM is still widely prevalent in Thailand and undermines the HIV response effort. HIV-positive MSM can experience stigma in response to their sexual orientation and their infection status.[11] In Thai MSM, stigmatisation is one of the major reasons for poor treatment received from primary care,[12] poor uptake of voluntary HIV testing, absence of serostatus disclosure to partners,[13] delay in access to health care,[14] depression, and isolation.[15] In 2011, the UN high-level meeting on HIV/AIDS adopted epidemiological targets of reduction of new HIV infections and HIV-related mortality by 50% by 2015.[16] Although attainment of these specific targets will lead to substantial progress towards ending AIDS, to achieve them by 2015 is no longer possible. In this study, we investigate the financial commitment needed to halve HIV-related deaths and new infections during 2013–22. Specifically, this study has two main objectives: to assess the cost, service load, and capacity of Bangkok's health facilities for linking and providing HIV testing and ART programmes to MSM at high risk of HIV; and to identify (on the basis of costs of service provision) the most effective strategy to allocate available and additional resources to achieve universal ART coverage (80% of treatment-eligible patients) and to minimise the number of new HIV cases and HIV-related deaths in MSM in Bangkok.

For the **National Health Security Office website** see http://www.nhso.go.th/eng/Site/Default.aspx

For the **Adam's Love website** see http://www.adamslove.org

See Online for appendix

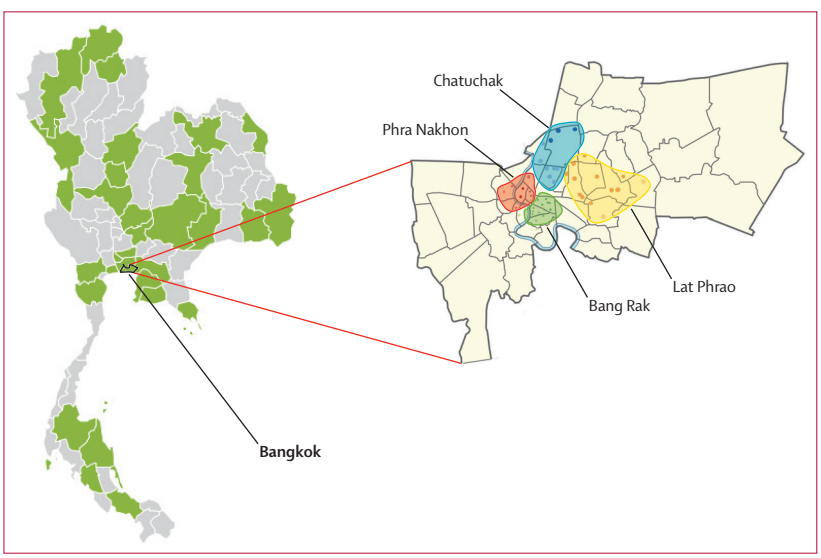


***Figure 1:*** **Distribution of people living with HIV and men who have sex with men hotspots in Bangkok**
The shaded 33 of 76 provinces in Thailand account for 70% of people living with HIV. Four districts of concentrated MSM activity (hotspots) in metropolitan Bangkok are shown. Reproduced with permission from the Joint UN Programme on HIV/AIDS.[1]

## Methods

### Target population

We included the population of sexually active MSM (defined as having had male-to-male sex in the past 12 months) in metropolitan Bangkok. We did not distinguish between further subgroups of MSM. However, we defined those who have engaged in condomless sex with casual or known HIV-positive partners as MSM at high risk. This subgroup accounts for about a third of all MSM in Bangkok.[6] We also assumed that MSM who used health facilities were also representative of this most at-risk subgroup of MSM in Bangkok in terms of their demographics and sexual behaviour.

### Epidemiological data

We collated and synthesised epidemiological and behavioural indicators related to MSM in Bangkok from a review of the scientific literature from Jan 1, 2000, to Dec 31, 2012. We obtained data from public peer-reviewed scientific literature domains, grey literature, and databases of the Thai Ministry of Public Health or HIV clinics in Bangkok. We used the National Health Security Office (NHSO) database to obtain data for health-care-seeking behaviours. NHSO programmes provided free HIV testing twice a year to Thai citizens via NHSO-registered facilities. For people living with HIV and supported by the NHSO scheme (about 80% of Thai people living with HIV), NHSO also provides free ART and CD4 cell count, viral load, and resistance testing when needed. NHSO-registered sites are obligated to report all test results to the Thai Ministry of Public Health.

Mapping of MSM hotspots in Bangkok was done through internet surveys via the Adam's Love website and experts (figure 1); we used this mapping information in this study. Mapped hotspots are related to venues frequented by MSM in Bangkok (appendix p 4). Venues mainly include saunas, spas, educational institutions, and department stores that are well known to MSM. On the basis of the location address recorded in the NHSO database, we estimated the walking distance from the facilities to the nearest MSM hotspot with Google Maps.

### Service load and capacity data

We did a telephone and postal survey to assess service load and capacity for HIV testing and ART services in all 91 NHSO-listed medical facilities across Bangkok in 2011 (appendix p 5). We define capacity as the ability to provide a specific minimum package of quality services to the target population with available resources, including infrastructure, personnel, commodities, and facilities, without extra investment. Specifically, we refer to sites able to test MSM for HIV and provide them with their results, link them to treatment sites, and initiate and maintain MSM

on ART. Public facilities and private hospitals can provide both testing and ART services, whereas clinics provide HIV testing services only. The survey had specific questions on capacity to provide HIV testing, ART, and treatment of HIV-related opportunistic infections and co-infections, and the capacity for HIV surveillance (appendix p 5). We assumed that spare capacity, which represents the capability to do further testing or ART services with available resources, could be prioritised for MSM. This assumption is because HIV prevalence is increasing in MSM, but decreasing elsewhere; testing is very low in MSM; and the MSM population is estimated to be three times greater than that of female sex workers and people who inject drugs in Thailand.[6]

### Costing data for service linkage and provision

In consultation with the Thai Ministry of Health, we reviewed available strategies for linkage of MSM at high risk to HIV testing and ART services during 2011–13. A full description of data collection processes is provided in the appendix (pp 21–25). In brief, we identified three major delivery models to connect MSM to HIV testing services: conventional peer-educator outreach; mobile point-of-care night clinics provided by Thai Red Cross AIDS Research Centre (TRCARC) and BMA clinics; and Adam's Love websites, with innovative follow-up technologies hosted by TRCARC. By contrast, only one service delivery model enables linkage of diagnosed HIV-positive MSM to treatment services. The AIDS Projects Management Group piloted the sole linkage programme (case-management model) to enable eligible HIV-positive MSM to connect to and be retained in ART services (appendix p 25). We collected indicators on programme spending and effectiveness through organisation internal reports and interviews with host organisation managers.

Of the 91 NHSO-listed medical facilities, we specifically chose 13 to collect detailed costing data on service provision (appendix pp 13–19). We selected these 13 sites on the basis of service volume, representativeness, and potential capacity to expand in the future. TRCARC collected data in conjunction with key personnel at each site.

### Modelling and assessment

We used a mathematical model to assess HIV epidemic trends and project the cost-effectiveness of investment scenarios. The epidemiological model, known as Optima, uses best-practice for HIV epidemic modelling techniques and incorporates biological transmission processes, infection progression, and sexual mixing patterns and other high-risk behaviours (appendix p 7).[17]

We investigate three ART scale-up scenarios to represent universal ART coverage of Bangkok high-risk MSM by 2022, 2017, and 2015. For each of these scenarios, we used an optimisation routine to identify the most economical way to achieve these targets. The two key optimisation indicators are the HIV testing rate and annual ART starting rate, as deemed possible through our survey information. The total costs of HIV services consist of costs for extra linkage to testing services, provision of HIV testing, and ART linkage and provision. The optimisation route minimises the total cost by finding the best combination of linkage and service provision strategies provided by various types of medical facilities (appendix pp 10–11).

We projected the trajectory of the HIV epidemic in MSM at high risk in Bangkok during 2013–22. The key indicators for effectiveness are the number of new HIV cases, deaths, and ART person-years in service provision. We estimated disability-adjusted life-years (DALYs) as a measure of the overall effect of HIV programmes and their cost-effectiveness. We obtained disability weights from the 2010 Global Burden of Disease Study.[18] On the basis of investment and forecasted epidemiological outcomes, we calculated key cost-effectiveness indicators, including cost of prevention of one HIV-related death, of one new HIV case, and of one DALY. We used a discounting rate of 3% for costs and DALYs (appendix p 12).

### Role of the funding source

The funder of the study had no role in data collection, data analysis, data interpretation, or writing of the report. The funder of the study provided review and input into study design, engaging with the Thai government to design practical implementation planning. The

| | Number of HIV testing sites | Total number of unused HIV tests per annum | Mean capacity used for HIV testing per site (%; n/N) | Proportion of testing clients who are MSM (%; n/N) | Number of ART sites | Total number of unused ARTs per annum | Mean capacity used for ART testing per site (%; n/N) |
|---|---|---|---|---|---|---|---|
| Public facilities* | 31 | 83 253 | 62% (4362/7047) | 3% (112/4362) | 33 | 72 476 | 48% (2021/4217) |
| Private hospitals | 14 | 297 220 | 11% (2522/23 752) | <1% (2/2522) | 15 | 21 908 | 36% (814/2274) |
| Research clinics† | 2 | 1662 | 95% (14 961/15 792) | 36% (5421/14 961) | .. | .. | .. |
| BMA centres‡ | 44 | 23 008 | 27% (194/717) | <1% (1/194) | .. | .. | .. |
| Overall | 91 | 405 143 | 34% (2297/6749) | 7% (158/2297) | 48 | 94 384 | 46% (1643/3610) |

MSM=men who have sex with men. ART=antiretroviral treatment. BMA=Bangkok Metropolitan Administration. *Includes public hospitals and BMA health centres that can provide both HIV testing and ART services. †Includes Thai Red Cross Anonymous Clinic and Silom Community Clinic—they provide HIV testing services only. ‡Provide HIV testing services only.

*Table 1:* **Operational load and capacity availability in Bangkok medical facilities for provision of HIV testing and ART services**

corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

Our capacity assessment survey showed that 14 387 MSM were tested for HIV in 91 Bangkok medical facilities in 2011, corresponding to a 12 month testing coverage of 23% (95% CI 17–36) in the estimated 61 975 (40 200–83 750) MSM at high risk. According to NHSO surveillance data, 4028 MSM were diagnosed as HIV-positive and 3303 (82%)[19] of them were treatment eligible (CD4 count <350 cells per μL) in 2011. Of treatment eligible MSM, just 989 (30%) initiated ART in 2011 (appendix p 4). Cumulatively, only 2043 (20%) of 10 215 treatment-eligible MSM at high risk were on ART in Bangkok in 2011.

91 Bangkok medical facilities provided HIV testing service information from March 15, 2012, to June 15, 2012, via telephone and postal surveys (table 1, appendix pp 13–16). Private hospitals have the largest capacity for HIV testing (23 752 tests per site per year), and 89% of this capacity is unused (table 1). Research clinics were capable of providing 15 792 HIV tests per site per year, but they almost exhausted their supply, with only 5% of their capacity currently unused. The 31 public providers could provide 7047 tests per site per year, with 38% of this capacity unused, and the 44 BMA health centres were capable of providing 717 tests per site per year, with 73% of this capacity unused. On top of the present service load, Bangkok medical facilities might still be able to provide an additional 400 000 HIV tests per year. Public facilities could accommodate up to 4217 patients on ART per site per year, whereas capacity in private hospitals was about half this (2274 patients per site per year; table 1). 52% of this capacity is unused in public facilities and 64% remains available in private hospitals, giving rise to a total 94 384 available ART spaces for further expansion. The distance between MSM hotspots and facilities did not associate with testing and ART service load (appendix p 20).

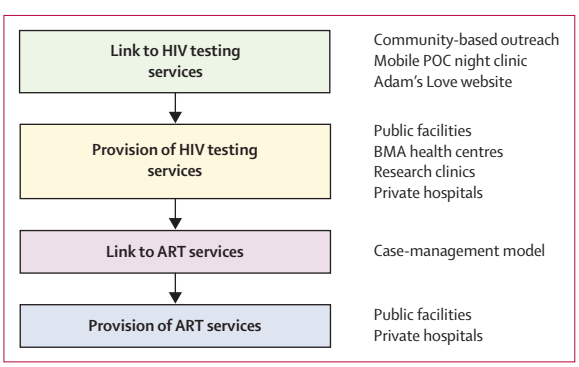


***Figure 2:*** **Strategies for linkage and provision of HIV testing and treatment in men who have sex with men in Bangkok**
ART=antiretroviral treatment. BMA=Bangkok Metropolitan Administration. POC=point of care.

Internet-based technologies (Adam's Love website) were the most effective way to recruit MSM for HIV testing ($24 per person; appendix pp 21–23; figure 2). Mobile night clinics that provided point-of-care HIV testing at MSM hotspots cost $26 per person tested. The conventional community-based outreach by peer educators is the most expensive approach ($72 per person). The so-called case-management model provided an effective mechanism for following up of diagnosed MSM to initiate and adhere to ART. This programme costed $177 per person linked to treatment. Public facilities had the lowest unit cost ($15 per test) for provision of HIV testing services, followed by research clinics ($33 per test), BMA health centres ($34 per test), and private hospitals ($40 per test). Notably, running of a

| | Total estimated investment (×US$ million) | Extra amount of linkage and service provision needed for MSM | | | | Estimated effects of ART scale-up | | | Estimated cost-effectiveness of ART scale-up | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of MSM linked to testing (×1000) | Number of tests to be done (×1000) | Number of HIV-positive MSM linked to ART (×1000) | ART person-years on MSM patients (×1000) | Number of HIV-related deaths averted (×1000) | Number of HIV infections averted (×1000) | Number of DALYs averted (×1000) | Cost per death averted (US$) | Cost per infection averted (US$) | Cost per DALY averted (US$) |
| Status quo | 73·8 (51·0–97·0) | 43·0 (27·9–58·0) | 157·7 (102·3–213·1) | 5·1 (3·5–6·7) | 50·6 (35·1–66·3) | .. | .. | .. | .. | .. | .. |
| Universal coverage by 2015 | 178·3 (123·4–235·4) | 52·1 (33·8–70·3) | 926·3 (600·8–1251·7) | 16·7 (11·6–21·9) | 138·8 (96·4–182·0) | 8·1 (5·6–10·6) | 7·6 (5·3–10·0) | 252·4 (175·2–330·9) | 12 924 (10 714–15 497) | 13 769 (11 326–14 017) | 418 (341–504) |
| Universal coverage by 2017 | 154·4 (106·9–202·7) | 50·8 (33·0–68·7) | 295·6 (191·8–399·5) | 15·4 (10·7–20·2) | 123·1 (85·5–161·4) | 6·9 (4·8–9·1) | 5·7 (4·0–7·5) | 215·2 (149·4–282·2) | 11 627 (9763–14 058) | 14 119 (11 579–16 849) | 375 (313–458) |
| Universal coverage by 2022 | 129·1 (89·4–169·5) | 46·7 (30·3–63·2) | 197·1 (127·8–266·3) | 12·6 (8·8–16·6) | 101·0 (70·1–132·4) | 5·1 (3·6–6·7) | 3·7 (2·6–4·9) | 157·7 (109·4–206·7) | 10 809 (9071–13 274) | 14 783 (12 389–17 960) | 351 (290–424) |

Values in brackets are 95% CIs. MSM=men who have sex with men. ART=antiretroviral treatment. DALY=disability-adjusted life-year.

***Table 2:*** **10 year total estimated investments needed for HIV testing and ART services for MSM in Bangkok and expected epidemiological outcomes and cost benefits during 2013–22**

public facility for HIV testing services needed $338 736 per year, whereas the cost was $34 619 per year for BMA health centres, $311 488 per year for private hospitals, and $495 260 per year for research clinics (appendix p 24). The proportion of spending on staff salaries was similar between public facilities, BMA health centres, and research clinics (30–40%; appendix p 24). By contrast, the percentage of spending on staff salaries in private hospitals is slightly greater (46%), whereas public and private hospitals spent most resources on HIV testing (public hospitals 67%; private hospitals 52%). About 30% of spending on BMA centres was dedicated to HIV testing (appendix p 24). Notably, the same staff members in BMA centres were also responsible for tests for sexually transmitted infections, and a typical ratio of workload split between testing for HIV and sexually transmitted infection is one to two (appendix p 6). On average, the cost of ART provision per person-year was 23% lower in public facilities ($1220) than in private hospitals ($1587).

If the present investment in HIV services is maintained during the next decade, by the end of 2022, 43 000 MSM at high risk will be linked to HIV testing and 5100 to ART services, increasing ART coverage of high-risk MSM from the present level of 20% to 44% in 2022 (table 2). However, if universal ART coverage (defined as 80% coverage of treatment-eligible people) is to be achieved by 2022, an additional 46 700 MSM would need to be linked to HIV testing, enabling a further 12 600 eligible high-risk MSM to initiate ART. Our model shows that this coverage would lead to aversion of 5100 HIV-related deaths and 3700 new HIV infections by 2022, corresponding to a 53% reduction in HIV-related deaths and a 35% reduction in new infections from 2012 levels. Achievement of universal coverage by 2017 will avert 6900 deaths and 5700 new infections, corresponding to a 68% reduction in deaths and a 46% reduction in new infections during the next decade, whereas achievement of this goal by 2015 would prevent 8100 deaths and 7600 new cases, corresponding to a 75% reduction in deaths and a 54% reduction in new cases (figure 3).

Available resources can be optimised for service expansion. The most efficient use of resources in Bangkok is to first use the testing spots in public facilities in view of their lowest unit cost for HIV testing (table 1, figure 4). Tests at research clinics are the next most efficient, followed by BMA centres, and, finally, private hospitals if necessary. However, the available capacity in public facilities alone is already sufficient to provide the necessary number of extra tests for all scale-up scenarios. Available clinical infrastructure for ART would suffice to provide necessary services in all scale-up scenarios. The most cost-efficient strategy would be to prioritise ART first in public facilities in light of its low provision cost.

To achieve universal ART coverage by 2022 of MSM at high risk, $129·1 million will be needed during the next decade, $55·3 million more than the spending to sustain the status quo (table 2). Achievement of universal coverage earlier will result in slightly greater cost-effectiveness ratios (table 2). ART scale-up from scenarios that achieve universal coverage in 10 years would yield higher incremental cost-effectiveness ratios per DALY averted than scenarios achieving universal coverage in 5 years ($440 [95% CI 360–529]) and 3 years ($518 [427–621]).

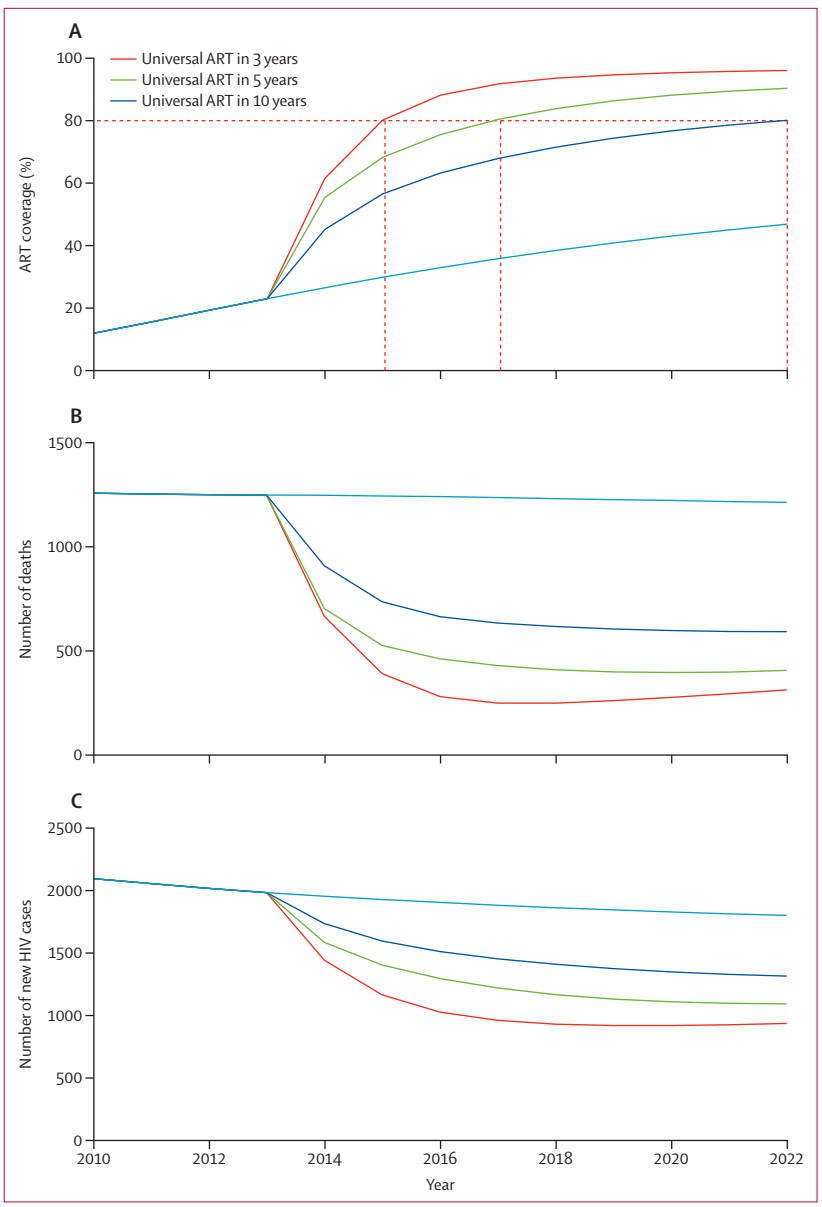


***Figure 3:*** **Projected epidemiological outcomes for scenarios of achievement of universal ART coverage (80%) for men who have sex with men (undiagnosed and diagnosed) in Bangkok in 3, 5, and 10 years**
(A) ART coverage; (B) number of HIV-related deaths; (C) number of new HIV cases. The blue line represents the status quo. The red dashed line marks universal coverage in 3, 5, and 10 years. ART=antiretroviral treatment.

## Discussion

Our findings show that use of HIV testing services by MSM at high risk in Bangkok is low, but sufficient infrastructure is available to support scale-up of testing and treatment towards universal coverage (panel).

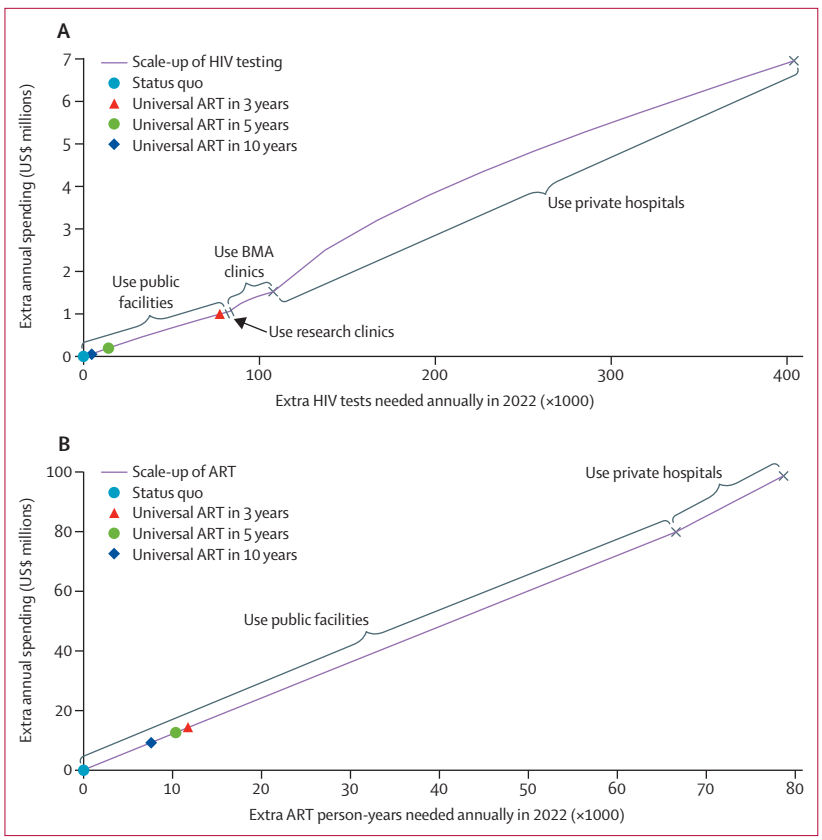


***Figure 4:*** **Most economical strategies to scale up (A) HIV testing and (B) ART services for MSM in Bangkok**
Crosses and lines mark the endpoint of each segment. ART=antiretroviral treatment. BMA=Bangkok Metropolitan Administration. MSM=men who have sex with men.

Because only a fifth of treatment-eligible MSM were on ART in 2012, treatment urgently needs expanding. Present service use and associated costs differ substantially between venue types. HIV testing has been most economically provided by major public hospitals. However, research clinics have been the most effective in reaching MSM at high risk in Bangkok, providing over 75% of HIV tests. However, these clinics cannot cope with increasing demand for HIV tests needed for ART expansion. One of the most important factors associated with any large-scale expansion of testing and treatment is to remove the social barriers from the most economic venue types. Successful experiences of research clinics, such as their efficient client-management system, friendly approach, and quick turnover of testing outcomes, can be drawn on for other settings that have substantial capacity for expanded use. Our analysis showed that public hospitals, together with small contributions from research clinics and BMA centres, could provide the necessary capacity for HIV testing in all ART scale-up scenarios to achieve universal coverage. By contrast, the present unit cost for private hospitals is high, with a greater proportion of its investment being spent on staffing costs than on testing and supporting other items. Private hospitals have the largest capacity for increasing HIV testing, but they are very rarely accessed. Stigma and discrimination are massive impediments to use of available services.

If stigma and discrimination barriers can be reduced such that available infrastructure is used, then capacity is available to service all need. We have investigated an optimised investment pathway to scale up ART to universal coverage and estimated that it can be effective in reduction of new HIV cases and related deaths. An additional $55·3 million investment in 2013–22 will reach the 80% coverage mark for MSM in Bangkok at high risk and would be expected to lead to a third reduction in the number of new infections and a halving of the number of HIV-related deaths in MSM at high risk by 2022 compared with 2012 levels. This finding is consistent with previous modelling in Thailand[37] and elsewhere.[38,31] The cost-effectiveness of ART scale-up scenarios ($351–414 per DALY averted) is deemed similar to funded ART programmes in other settings, including in low-resource settings.[31]

Investment in HIV responses for MSM in Thailand is underfunded. More importantly, because of persistent social stigma, MSM are often afraid of being seen by peers and discriminated against by health-care workers when receiving HIV tests. Stigma and discrimination are the most important barriers to the scale-up of services for MSM. Inconvenient operating hours of testing sites, concerns about confidentiality, and non-friendliness of medical personnel are characteristic of the barriers to HIV testing.[39] The two research clinics that provide HIV testing services to most Bangkok MSM have operating hours in the evenings and during weekends. Internet sites have proven efficient for recruitment of MSM into HIV testing services compared with conventional community-based outreach; this approach has become highly effective in other settings, shown by pilot programmes in British Columbia, Canada.[40] However, internet technology cannot be a replacement of community-based outreach, particularly for retention of MSM in care. Use of different recruitment strategies for linkage of MSM to services is needed to access all people. In addition to the common barriers to HIV testing, HIV-positive MSM can experience discrimination because of their infection status and homosexuality.[41] So far, the case-management model is possibly the only piloted model in Thailand to bridge many of the barriers faced by HIV-positive MSM, offering peer-based follow-up, workshops, and community support from diagnosis to achievement of stable adherence on ART.

We note some limitations of our study. First, we investigated four HIV service linkage models. Other service delivery models, such as mass media, peer-driven interventions, use of mobile phone applications, and online HIV test registration, could also have substantial effects. Second, although the NHSO database is the most comprehensive database available for Thailand, it does not cover all medical facilities in both public and private sectors. Because of accessibility issues, stigma, and other

structural barriers, MSM might choose to access health care outside of the NHSO system. These choices might underestimate the overall available service capacity and access to services in Bangkok. Our analysis did not distinguish between general and specialised hospitals either, which could differ in their service provision approaches. Third, Bangkok's MSM have heterogeneous sexual identities (homosexual men, straight-acting bisexual men, and transgender individuals, among others) and diversified risk behavioural mixing and HIV risk-related activity patterns. We did not factor these differences into modelled estimates of potential effect. We only modelled transmission of HIV through unprotected anal intercourse between MSM at high risk, but not transmission by injecting drug use and commercial sex. Fourth, MSM at high risk might be more reachable. Costs are likely to be greater to reach MSM at lower risk. Fifth, MSM tested in public facilities might not be willing to self-identify openly as MSM because of stigma and discrimination, leading to underestimation of its present use. Assumptions about uniform demographics, sexual behaviour, and preference for health-care services in our studied population might also lead to bias in our calculation. Sixth, we have not incorporated structural barriers into our epidemiological model. Such structural barriers are difficult to incorporate in a rigorous manner. Seventh, ART coverage of MSM in Bangkok is low. However, because no system exists to track individuals through the cascade of care from HIV testing to linkage to care and receipt of ART, the actual numbers linked to care and on ART might differ from what we used in this study.

Worldwide, a focus exists on increasing of HIV testing, linkage to care, initiation of treatment, and regular monitoring. This focus is particularly pertinent for marginalised populations at high risk of HIV infection. In many settings, disproportionately less attention has been given to prevention, testing, and treatment for some of these key affected populations. MSM in Bangkok is one such example. In this study, we have addressed this issue to establish what is actually needed in terms of infrastructure and cost to scale up testing and treatment. The recommendations from this study to create a patient-friendly environment in public facilities and to use different methods to link MSM to HIV testing services and ART initiation support many strategies that are being discussed or have been recently initiated in Bangkok. One example of improvement of accessibility to public facilities is initiatives of BMA health centres starting night mobile clinics every week to venues frequented by Bangkok MSM. Drop-in centres located in major MSM hotspots in Bangkok have also been established. This study's approach is likely to be applicable to other low-income country settings in southeast Asia. Hopefully, how services can best be used in other settings can be established, the most cost-effective pathway for expansion of service use can be established, and such strategies can be implemented to yield large health and economic benefits.

### *Panel:* Research in context

#### Systematic review

We searched PubMed for articles published in English anytime up to Jan 6, 2015, with the keywords "HIV", "cost-effectiveness", "antiretroviral", and "treatment as prevention". The full-text search resulted in 272 articles, but only 17 addressed the implementation and cost-effectiveness of antiretroviral treatment scale-up. Early in 2011, through a systematic review, Kahn and colleagues[20] proposed a conceptual model for how to do and interpret cost-effectiveness analyses of antiretroviral treatment (ART) as prevention. Various studies have since addressed the cost-effectiveness of ART scale-up in many contexts (eg, China,[21] Vietnam,[22] Zambia,[23] South Africa,[24-27] the USA,[28,29] and Canada[30]). Eaton and colleagues,[31] through a combined analysis of 12 mathematical models, showed that early eligibility for antiretroviral treatment yields good health and economic return in low-income and middle-income settings. This finding showed the importance of early diagnosis and linkage to HIV care. Consistently, Nosyk and coworkers[32] and Wilson and colleagues[33] both concluded that substantial scale-up of ART under a treatment-as-prevention approach will pose enormous challenges at all stages of the HIV continuum of care. Delva and coworkers[34] showed that important environmental factors that affect feasibility, affordability, acceptability, and equity of ART programmes will change its effectiveness. In this study, we concluded that substantial knowledge gaps remain for interventions to improve linkage and retention in HIV care in all income settings and generalised and concentrated epidemics. Nosyk and colleagues[35] did a further systematic review of economic assessments of interventions that could improve specific stages of the HIV care cascade. Ying and coworkers[36] noted that to guide future policy, new mathematical models should consider the barriers that patients face in receiving ART. Our study's innovation is its assessment of optimum expansion pathways in planning pragmatic interventions of testing and treatment scale-up in real-world settings, considering available geography and infrastructure in a major city containing a population group (men who have sex with men [MSM]) with high HIV prevalence.

#### Interpretation

Scale-up of ART is currently probably the highest priority in response to HIV epidemics worldwide. Modelling has shown that if coverage of diagnosis and treatment increases, then it has the potential to have large epidemiological benefits, and various expansion and targeted strategies are cost effective. Our study takes modelling and health economic studies a step further for pragmatic actual programme planning by assessing present and possible infrastructure of HIV testing and ART services, and their geographical accessibility. We apply this approach to planning of scale-up of ART for MSM in Bangkok and assess the most cost-effective expansion pathway of service use to attain universal coverage of ART. Currently available spare capacity in Bangkok's medical facilities can be used to expand ART access for MSM, potentially achieving large epidemiological benefits. Expansion will require moderate-to-large increases in funding to be directed to severely underfunded services for MSM.

#### Contributors

RO, LZ, NP, KH, JA, and DPW designed the study. NP, SN, and SS did the telephone and field surveys, and collected field data. LZ and AJS collected epidemiological data. KH developed the costing and outputs template, and provided support to field workers for study implementation. SN, SS, KH, and BO collected and reviewed costing data. LZ, AJS, and CCK constructed the mathematical model. LZ did cost-effectiveness analysis. FvG, SO, RO, and JA had advisory roles, helped with and supervised data collection, and interpreted and disseminated results to Thai stakeholders. LZ, NP, and DPW drafted the manuscript. All authors read and approved the manuscript.

#### Declaration of interests

We declare no competing interests.

#### Acknowledgments

This study was funded by the World Bank Group with support from the Australian National Health and Medical Research Council. The Kirby Institute is funded by the Australian Government Department of Health and Ageing. The views expressed in this publication do not necessarily

represent the position of the Australian Government, US Army, or Department of Defense. The Kirby Institute is affiliated with the University of New South Wales. The findings, interpretations, and conclusions expressed in this work are those of the authors and do not necessarily reflect the views of the World Bank, its Board of Executive Directors, or the governments that they represent. We wish to thank the Thai Ministry of Public Health, the National Health Security Office Program, and managers and other staff in all sites that were surveyed.

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