Cost-of-testing-per-new-HIV-diagnosis as a metric for monitoring cost effectiveness of testing programmes in low income settings in southern Africa

Background

HIV testing is key to global ART-based HIV prevention efforts. It is widely accepted that testing in pregnant women, testing for diagnosis of symptoms, testing in sex workers who have condomless sex; and men coming forward for circumcision is beneficial and cost-effective. We refer to this as **core testing**.

However, as prevalence of undiagnosed HIV declines, it is unclear whether **additional** testing beyond this core testing will be cost effective.

Cost effectiveness of an intervention is assessed by calculating the cost per DALY averted (incremental cost effectiveness ratio) over a long time horizon, but this metric cannot easily be measured directly by a testing programme.

To guide their HIV testing programmes, countries require appropriate metrics that can be measured. The cost-of-testing-per-new-HIV-diagnosis is a potentially useful metric.

Objective

To assess whether cost-of-testing-per-new-HIV-diagnosis is a suitable metric for measuring the cost effectiveness of on-going testing programmes in the context of HIV epidemics in southern Africa.

To assess the maximum cost-of-testing-per-new-HIV-diagnosis for a testing programme to be cost effective in this setting.

To consider the implications for monitoring of HIV testing programmes in southern Africa.

Methods

We use an individual-based mathematical simulation model of sexual activity, HIV testing, HIV transmission, progression and the effect of ART.

We generate several ***setting-scenarios*** which resemble those seen in southern Africa.

Baseline characteristics of setting scenarios at baseline

n = 1000 setting-scenarios

	Median (90% range) across setting-scenarios (n = 1000)	**Examples of observed data**
HIV prevalence (age 15-49)	8.2% (4.7% - 17.4%)	Zimbabwe DHS (2015) 14%, Tanzania (2011) 5%, Uganda (2011) 9%, Lesotho (2014)25%
Proportion tested:		
Overall in past year **women** age 15-49	37% (22% - 48%)	Zimbabwe DHS 2015 49% women, 36% men (age 15-49). Namibia DHS 2013 49% women, 38% men (age 15-49). Nigeria DHS 2013 10% women, 10% men.
Overall in past year **men** age 15-49	16% (7% - 25%)	
Amongst those symptomatic with HIV symptoms	90% (46% - 93%)	
In pregnancy	92% (89% - 93%)	
FSW (in each 3 month period)	25% (17% - 41%)	

Testing policies

For each setting-scenario we continue the simulation to project forward 50 years from baseline under two policies:

1. Core testing **only**
2. Core testing **+ additional testing**

The **additional testing** is determined by sampling at random the **rate of testing** and **relative probability of HIV positive people being tested compared with HIV negative people**.

We consider additional testing:

- only for men
- only for women
- both sexes

Setting scenario / unit cost combinations

We considered 16 different unit costs of HIV tests in addition to the baseline cost of $3.70: $1, $2, $5, $7, $10, $12, and increments of $3 up to $36.

A total of 16,000 setting-scenario / test unit cost combinations were therefore considered (16 different unit costs for each of 1000 setting-scenarios). For each we calculated:

- the **cost-of-testing-per-new-HIV-diagnosis** resulting from the additional testing as the ratio between the cumulative cost of additional testing and the number of diagnoses due to additional testing, averaged over the 5 years 2018-2023.

- the **cost-per-DALY-averted** (incremental cost effectiveness ratio) of the core + additional testing compared with core testing only over a 50 year time horizon

Cost effectiveness analysis

We take a health care perspective.

In each setting-scenario / unit test cost combination, **additional testing** was deemed to be cost effective if the cost per DALY averted was below **$500 per DALY averted**

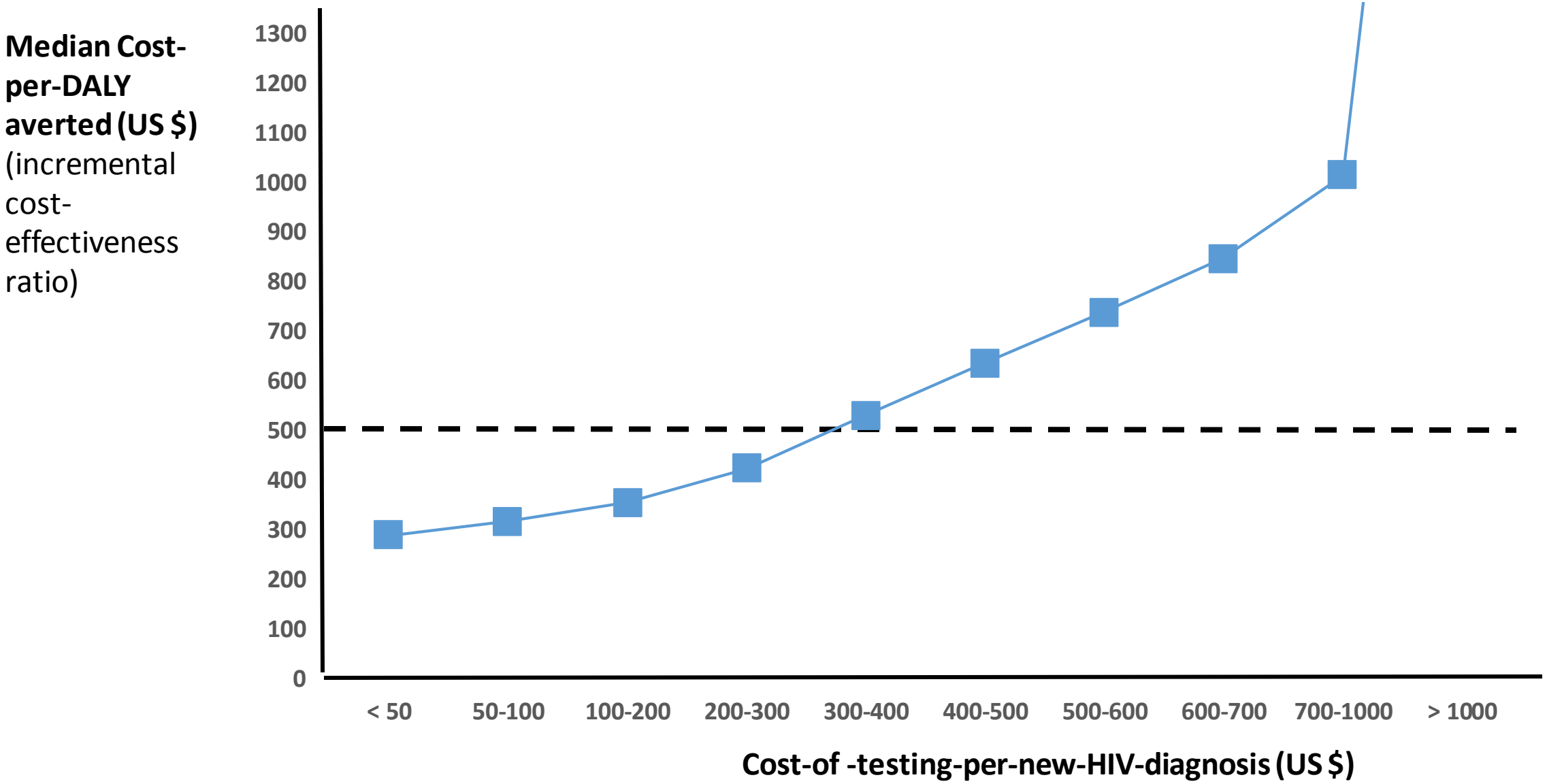
This use of the cost-effectiveness threshold reflects the health foregone (opportunity costs) due to resources committed to HIV testing consequentially being unavailable to provide other interventions (so that $500 reflects the cost-per-DALY-averted of these foregone activities).

We use $300 and $150 in sensitivity analyses.

Results - effect of additional testing on intermediate outcomes

	Median (90% range) across setting-scenarios of the mean value over 2018-2023
Proportion tested in the past year (age 15-49):	
Women	+8% (+0.4% - +67%)
Men	+6% (+0.4% - +75%)
Of HIV positive people, proportion diagnosed	
Women	+7% (+2% - +12%)
Men	+21% (+5% - +33%)
Cost-of-testing-per-new-HIV-diagnosis with additional testing	
Women	$399 ($25 - $7,187)
Men	$288 ($21 - $4,975)

Relationship between cost-of -testing-per-new-HIV-diagnosis and cost per DALY averted over 16,000 setting-scenario - test unit cost combinations



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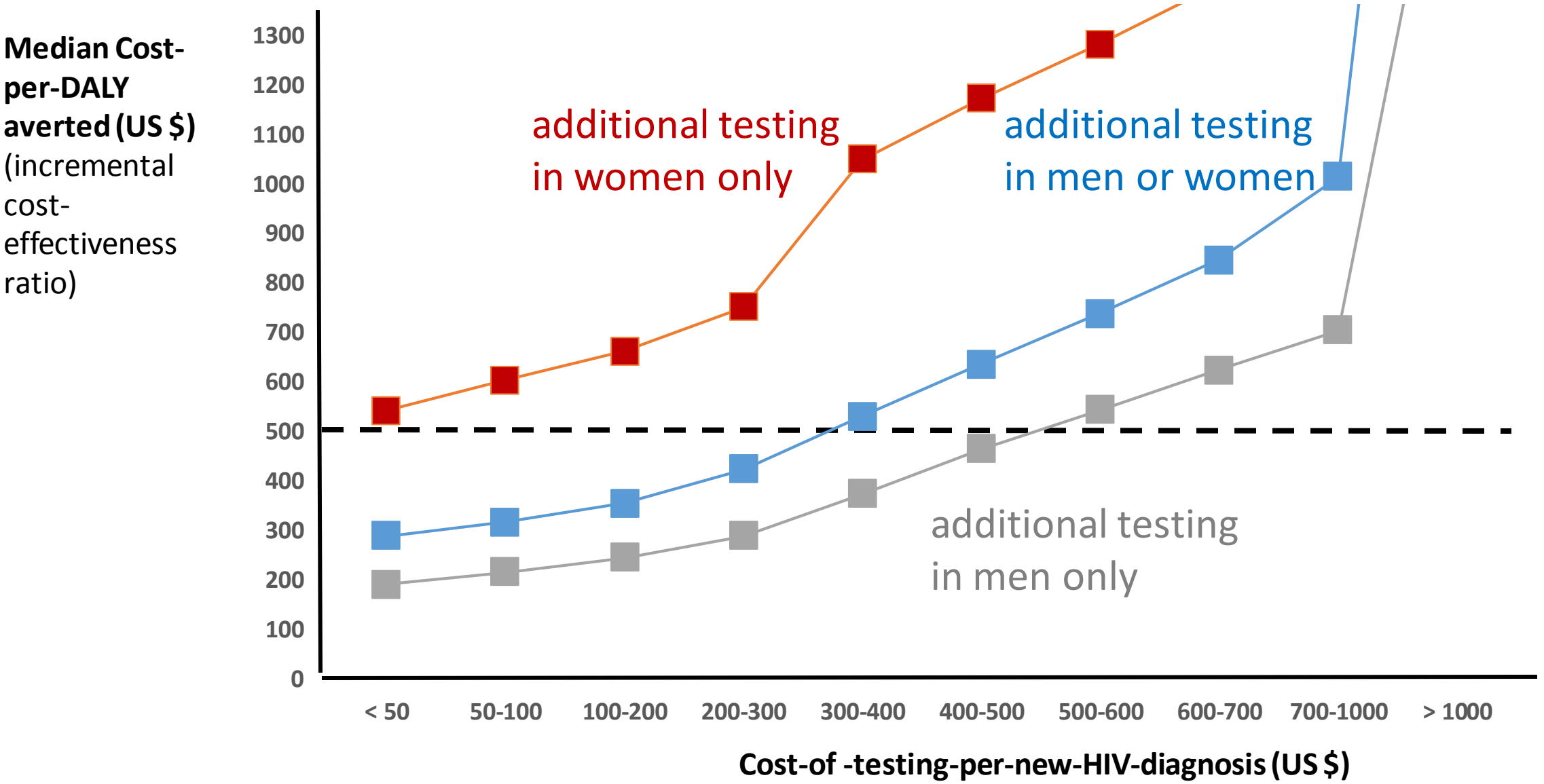
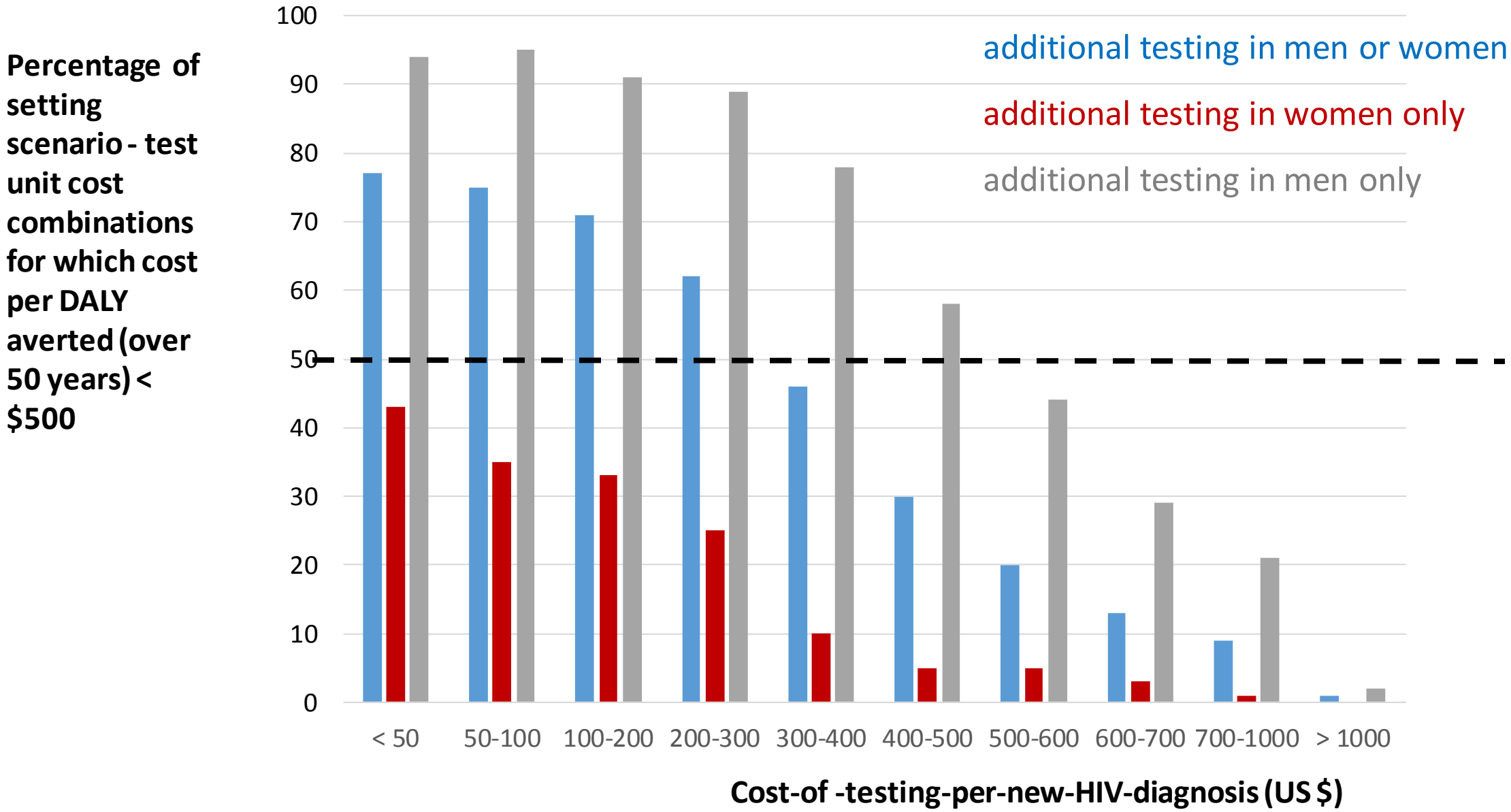


Relationship between cost-of-testing-per-new-HIV-diagnosis and cost per DALY averted over 16,000 setting scenario - test unit cost combinations



Comments

Implementation of our results requires that programmes can estimate:

- the full cost of testing
- the number of new HIV diagnoses in a given period

Programmes need to account for the fact that some incorrectly report no previous diagnosis.

We calculated the cost-of-testing-per-new-HIV-diagnosis over the first 5 years but this can change over the subsequent years of the projection. Time limited testing programmes may be more cost effective.

Conclusions

The cost-of-testing-per-new-HIV-diagnosis is a suitable metric for measuring the on-going cost effectiveness of additional testing programmes (beyond core testing) in the context of HIV epidemics in southern Africa.

Considering a cost effectiveness threshold of $500 per DALY averted, such additional testing programmes in men are likely to be cost effective so long as the cost-of-testing-per-new-HIV-diagnosis is below $585.

Additional testing programmes in women are unlikely to be cost effective.

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Working group on cost effectiveness of HIV testing in low income settings in southern Africa

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Baseline characteristics of setting scenarios at baseline

n = 1000 HIV epidemic / ART programme setting-scenarios in 2017

	Median (90% range) across setting-scenarios (n = 1000)		Examples of observed data
HIV prevalence (age 15-49)	8.2% (4.7% - 17.4%)		Zimbabwe DHS (2015) 14%, Tanzania (2011) 5%, Uganda (2011) 9%, Lesotho (2014)25% [16].
Relative HIV prevalence by age and sex (relative to men age 25-34)	Women	Men	Zimbabwe DHS 2015 men age 15-24 0.29, age 35-44 2.18, age 45-54 2.52; women age 15-24 0.69, age 25-34 1.82, age 35-45 2.88 [16].
15-24	0.52 (0.28 – 0.77)	0.22 (0.12 – 0.33)	
25-34	1.88 (1.56 – 2.38)	1.00	
35-44	3.11 (2.37 – 4.41)	2.15 (1.67 – 3.01)	
45-54	2.62 (1.85 – 4.16)	1.91 (1.37 – 2.90)	
55-64	1.12 (0.69 – 1.88)	1.12 (0.73 – 1.69)	

Baseline characteristics of setting scenarios at baseline

	Median (90% range) across setting-scenarios (n = 1000)	Examples of observed data
Prevalence of undiagnosed HIV		Malawi 2.9%, Zimbabwe 3.8%, Zambia 4.0 (PHIA 2016). Rwanda ~ 0.3% (Nsanzimana) (Survey estimates could be over-estimates due to undisclosed diagnosed HIV; Kim et al)
Overall	1.5% (0.7% - 3.5%)	
Women	1.2% (0.5% - 2.9%)	
Men	1.9% (0.8% - 4.3%)	
Time since infection amongst undiagnosed population		No data known to be available
Women		
< 1 year	38% (25% - 51%)	
1-5 years	41% (32% - 52%)	
≥ 5 years	20% (11% - 33%)	
Men		
< 1 year	24% (15% - 34%)	
1-5 years	50% (41% - 57%)	
≥ 5 years	26% (14% - 40%)	

Baseline characteristics of setting scenarios at baseline

	Median (90% range) across setting-scenarios (n = 1000)	Examples of observed data
HIV incidence (age 15-49) per 100 person years	0.64 (0.25 – 1.52)	MPHIA (0.37%), ZAMPHIA (0.66%), ZIMPHIA (0.45%), Swaziland 2.4% (Justman), Mbongolwane and Eshowe, KZN 1.2% (Huerga)
Proportion tested:		
Overall in past year women age 15-49	37% (22% - 48%)	Zimbabwe DHS 2015 49% women, 36% men (age 15-49). Namibia DHS 2013 49% women, 38% men (age 15-49). Nigeria DHS 2013 10% women, 10% men.
Overall in past year males age 15-49	16% (7% - 25%)	
Amongst those symptomatic with HIV symptoms^	90% (46% - 93%)	
In pregnancy	92% (89% - 93%)	
FSW (proportion tested in each 3 month period)	25% (17% - 41%)	

Baseline characteristics of setting scenarios at baseline

	Median (90% range) across setting-scenarios (n = 1000)	Examples of observed data
Percentage of tests resulting in HIV diagnosis		
All adults	2.9% (1.2% - 7.7%)	Estimates are susceptible to bias due to re-diagnosis of people who do not report previous diagnosis. 6%-55% depending on group (Sharma et al).
Women overall	2.6% (1.0% - 7.7%)	
Men overall	3.5% (1.4% - 9.1%)	
ANC	2.8% (0.8% - 22.9%)	
FSW	33.7% (10.8% - 49.2%)	
Symptomatic	7.7% (3.3% - 16.6%)	
Men for VMMC	1.3% (0.4% - 3.6%)	
Testing beyond core testing [=]		
All adults	1.7% (0.8% - 4.1%)	
Women	1.4% (0.6% - 3.6%)	
Men	2.2% (1.0% - 5.3%)	

Baseline characteristics of setting scenarios at baseline

	Median (90% range) across setting-scenarios (n = 1000)	Examples of observed data
Cost of testing per new HIV diagnosis *		
All adults	$159 ($73 - $357)	Few estimates reported. Estimates are susceptible to bias described above. >$500 (Bogart 2017; fisher folk Uganda). $36 (Rutstein 2014; partner notification Malawi); $157-$189 in 2010 (Grabbe; mobile and stand-alone HIV counselling and testing approaches in Kenya); $25-$76 (Maheswaran; facility based testing in Malawi).
Women overall	$188 ($81 - $452)	
Men overall	$133 ($63 - $314)	
ANC	$233 ($95 - $650)	
FSW	$30 ($27 - $48)	
Symptomatic	$71 ($42 - $157)	
Men for VMMC	$139 ($112 - $161)	
Testing beyond core testing		
All adults	$253 ($115 - $540)	
Women	$336 ($135 - $792)	
Men	$214 ($101 - $472)	

* assuming CHAI cost per test of $3.70

Baseline characteristics of setting scenarios at baseline

	Median (90% range) across setting-scenarios (n = 1000)	Examples of observed data
Of HIV positive people, proportion diagnosed		MPHIA 2016 Malawi (73%; 76% in women, 67% in men), ZAMPHIA 2016 Zambia (67%), ZIMPHIA 2016 Zimbabwe (74%), Huerga (75%), Maman (77%), Gaolathe (78%, higher in women than men). (Survey estimates likely to be over-estimates due to undisclosed diagnosed HIV; Kim et al)
Men	73% (59% - 82%)	
Women	89% (82% - 93%)	
Proportion of diagnosed people on ART	83% (66% - 92%)	Zimbabwe 87% (ZIMPHIA), Malawi 89% (MPHIA), Zambia 85% (ZAMPHIA), Botswana 85% (Gaolathe).
Proportion of people on ART with VL < 1000 cps/mL	88% (84% - 92%)	World Bank South Africa (60%-88% over districts), ZAMPHIA (89%), MPHIA (91%), ZIMPHIA (87%), Maman (91%), Huerga (90%), Brown (90%), Botswana 94% (Gaolathe; among citzens of Botswana)

Cost effectiveness analysis

We take a health care perspective.

In each setting-scenario / unit test cost combination, **additional testing** was deemed to be cost effective if the ICER was below **$500 per DALY averted** or if there was a saving in cost with the additional testing policy and DALYs were averted.

This use of the cost-effectiveness threshold reflects the health foregone (opportunity costs) due to resources committed to HIV testing consequentially being unavailable to provide other interventions (so that $500 reflects the cost-per-DALY-averted of these foregone activities).

We use $300 and $150 in sensitivity analyses. We follow convention and use a discount rate of 3% per annum for both costs and outcomes in the main analysis, We consider discount rates of 0% and 10% in sensitivity analyses.

Costs and disability weights

Costs assumed

ART	$100 per person year, $75 after 2019.
Programme costs for clinic visits	$20 ($10 if viral load < 1000)
Viral load tests	$22

Disability weights to calculate DALYs were derived from Salamon et al.

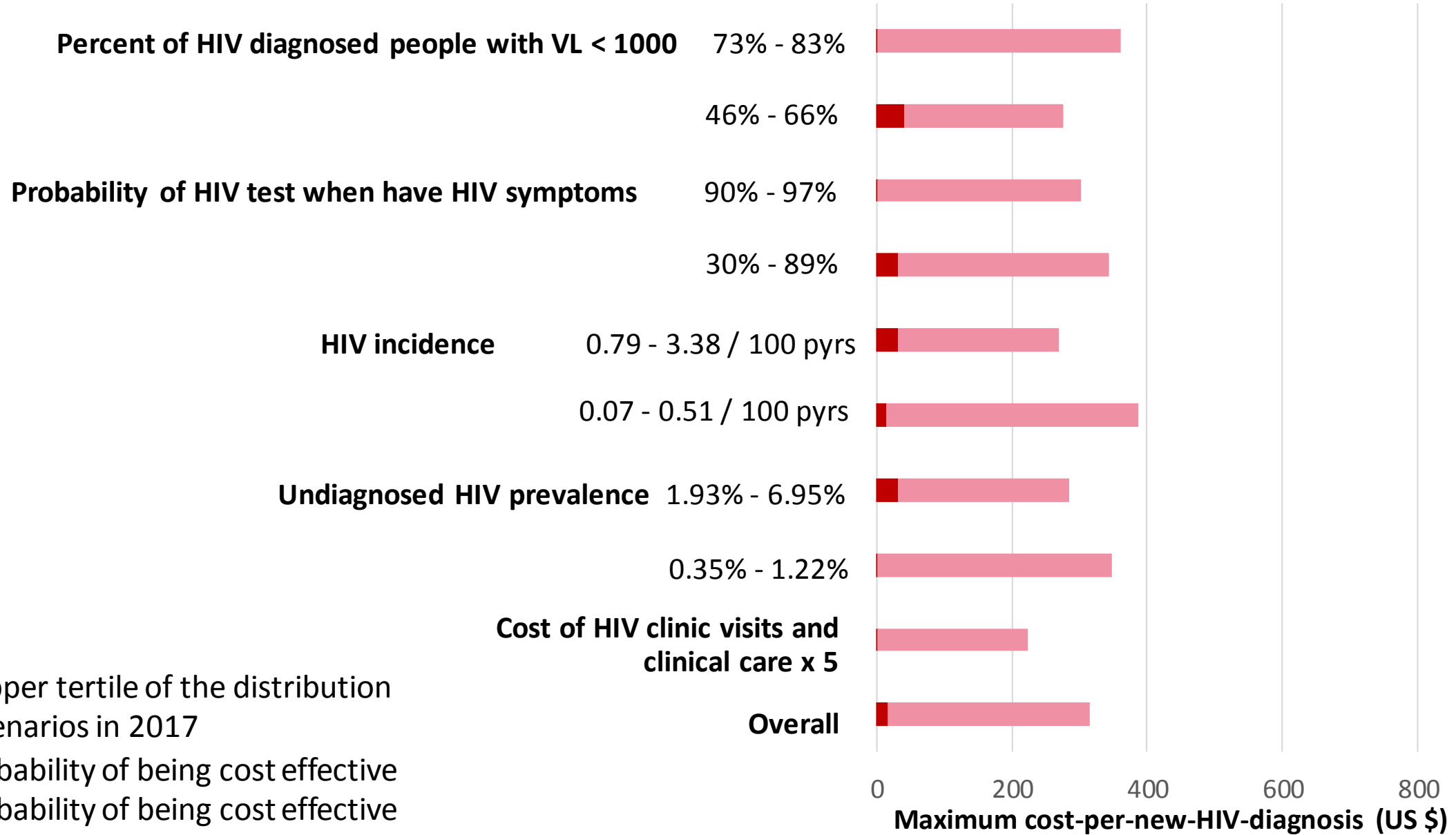
Cost effectiveness analysis

We then assessed the relationship between the cost-of-testing-per-new-HIV-diagnosis and the incremental cost effectiveness ratio (ICER) for additional testing over core testing alone, with the ICER calculated over the 50 year time horizon.

The ICER takes account of all costs, including downstream costs (and potential savings in downstream costs) resulting from the testing and diagnosis.

Unlike the cost-of-testing-per-new-HIV-diagnosis, the cost-per-DALY-averted cannot be readily measured by programmes and used directly to monitor them.

Maximum cost-per-new-HIV-diagnosis for additional testing to be cost-effective. Variations in sensitivity analyses - 1

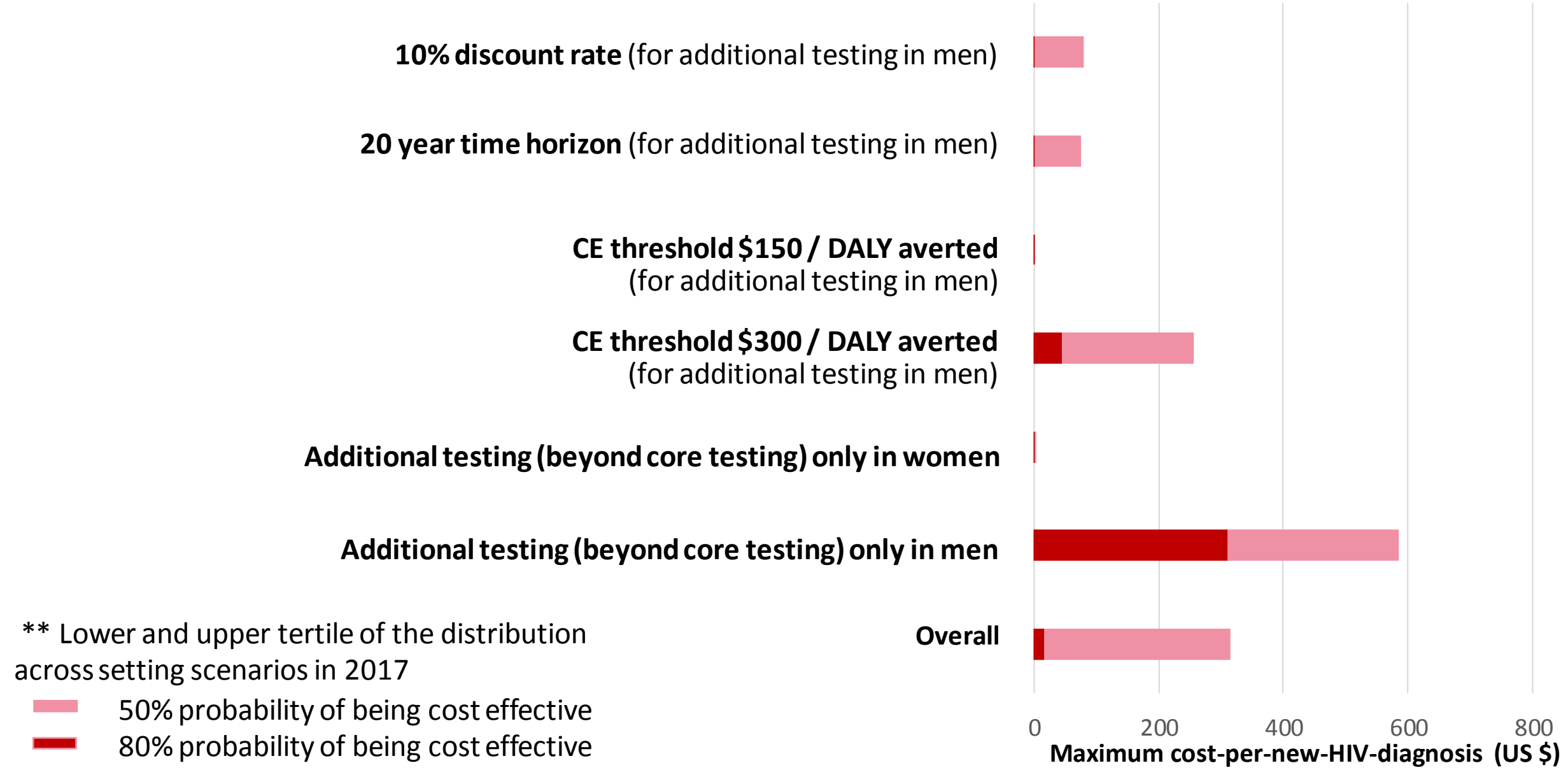


** Lower and upper tertile of the distribution across setting scenarios in 2017

50% probability of being cost effective

80% probability of being cost effective

Maximum cost-per-new-HIV-diagnosis for additional testing to be cost-effective. Variations in sensitivity analyses - 2



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Limitations

Although our model is detailed and informed by multiple data sources, modelling is inevitably an imperfect representation of reality.

Future changes in ART programmes are taken into account in so far as we assume that current rates of testing, ART initiation etc will continue. However, we cannot know which other changes might occur over the coming 50 years.

We sampled from an array of parameter distributions and then applied some filtering, in order to generate a range of setting-scenarios which appear to broadly represent the distribution of a number of characteristics. Based on this, we interpret the proportion of setting-scenarios in which additional testing is cost-effective as a probability. Given that the various characteristics of setting-scenarios that we considered did not predict cost effectiveness we consider this to be a reasonable interpretation for practical purposes.