Inégalités socio-économiques dans le recours au dépistage du VIH en Afrique subsaharienne : une analyse multi-pays des enquêtes de population

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Socioeconomic inequalities in HIV testing uptake in sub-Saharan Africa:

A multi-country analysis of population-based surveys

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Affidavit

Je soussignée, Pearl Anne ANTE-TESTARD, déclare par la présente que le travail présenté dans ce manuscrit est mon propre travail, réalisé sous la direction scientifique de Pr. Laura TEMIME (directrice) et de Dr. Kévin JEAN (co-encadrant), dans le respect des principes d'honnêteté, d'intégrité et de responsabilité inhérents à la mission de recherche. Les travaux de recherche et la rédaction de ce manuscrit ont été réalisés dans le respect de la charte nationale de déontologie des métiers de la recherche.
Ce travail n'a pas été précédemment soumis en France ou à l'étranger dans une version identique ou similaire à un organisme examinateur.

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I, undersigned, Pearl Anne ANTE-TESTARD, hereby declare that the work presented in this manuscript is my own work, carried out under the scientific direction of Prof. Laura TEMIME (thesis director) and of Dr. Kévin JEAN (co-thesis supervisor), in accordance with the principles of honesty, integrity and responsibility inherent to the research mission. The research work and the writing of this manuscript have been carried out in compliance with the French charter for Research Integrity.
This work has not been submitted previously either in France or abroad in the same or in a similar version to any other examination body.

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I dedicate this thesis to God and my family.

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Summary

Human immunodeficiency virus/ acquired immunodeficiency syndrome (HIV/AIDS) remains a public health threat worldwide causing substantial impact on societies and population health. HIV testing plays a critical role within the HIV prevention continuum and cascade of care. Successful scale-up of HIV testing services in sub-Saharan Africa (SSA) has increased the overall uptake of HIV testing in recent years. However, such an overall increase may hide important disparities across socioeconomic groups that may prevent reaching the UNAIDS first 95 target (i.e., 95% of people living with HIV [PLHIV] will know their status) by 2030. The overall aim of this thesis is to investigate socioeconomic inequalities in HIV testing uptake through multi-country analysis of population-based surveys in SSA. More specifically, this thesis aimed at: i) quantifying socioeconomic inequalities in HIV testing uptake and assess their trends over time; ii) exploring the spatial distribution of socioeconomic inequalities in HIV testing uptake across various geographical scales; iii) identifying contextual factors associated with socioeconomic inequalities in HIV testing uptake; and iv) understanding the mediating pathways linking socioeconomic position (SEP) to HIV testing uptake at the individual level in several SSA countries.

In order to fulfil these objectives, we analyzed standardized nationally representative population-based surveys. Recent HIV testing was defined as self-reported uptake of HIV test within the 12 months preceding data collection. We found that large scale-ups in HIV testing overall concealed socioeconomic inequalities in recent HIV testing and other inequalities related to gender and geography. We found substantial increase in recent HIV testing in all selected SSA countries after 2008, mostly driven by increases among female participants in the post-2008 surveys. Overall, after 2008, pro-rich relative inequalities in recent HIV testing decreased both in female and male participants, while absolute inequalities in recent testing plateaued in female and increased in male participants. Inequalities were more marked in Western and Central Africa and among men. Inequalities were also observed with varying magnitudes across geography and administrative levels – national and subnational. At the national level, HIV testing programs seemed to be efficient, however at subnational levels, testing programs tended to be less efficient (i.e., the level of HIV testing uptake did not match the level of HIV prevalence) in the majority of countries. Different contextual- and individual-level factors were observed that may explain wealth-related inequalities in recent HIV testing.

National HIV prevalence tended to be associated with country-level inequality estimates but not per capita Gross Domestic Product (i.e., indicator of national economic development). At the individual level, we found no single, strong individual-level mediator in the pathway between wealth and recent testing that was consistently strong across all countries and genders, but our findings showed that inequalities were mediated more by demand- (i.e., comprehensive HIV-related knowledge and positive attitudes towards PLHIV) than supply-side individual characteristics. The findings of this thesis may be useful for designing well-tailored HIV testing strategies that do not generate nor worsen inequalities in order to reach the UNAIDS first 95 by 2030.

Keywords: HIV, HIV testing, socioeconomic inequality, sub-Saharan Africa, social epidemiology, population-based survey

Résumé

Le virus de l'immunodéficience humaine/syndrome d'immunodéficience acquise (VIH/SIDA) reste une menace pour la santé mondiale. Le dépistage du VIH joue un rôle essentiel dans le continuum de la prévention du VIH et la cascade de soins. La montée en puissance des services de dépistage du VIH en Afrique subsaharienne (ASS) a permis d'augmenter le recours global au dépistage du VIH au cours des dernières années. Cependant, cette augmentation globale peut cacher d'importantes disparités entre les groupes socioéconomiques qui peuvent empêcher d'atteindre l'objectif des 95 premiers de l'ONUSIDA (i.e., 95% des personnes vivant avec le VIH [PVVIH] connaîtront leur statut) d'ici 2030. L'objectif général de cette thèse est d'étudier les inégalités socio-économiques dans le recours au dépistage du VIH par le biais d'une analyse multi-pays des enquêtes de population en ASS. Plus précisément, cette thèse vise à : i) quantifier les inégalités socio-économiques dans le dépistage du VIH et évaluer leurs tendances dans le temps ; ii) explorer la distribution spatiale des inégalités dans le dépistage du VIH à différentes échelles géographiques ; iii) identifier les facteurs contextuels associés aux inégalités socio-économiques dans le dépistage du VIH ; et iv) comprendre les voies médiatrices reliant le position socioéconomique (PSE) au dépistage du VIH au niveau individuel dans plusieurs pays d'ASS.

Afin d'atteindre ces objectifs, nous avons analysé des enquêtes standardisées représentatives de la population au niveau national. Le dépistage récent du VIH a été défini comme la réalisation d'un test du VIH dans les 12 mois précédant la collecte des données. Nous avons constaté que la généralisation du dépistage du VIH dissimulait globalement les inégalités socio-économiques en matière de dépistage récent du VIH et d'autres inégalités liées au sexe et à la géographie. Nous avons constaté une augmentation substantielle des dépistages du VIH dans tous les pays d'ASS sélectionnés après 2008, principalement en raison de l'augmentation du nombre de femmes participant aux enquêtes postérieures à 2008. Globalement, après 2008, les inégalités relatives pro-riches en matière de dépistage récent du VIH ont diminué tant chez les femmes que chez les hommes, tandis que les inégalités absolues en matière de dépistage récent se sont stabilisées chez les femmes et ont augmenté chez les hommes. Les inégalités étaient plus marquées en Afrique occidentale et centrale et chez les hommes. Des inégalités ont également été observées avec des amplitudes variables selon la géographie et les niveaux administratifs - national et infranational. Au niveau national, les programmes de dépistage du VIH semblaient

être efficaces, mais au niveau infranational, les programmes de dépistage avaient tendance à être moins efficaces (i.e., le niveau de dépistage du VIH ne correspondait pas au niveau de prévalence du VIH) dans la majorité des pays. Au niveau individuel, nous n'avons pas trouvé de médiateur unique et fort dans le chemin entre la richesse et le dépistage récent, qui soit systématiquement fort dans tous les pays et pour tous les sexes, mais nos résultats montrent que les inégalités sont davantage médiatisées par la demande (i.e., des connaissances complètes sur le VIH et des attitudes positives envers les PVVIH) que par les caractéristiques individuelles de l'offre. Les résultats pourraient contribuer au développement de stratégies de dépistage du VIH bien adaptées, qui ne génèrent ni n'aggravent les inégalités, afin d'atteindre les 95 premiers objectifs de l'ONUSIDA d'ici 2030.

Mots-clés : VIH, dépistage du VIH, inégalité socio-économique, Afrique subsaharienne, épidémiologie sociale, enquête en population

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List of abbreviations

AIDS: Acquired immunodeficiency syndrome

AIS: AIDS Indicator Survey

ART: Antiretroviral therapy

CDC: US Centers for Disease Control and Prevention

CDE: Controlled Direct Effect

CI: Concentration Index

DAG: Directed Acyclic Graph

DHS: Demographic and Health Surveys

ECI: Erreygers Concentration Index

ESA: Eastern and Southern Africa

GDP: Gross Domestic Product

HIV: Human immunodeficiency virus

HIVST: HIV self-testing

HTS: HIV testing services

MSM: Men who have sex with men

NIE: Natural Indirect Effect

NGO: Non-governmental organizations

PEPFAR: President's Emergency Plan for AIDS Relief

PITC: Provider-initiated testing and counselling

PMTCT: Prevention of mother-to-child transmission

PLHIV: People living with HIV

PM: Proportion mediated

PR: Prevalence ratio

PrEP: Pre-exposure prophylaxis

PSU: Primary Sampling Units

PWID: People who inject drugs

RIF: Recentered Influence Function

RII: Relative Index of Inequality

SDG: Sustainable Development Goals

SEP: Socioeconomic position

SES: Socioeconomic status

SII: Slope Index of Inequality

SSA: Sub-Saharan Africa

SW: Sex workers

TasP: Treatment as prevention

TE: Total Effect

UN: United Nations

UNAIDS: Joint United Nations Programme on HIV/AIDS

VCT: Voluntary counselling and testing

VMMC: Voluntary male medical circumcision

WCA: Western and Central Africa

WHO: World Health Organization

Scientific communication

Articles

Within the PhD thematic

- **Ante-Testard PA**, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Temporal trends in socioeconomic inequalities in HIV testing: an analysis of cross-sectional surveys from 16 sub-Saharan African countries, *Lancet Global Health*. 2020. https://doi.org/10.1016/S2214-109X(20)30108-X

- **Ante-Testard PA**, Hamidouche M, Apouey B, Baggaley R, Larmarange J, Benmarhnia T, Temime L, Jean K. Understanding the pathways leading to socioeconomic inequalities in HIV testing uptake in 18 sub-Saharan African countries: a mediation analysis. (Under review, *AIDS*)
  medRXiv, https://doi.org/10.1101/2021.09.18.21263768

- **Ante-Testard PA**, Temime L, Jean K. Epidemiological rather than macro-economic factors correlate with socioeconomic inequalities in HIV testing in 16 sub-Saharan African countries. (Pre-print)
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- **Ante-Testard PA**, Carrasco-Escobar G, Benmarhnia T, Temime L, Jean K. Investigating inequalities in HIV testing in sub-Saharan Africa: insights from a spatial analysis of 25 countries. (In finalization)

- Hamidouche M, **Ante-Testard PA**, Baggaley R, Temime L, Jean K. Monitoring socioeconomic inequalities across HIV knowledge, attitudes, behaviours and prevention in 18 sub-Saharan African countries. *AIDS*, Publish Ahead of Print. https://doi.org/10.1097/QAD.0000000000003191

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- Ravalihasy A, **Ante-Testard PA**, Kardas-Sloma L, Yazdanpanah Y, de Allegri M, Ridde V. Quantitative methods used to evaluate impact of combination HIV prevention intervention: a methodological systematic review. (Submitted)

Conferences and seminars

Oral presentation

- AFRAVIH 2020: 10^{e} Conférence Internationale Francophone VIH, Hépatites, Santé sexuelle et COVID-19, Senegal (Virtual)
  Ante-Testard PA, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Évolution des inégalités socioéconomiques dans l'accès au dépistage du VIH chez les femmes: résultats tirés d'enquêtes en population dans 16 pays d'Afrique subsaharienne.

Poster presentation

- UJC 2019: Université des Jeunes Chercheurs, Carry-le-Rouet, France
  Ante-Testard PA, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Time trends in socio-economic inequalities in HIV testing: insights from population-based surveys in 16 sub-Saharan African countries.

- Journées scientifiques de l'ANRS 2019, Paris, France
  Ante-Testard PA, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Time trends in socio-economic inequalities in HIV testing: insights from population-based surveys in 16 sub-Saharan African countries.

- ICASA 2019: 20th ICASA International Conference on AIDS and STIs in Africa, Kigali, Rwanda

Ante-Testard PA, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Time trends in socio-economic inequalities in HIV testing: insights from population-based surveys in 16 sub-Saharan African countries.

- AIDS 2020: 23rd International AIDS Conference, San Francisco and Oakland, USA (Virtual)
  Ante-Testard PA, Benmarhnia T, Bekelynck A, Baggaley RC, Ouattara E, Temime L, Jean K. Decomposing socioeconomic inequalities in HIV testing in 16 sub-Saharan African countries: the role of epidemiological and macro-economic factors.

- IAS 2021: 11th IAS Conference on HIV Science, Germany (Virtual)
  Ante-Testard PA, Hamidouche M, Temime L, Benmarhnia T, Jean K. Understanding the pathways leading to socioeconomic inequalities in HIV testing uptake among women in 4 sub-Saharan African countries: a mediation analysis.
  Hamidouche M, **Ante-Testard PA**, Jean K. Socioeconomic inequalities in the access to HIV prevention and care services in sub-Saharan Africa.

- Journées scientifiques de l'ANRS 2022, Paris, France
  Ante-Testard PA, Carrasco-Escobar G, Benmarhnia T, Temime L, Jean K. Investigating inequalities in HIV testing in sub-Saharan Africa: insights from a spatial analysis of 25 countries.

Invited talk

- ERES seminar, March 11, 2021: Equipe de Recherche en Epidémiologie Sociale, Inserm, IPLESP, Paris, France (Virtual)
  Socioeconomic inequalities in HIV testing in sub-Saharan Africa: multi-country analysis of population-based surveys

Introduction

"Of all forms of inequality, injustice in healthcare is the most shocking and inhumane."

-Dr. Martin Luther King, Jr.

Four decades since its recognition, human immunodeficiency virus/ acquired immunodeficiency syndrome (HIV/AIDS) continues to be a public health threat worldwide causing massive impact on societies and population health. It is one of the largest killers globally especially in sub-Saharan Africa (SSA). The region, which is home to 67% of all people living with HIV (PLHIV) in 2020 (UNAIDS, 2021a), is the epicenter of the disease. Considerable progress has been made over the years to end AIDS but stigma and inequalities, among other factors, continue to drive the epidemic (UNAIDS, 2020a).

There is no effective cure to this fatal disease. Prevention and treatment are key to battling the infection. In particular, HIV testing plays a critical role within the HIV prevention continuum and cascade of care. To optimize HIV treatment benefits, the Joint United Nations Programme on HIV/AIDS (UNAIDS) had set ambitious but achievable targets - the "90-90-90" strategic framework to reach 90% of HIV-infected people diagnosed, 90% of those diagnosed receiving treatment and for 90% of those receiving treatment to be virally suppressed by 2020 (UNAIDS, 2014). This, together with increasing availability of antiretroviral therapy (ART), led to successful scale-up of HIV testing programs in SSA. The proportion of PLHIV who knew their status rose from about 10% in 2005 to 84% globally in 2020 (UNAIDS, 2021c; World Health Organization, 2019a). However, such an overall increase may mask important disparities across socioeconomic groups.

The goal of public health interventions is to improve overall population health. Nevertheless, they may also generate or even increase existing health inequalities. This may happen when careful attention is not taken to disadvantaged and marginalized groups when implementing

programs and interventions. This phenomenon has been well described in the Global North[1]. For instance, contrary to what one may assume, programs that increased cancer screening services did not necessarily decrease health inequalities (de Klerk et al., 2017). Conversely, little is known in the Global South[2], notably due to limited national and decentralized systems of data collection to provide reliable data. However, several theories have formalized how intervention-related inequalities may also occur in these settings. In particular, the "inverse equity hypothesis" suggests that health inequalities change dynamically over time. This hypothesis, which was originally developed for child health in 2000 by Victora et al. proposes that higher socioeconomic groups benefit first from new public health interventions and only when the wealthy have reached a level of development that is unlikely to continue more that the poor will begin to catch up, narrowing the gap over time (Victora et al., 2000). This is a corollary to the "inverse care law" proposed by Tudor Hart in public health which states that the "availability of good medical care seems to vary inversely with the need for it in the population served" (Tudor Hart, 1971). Another potential reason why there is little evidence in the Global South, specifically in SSA, regarding such phenomena is because it has long been viewed by many that the HIV epidemic is a public health emergency requiring a global response that takes precedence over other issues such as health inequalities. However, this may have changed lately with the release of the first comprehensive report on health inequalities in HIV, tuberculosis and malaria by the World Health Organization (WHO) (World Health Organization, 2021a).

Several epidemiological studies have previously documented socioeconomic inequalities in the HIV continuum of care, particularly in uptake of and access to HIV testing. However, these inequalities have been documented across various populations and settings and using different study designs. A largescale picture of socioeconomic inequalities in HIV testing is still lacking.

In this context, this PhD aims at investigating socioeconomic inequalities in HIV testing in SSA, their trends, spatial distribution, and drivers. We will demonstrate that these inequalities

1 Global North is used neutrally to refer to high-income countries or developed countries.
2 Global South is used neutrally to refer to low- and middle-income countries or developing countries. I will be using these terms throughout the thesis except in the articles. These terms were preferred because they are currently used in Global Health as part of the movement to decolonize the field. Kyobutungi C, Robinson J, Pai M. PLOS Global Public Health, charting a new path towards equity, diversity and inclusion in global health. PLOS Glob Public Health. 2021 Oct 13;1(10):e0000038.

can be assessed using data collected within the Demographic and Health Surveys (DHS) which represent a rich data source but have not systematically been used to assess health inequalities in SSA. Therefore, the original contribution of this thesis to the body of knowledge is to provide a comprehensive assessment and multi-country analysis of these inequalities using population-based surveys.

The results will hopefully help policymakers and public health practitioners in devising testing strategies that are equitable and efficient despite decreasing international funding and the current disruptions caused by COVID-19. We need to learn from lessons of the past and to address inequalities deeply entrenched within and across societies to reach the first 95 of the new 2030 UNAIDS 95-95-95 and the Sustainable Development Goal (SDG) of reducing inequalities within and among countries by 2030.

This thesis is organized into the following:

- Part One introduces the major themes of this thesis which are HIV/AIDS, HIV testing and health inequalities (Chapters 1, 2 and 3), as well as discusses the gaps in the literature, overall aim and specific objectives of the thesis (Chapter 4).
- Part Two (Chapters 5, 6 and 7) covers the population-based surveys used throughout the thesis, introduces the different measures of socioeconomic position (SEP) and measures of health inequalities.
- Part Three (Chapters 8, 9, 10 and 11) addresses the overall aim of this thesis by tackling the specific objectives by quantifying socioeconomic inequalities in HIV testing and assessing their trends over time (first article), exploring spatial distribution of socioeconomic inequalities in HIV testing (second article), assessing contextual factors associated with socioeconomic inequalities in HIV testing (third short article) and assessing individual-level mediating factors linking SEP and HIV testing (fourth article).
- Part Four (Chapters 12 and 13) covers the general discussion of the main results, perspectives and public health implications.
- Conclusion

Part One:

Context and objectives

1. HIV/AIDS

"HIV is not just a disease. It is a social justice issue."

-Winnie Byanyima, Executive Director of UNAIDS

1.1. What is HIV/AIDS?

HIV/AIDS is one of the most devastating infectious diseases that has befallen humankind since the 20th century. The virus first transferred from African primates to humans around a hundred years ago (D'arc et al., 2015; Sharp & Hahn, 2011). HIV is a retrovirus that attacks the body's immune system (World Health Organization, 2021b). Exchange of body fluids from infected people, such as blood, semen, breast milk and vaginal secretions, can transmit the virus through sexual intercourse, blood transfusion, sharing needles and syringes or any drug equipment by intravenous drug users, and vertical transmission from mother to child (World Health Organization, 2021b).

There are three stages PLHIV undergo upon being infected by the virus. The first stage is the acute or primary infection (which lasts two to four weeks after infection) wherein PLHIV experience flu-like symptoms such as fever, chills, night sweats, sore throat, fatigue, swollen lymph nodes and mouth ulcers (HIV.gov, 2020). The second stage is clinical latency or also called chronic HIV infection. By this stage, the virus replicates but at low levels and PLHIV are usually asymptomatic (Hernandez-Vargas & Middleton, 2013). People can stay at this phase for 10 to 15 years without treatment, but some progress to the last stage a lot faster. They can experience mild infections or chronic signs and symptoms such as fever, diarrhea, shingles and pneumonia, as the body fights off the virus (HIV.gov, 2020; Mayo Clinic, 2021). Without treatment, HIV can progress to AIDS between eight to 10 years, with a CD4 cell count[3] less

3 WHO recommends ART initiation regardless of the CD4 cell count. However, it remains the best measurement to monitor patient's immune and clinical status. Source: Ford N, Meintjes G, Vitoria M, Greene G, Chiller T. The evolving role of CD4 cell counts in HIV care. Current Opinion in HIV and AIDS. 2017 Mar;12(2):123-128. DOI: 10.1097/coh.0000000000000348. PubMed ID 28059957.

than 200 cells/mm^3 or with the development of certain opportunistic infections (Centers for Disease Control and Prevention, 2021; Mayo Clinic, 2021). At this stage, the virus weakens one's immune system making the body prone to opportunistic infections. Symptoms of AIDS include rapid weight loss, pneumonia, recurring fever or profuse night sweats, colored blotches on or under the skin or inside the mouth, nose or eyelids, chronic diarrhea and swollen lymph nodes (Mayo Clinic, 2021). With no treatment, AIDS patients only survive up to three years on average (Centers for Disease Control and Prevention, 2021).

1.1.1. A brief walk through time

AIDS was first recognized in the summer of 1981 when an increasing number of young homosexual men presented signs of rare malignancies and unusual opportunistic infections (Greene, 2007; Merson et al., 2008). The health status of those affected quickly deteriorated. Death was almost inevitable, alarming doctors and arousing fear in people. In the beginning, there were several theories as to the cause of the disease. They mostly focused on lifestyle issues such as the use of drugs, "immune overload" from multiple infections, and the reaction to semen and multiple sexual partners (Greene, 2007). Most believed that it only affected gay men (Fauci, 2003) and intravenous drug users (Greene, 2007). This began to change when heterosexual transmission was documented in 1983 (Centers for Disease Control, 1983). These different theories have led to fear, prejudice and stigma surrounding the disease that we can still observe to this day. Before the identification of the causative agent of this fatal disease, initial prevention recommendations were released in 1982 which were based on precautions previously developed to prevent the spread of hepatitis B in healthcare settings and was geared towards the clinicians and laboratory workers (Valdiserri, 2018). Scientists at the Pasteur Institute discovered that the causative agent was a new retrovirus which was later named HIV in 1983 (Barre-Sinoussi et al., 1983; Jaffe, 2008).

Over the next years, the discovery of HIV led to scientific breakthroughs including targeted blood screening tests and antiretroviral therapy (ART). Licensure of a serological test to detect viral antibodies happened in 1985. The first anti-HIV drug was first developed in 1987, and the Food and Drug Administration approved the first protease inhibitor in 1995, which marked the beginning of the era of the highly active antiretroviral therapy (Greene, 2007; Valdiserri, 2018). This has changed AIDS from a lethal to a chronic and manageable infectious disease.

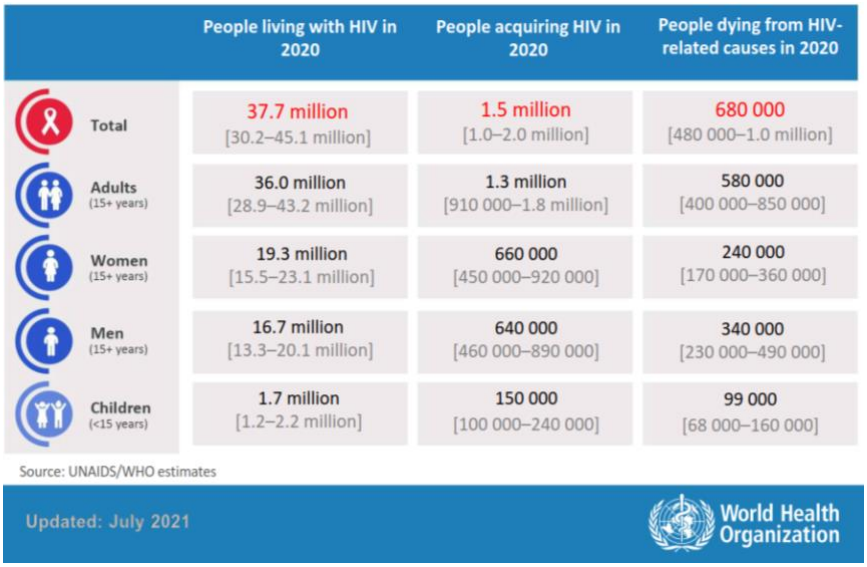
Between 1983 and 1986, it became apparent that AIDS was not a localized epidemic in the US metropolitan areas, but instead a pandemic that spread around the globe and throughout different groups of populations (Hofer, 2018). Several studies documented the existence of HIV/AIDS in Africa. In 1983, Clumeck et al. described AIDS in five African men who emigrated to Belgium which began to point to the existence of the disease in Africa (Clumeck et al., 1983). They also followed up with a more detailed report of 23 previously healthy AIDS hospitalized patients, nine of whom were women, indicating heterosexual transmission (Clumeck et al., 1984). In 1985, Serwadda et al. identified 71 AIDS patients in Uganda, but referred to AIDS as "Slim" disease because diarrhea and weight loss were the dominant clinical presentations (Greene, 2007; Serwadda et al., 1985). Similarly with the studies above, about half of the cases were women and most cases occurred in rural and heterosexual population (Hofer, 2018).

1.2. HIV around the world

In 2019, HIV/AIDS was the second leading cause of morbidity among adults according to the Global Burden of Disease Study[4] despite a decrease since 2005 when ART became increasingly available (Vos et al., 2020). Overall, 79.3 million people have been infected by HIV and 36.3 million have died from AIDS-related illnesses by 2020 since its emergence (UNAIDS, 2021c). In 2020, 37.7 million people were living with HIV globally (Figure 1) with 84% of all PLHIV aware of their HIV status. About 1.5 million were newly infected and 680,000 died from AIDS-related illnesses (Figure 1). Men and women are affected by HIV differently, with women bearing a higher burden. About 53% of all PLHIV in 2020 were women and girls.

4 Hosted by the Lancet, brings together all comprehensive data and analysis in global health led by the Institute for Health Metrics and Evaluation at the University of Washington.
Source: https://www.thelancet.com/gbd

Figure 1. Summary of global HIV epidemic, 2020.

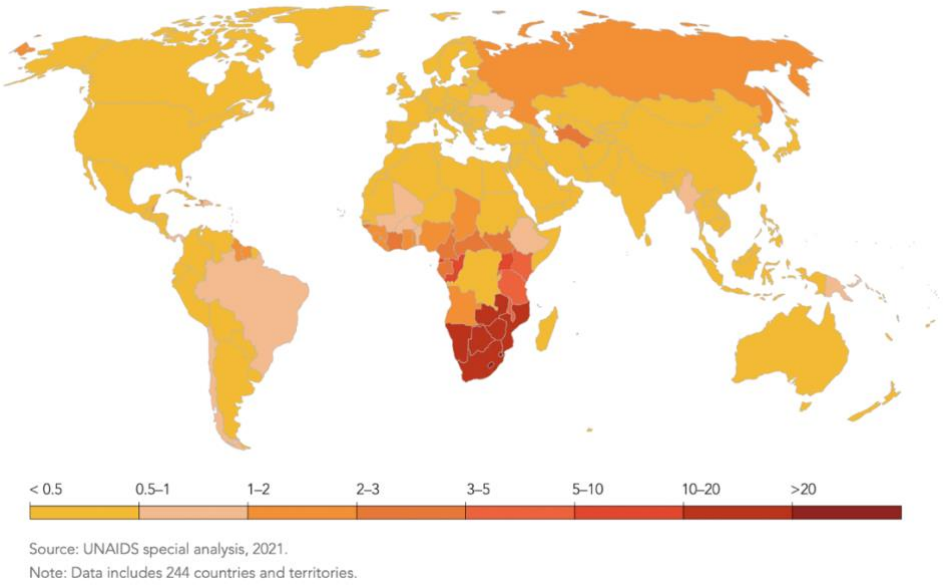


Source: (WHO, 2021)

1.3. HIV in sub-Saharan Africa

SSA is currently home to the majority of HIV infections worldwide (Figure 2), with around 67% of PLHIV in 2020 (UNAIDS, 2021a). HIV/AIDS is the principal cause of morbidity and mortality in the region (James et al., 2018; Roth et al., 2018; Vos et al., 2020). The majority of transmission occurs through heterosexual sex, with women and girls accounting for 63% of all new HIV infections in 2020 (UNAIDS, 2021c). It was shown that SSA had a four-fold more elevated risk of male-to-female HIV transmission per contact compared to higher income countries (0.3% versus 0.08%) (Boily et al., 2009; Yegorov et al., 2019). Adolescent girls and young women are disproportionately affected by HIV. This is due to several factors that put them at higher risk when compared to men including gender discrimination and gender-based violence (Ramjee & Daniels, 2013). This thesis will be focusing on SSA as it is the region mostly affected by the disease.

Figure 2. HIV prevalence among adults (aged 15-49 years), 2020.



Source: (UNAIDS, 2021b)

There is a geographical pattern in the prevalence and incidence of HIV in SSA. Eastern and Southern Africa (ESA) tends to have higher HIV prevalence and incidence compared to Western and Central Africa (WCA). According to UNAIDS estimates in 2020, 20.6 million of PLHIV were from ESA, while 4.7 million of PLHIV from WCA. The epidemic is rather generalized in the population over ESA, while WCA presents a mixed pattern of the epidemic - generalized and concentrated in subpopulations – within countries (Sam-Agudu et al., 2016).

1.4. Social epidemiology of HIV in sub-Saharan Africa

The social epidemiology[5] of HIV in SSA is different compared to other diseases (Fox, 2012; Hargreaves et al., 2015). Before 2000, like other infectious diseases, it was seen as a "disease of poverty and ignorance" according to Gregson et al. (Gregson et al., 2001). However, such a

5 Social epidemiology first gained its name in the 1950s. It is a branch of epidemiology that investigates the social determinants of population distribution of health, disease and well-being "rather than treating such determinants as mere background to biomedical phenomena".
Source: Krieger N. A glossary for social epidemiology. J Epidemiol Community Health. 2001 Oct 1;55(10):693–700.

disease perception appeared in contradiction with observations made between the 1980s and early 2000, which described that HIV/AIDS was mostly observed among individuals with higher SEP, particularly in SSA (Fortson, 2008; Gregson et al., 2001; Hargreaves et al., 2015; Over & Piot, 1991; Shelton et al., 2005). They purported that HIV/AIDS was more prevalent among people with higher educational attainment and household wealth. HIV prevalence was also found to be highest in some of the most economically advanced countries in Africa such as Botswana and South Africa (Shelton et al., 2005). This contrasts with the social trends of other diseases, where high prevalence is observed more among populations with lower SEP (Fox, 2010). This early pattern of HIV might have been due to the "mobility and size of sexual network" of the affluent groups (Hargreaves et al., 2015). Hargreaves et al. also argued that during this period, HIV prevention and treatment efforts were still undeveloped, HIV awareness was low and behavior change was lacking (Hargreaves & Howe, 2010).

More recent studies proposed that the social trend of HIV may have been changing during the 2000s decade, with HIV prevalence becoming higher among those with lower SEP, at least in some African regions (Hargreaves et al., 2011; Hargreaves et al., 2008, 2015; Kayeyi et al., 2012). For example, in a study done by Hargreaves et al., HIV prevalence in Tanzania decreased faster among those with higher educational level compared to those with lower education between 2003-04 and 2007-08 (Hargreaves & Howe, 2010). Kayeyi et al. also found that more educated pregnant women had substantial decline in HIV prevalence compared to less educated women who had a stable HIV prevalence in Zambia between 2001-02 and 2007 (Kayeyi et al., 2012). A recent cohort study using HIV incidence also confirmed this latest social trend of HIV wherein they found that individuals with lower SEP tended to have high HIV incidence after 1997 (Santelli et al., 2021). This is a game changer since most of the previous studies relied on HIV prevalence which changes slowly and integrates past and present dynamics of the infection.

1.5. HIV cascade of care and prevention

To this day, there are no vaccines nor effective cure (except on rare cases) for HIV/ AIDS. Still, various strategies have been developed for prevention and care. HIV prevention strategies have evolved from early, information-based efforts about risk and risk

reduction to theory-informed behavioral interventions and evidence-based biomedical approaches based on health products, from condoms to ART (Valdiserri, 2018).

HIV prevention and treatment strategies rely on behavioral interventions, biomedical prevention tools and treatment strategies. Behavioral interventions include sexual partner reduction and harm reduction for people who use drugs (Bekker et al., 2012). Biomedical prevention tools include use of condoms, voluntary medical male circumcision (VMMC), and pre-exposure prophylaxis (PrEP) and post-exposure prophylaxis (Bekker et al., 2012; Mayer et al., 2010). Treatment strategies include ART. Although it cannot cure HIV, it can help PLHIV live longer and healthier lives. It also carries additional prevention benefits for PLHIV as it drastically reduces HIV transmission, which is often called "treatment as prevention" (TasP), and prevention of mother-to-child transmission of HIV (PMTCT) (Hull & Montaner, 2013). Significant progress has also been made in the Global South tailored to the socioeconomic and cultural context of women in SSA (Ramjee & Daniels, 2013), with the UNAIDS continuously advocating for tailored programs for women (UNAIDS, 2019).

In recent years, countries have encouraged the adoption of multisectoral responses and deliver a combination of these HIV prevention strategies for greatest impact, and to address the many determinants of HIV (e.g., gender inequality, economic inequality, poverty, and social stigmatization of HIV/AIDS) (Hargreaves et al., 2016). A problem, identified by Hargreaves et al., is the tendency to view technology, behaviors and social factors in isolation which can cast biomedical products, behavior change and structural interventions as opposing interventions. Moreover, according to the authors, the variation in the volume, type and quality of evidence can also lead to overoptimism of the efficiency of biomedical interventions and under appreciate the importance of behavioral and structural interventions on the effectiveness of these biomedical interventions on population-level HIV incidence (Hargreaves et al., 2016).

1.5.1. HIV care continuum

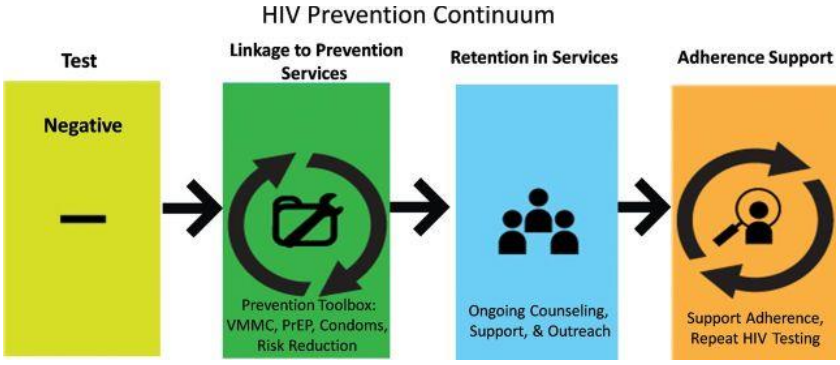
The care continuum is a useful public health tool popularized by Gardner et al. to evaluate the main steps in the cascade of care that PLHIV undergo (Gardner et al., 2011). The main steps include diagnosis of HIV infection, ART initiation and viral suppression and retention to care (CDC, 2019; Jose et al., 2018; MacCarthy et al., 2015; McNairy & El-Sadr, 2014).

Different versions of the cascade of care are used by different countries and institutions. For instance, the US Centers for Disease Control and Prevention (CDC) identified five primary stages, including HIV testing and diagnosis, linkage to care, retention in care, treatment and viral suppression (CDC, 2019). Meanwhile, the WHO in 2013, provided a more detailed model with sub-stages (McNairy & El-Sadr, 2014). Despite these differences, their ultimate goal is to achieve viral suppression for PLHIV in order to maximize individual and prevention benefits of ART.

1.5.2. HIV prevention continuum

Similar to the cascade of care, McNairy et al. proposed the HIV prevention continuum (Figure 3) that builds on HIV testing as its foundation while focusing on the individual's perspective (McNairy & El-Sadr, 2014). In this model, the desired endpoint is that individuals remain HIV uninfected. It also demonstrates that HIV prevention should not be seen as a one-time event, but as an ongoing engagement in the prevention process for as long as the risk remains.

Figure 3. The HIV prevention continuum.



Source: (McNairy & El-Sadr, 2014)

For both the care continuum and the HIV prevention continuum model, the first and most crucial step in prevention is HIV testing because it links individuals to several prevention and care services. In the absence of a cure, closing the gap in HIV testing and linking individuals to HIV treatment and care is critical in the success of the global HIV response (World Health Organization, 2019a).

1.6. International organizations to combat HIV/AIDS

Various global initiatives and organizations were created to combat HIV/AIDS since its recognition. The UNAIDS was created in 1996 to lead and inspire "global, regional, national and local leadership, innovation and partnership to ultimately consign HIV to history" (UNAIDS, 2018).

The Global Fund was founded in 2002 to "accelerate the end of AIDS, tuberculosis and malaria as epidemics" and it raises and invests 4 billion US dollars a year to support programs (The Global Fund, 2021). In 2003, the US government launched the President's Emergency Plan for AIDS Relief (PEPFAR) for HIV prevention, treatment and care (US Department of State, 2021). PEPFAR focuses on countries most affected by HIV (initially 15 countries which expanded to 32 countries today) through bilateral cooperation (i.e., a financial and diplomatic instruments) whose offices are in US embassies (Bekelynck, 2019). Meanwhile, the Global Fund has a broader coverage (134 countries had already received funding with 74 countries currently being funded) operating through multilateral cooperation only as a financial instrument, without a presence in the countries they operate (Bekelynck, 2019). According to Bekelynck et al., since 2012, it has been in a transition phase to withdraw from countries considered to have the capacity to fight the epidemics. PEPFAR typically develops its own projects with local actors acting in advisory roles, while the Global Fund lets grants be developed and monitored by the Country Coordinating Mechanism (Bekelynck, 2019). Several international and non-governmental organizations (NGO) have also stepped up to help in the fight. Over the years, HIV response efforts were heavily funded by international donors and governments.

In 2014, the UNAIDS set fast track targets to finally end the AIDS epidemic by 2030: 95% of PLHIV will be diagnosed, 95% of those diagnosed will be undergoing ART and 95% of those treated will be virally suppressed. An intermediate target of 90-90-90 was set for 2020.

1.7. Decreasing international donor funding

International donor funding for the Global South reached 19.1 billion US dollars in 2013 but still fell short of the UNAIDS estimates of resource needs, which was about 22-24 billion US dollars for 2015 and 36 billion for 2020, to reach the UNAIDS fast-track targets to reduce HIV

infections and AIDS-related deaths by 2030 (Remme et al., 2016). Several international and regional declarations called on African governments to fund more of their HIV responses (Buse & Martin, 2012; Remme et al., 2016) which would allow for funding of other countries who need more external support (Remme et al., 2016). There is also a shift to non-health development priorities after 2015 in response to the SDG (The Lancet, 2013). Between 2017 and 2019, HIV international funding decreased by 7% in the Global South, while domestic funding has grown by about 50% since 2010. Currently, 21.5 billion US dollars is available for the AIDS response in the Global South, with around 61% coming from domestic funding at the end of 2020 (UNAIDS, 2020b). UNAIDS estimated that around 29 billion US dollars will be required for the response of the Global South in 2025 to end AIDS (UNAIDS, 2021a).

This has both advantages and disadvantages. Increase in domestic funding signifies improvements in sustainable financing of the HIV response in the Global South. However, countries that may have been depending mostly on international funding may encounter difficulties in their HIV response, especially if the country is also experiencing political unrest and poverty. The findings in this thesis will hopefully serve as a guide as to where to focus efforts to fight the HIV epidemic.

2. HIV testing

"Every time someone gets tested for HIV; we are one step closer to ending the AIDS epidemic. Learning your HIV status opens the door to powerful HIV prevention and treatment options that could save your life or the life of someone you love."

-Dr. Jonathan Mermin, Director of CDC

As we have seen in the previous chapter, HIV testing serves as the gateway to many HIV prevention and care services. HIV testing services (HTS) consist of a full range of services in addition to HIV testing, which includes pre- and post-counselling, linkage to care and treatment and coordination with laboratory services for quality assurance and delivery of correct results (World Health Organization, 2019a). All HTS should be provided in line with the WHO's essential 5 Cs which are consent, confidentiality, counselling, correct test results, and connection/linkage to prevention, care, and treatment (World Health Organization, 2019a).

2.1. Brief clinical background of HIV testing

Today's HIV tests are considered high-performing due to their high sensitivity (100%) and specificity (greater than 99%) (Salmona et al., 2014). However, it was not always like this. Like other tests, it underwent many developments. In fact, the first HIV antibody test was developed in 1985, not to directly detect HIV but to screen blood products which used the enzyme-linked immunosorbent assay (ELISA) method (Alexander, 2016). This test was later found to be inaccurate and yielded a significant number of false positives especially when low risk individuals were tested (Alexander, 2016). In 1987, the Western Blot test became available which was more accurate but more difficult to perform (Alexander, 2016). Individuals would first undergo the ELISA test and, if tested positive, would be sent for a Western Blot as a confirmatory test. Second, third and fourth generation HIV tests came out in the 1980s and late 1990s which were more accurate

(Bentsen et al., 2011) and allowed for earlier diagnosis (Alexander, 2016). The fifth generation test we have today can detect HIV infection approximately two weeks after exposure with a better positive predictive value (Alexander, 2016).

The need to provide HIV results to patients in a clinic or emergency room or during labor and delivery, or in the advent of HIV prophylactic treatments after an occupational blood or body fluid exposure set the stage for the development of rapid HIV assays (Alexander, 2016). Rapid HIV tests have been developed for whole blood, serum and oral fluid samples. However, for a long time, it was not considered as a diagnostic test and results needed to be confirmed. Presently, the WHO recommends that countries move away from Western blotting and line immunoassays and to use simpler tests such as rapid diagnostic tests at the point-of-care and enzyme immunoassays (World Health Organization, 2019b). They are cheaper, produce results faster and accurate results more often, and can be performed by several health professionals (World Health Organization, 2019a), thus facilitating more access to and uptake of HTS among individuals who need them.

2.2. Evolution of HIV testing strategies

When HIV testing became increasingly available in the mid-1980s, public health measures that were common in other diseases such as compulsory testing, contact tracing and quarantine were questioned due to fear of the social and political implications of mandatory reporting of HIV-positive status (Obermeyer & Osborn, 2007). Moreover, concerns that such measures could lead to discrimination and stigma and "drive the epidemic underground" prevailed over traditional public health approaches and only confidential and anonymous testing was the considered approach (Bayer, 1991; Obermeyer & Osborn, 2007). HIV/AIDS was treated in law and policy differently from other diseases which was termed as "HIV exceptionalism" (Oppenheimer & Bayer, 2009). However, with increasing availability of ART, such exceptionalism became less justifiable, and scaled-up testing has largely been advocated as the gateway to prevention and treatment and as a way to normalizing and destigmatizing HIV (De Cock & Johnson, 1998; Koo et al., 2006; Manavi & Welsby, 2005; Obermeyer & Osborn, 2007). There was a growing support to incorporate HIV testing and counselling into routine care.

In 2004, the WHO and the UNAIDS recommended offering routine opt-out[6] testing and, in 2007, they issued guidelines recommending opt-out provider-initiated testing in health facilities (Programme commun des Nations Unies sur le VIH/SIDA & Organisation mondiale de la santé, 2007). The CDC called for the routine testing of individuals aged 13-64 years and for simplifying the process of obtaining consent (Centers for Disease Control and Prevention, 2007). The provider-initiated opt-out testing changed the profiles of testing users from a small self-selecting group of people to a more general and wider part of the population accessing health care (Cremin et al., 2012).

2.3. HIV testing services delivery approaches

Unlike other diseases, getting tested for HIV involves facing stigma or the fear of being judged by others despite the evolutions in HIV testing strategies. As we have seen before, the beginning of HIV/AIDS had been a challenging road involving a lot of prejudice and stigma towards gay people, drug users and people engaging in risky sexual behaviors despite knowledge of heterosexual and vertical transmissions. There is a misconception that being identified as PLHIV is synonymous with membership to these groups. For this reason, several HTS modalities have been developed to reach everyone, especially individuals who are hard to reach and who fear to seek testing.

2.3.1. Facility-based HIV testing services

This is a type of testing routinely offered in health facilities such as antenatal clinics and reproductive health clinics (Chamie et al., 2021). HIV testing is recommended by the WHO to be routinely offered as part of health services such as sexually-transmitted infections, viral hepatitis, and tuberculosis services, as well as in antenatal care and malnutrition clinics for key populations in all settings and in high HIV burden settings (World Health Organization, 2019b). Facility-based HTS could be either initiated by the client or patients (known as voluntary counselling and testing or client-initiated counselling and testing) or by the health providers (known as provider-initiated counselling and testing).

6 Patients are informed that the health facility routinely tests patients for HIV unless the patient refuses. Source: https://www.cdc.gov/hiv/clinicians/screening/opt-out.html

In general, facility-based testing has several advantages including stable location, low cost, higher yields of HIV diagnosis among patients seeking care and ease of linking HIV-negative patients to prevention services and HIV-positive patients to treatment (Chamie et al., 2021; Sharma et al., 2015). However, structural factors such as limited access to health services and testing kits, negative perceptions of the attitudes of health providers, poor HIV knowledge or risk perception, non-specific or no symptoms in the early stages and stigma are barriers especially among men, youth and key populations (Chamie et al., 2021; Okal et al., 2020; Strauss et al., 2015).

2.3.1.1. Voluntary counselling and testing

Voluntary counselling and testing (VCT) is a client-initiated testing service located in health facilities. The advantages include instantaneous linkage to care such as same-day ART initiation, and prevention including PrEP and VMMC, ease of incorporating non-HIV clinical services and low cost (Chamie et al., 2021). Disadvantages are low population coverage due to the missed cases in those who do not seek testing, fear of being judged by others, late diagnosis and financial costs to patients for transportation to the facility and time away from employment (Chamie et al., 2021).

2.3.1.2. Provider-initiated HIV counselling and testing

Provider-initiated counselling and testing (PITC) is an opt-out health testing service offered by health care providers at clinics and hospitals. It can also reach individuals who do not seek testing for themselves. Since testing is offered at a general clinic not specifically intended for PLHIV, stigma related to requesting HIV testing and sharing of sexual behaviors may be overcome. It can also reach individuals that are at-risk of negative health outcomes with short delays in diagnosis (Chamie et al., 2021). The disadvantages are low coverage due to the overall lack of routine and primary care in SSA, inability to diagnose those who does not seek healthcare, tendency to diagnose PLHIV late in the disease due to passive testing, distance, transportation costs for patients, and time away from employment and concerns about confidentiality (Angotti et al., 2009; Chamie et al., 2021; Morin et al., 2006; Sande et al., 2018). As mentioned previously, the WHO recommended offering routine testing in health facilities through the expanded provider-initiated opt-out testing and counselling in 2007 that may have changed the profiles of testing users (Programme commun des Nations Unies sur le VIH/SIDA

& Organisation mondiale de la santé, 2007). Women tend to have more access to routine HIV testing due to its integration in antenatal care and services. However, men do not have this opportunity, and they were documented to access healthcare services less than women.

2.3.2. Community-based HIV testing services

Community-based testing is a type of testing offered outside of healthcare settings. It is recommended to key populations as complementary to facility-based testing with a focus on efficiently reaching hard-to-reach groups. In high burden settings, it is recommended for all populations (World Health Organization, 2019b). Community-based testing reaches higher levels of HIV testing uptake than facility-based testing because services can reach people who do not usually seek health care and can also detect high levels of CD4 count (Chamie et al., 2021; Sharma et al., 2015; Suthar et al., 2013). Types of community-based testing include, but not limited to the following:

2.3.2.1. Home-based testing

Home-based testing involves health workers conducting door-to-door to offer opt-out testing. This has been found to be effective in targeting women and young children, however, issues about confidentiality, privacy, fear of experiencing community-level stigma and disclosure of status at home have been documented to limit uptake (Hershow et al., 2019). Based on some studies, this approach was poorly effective in reaching men, highly mobile people and young adults (Floyd et al., 2018; Iwuji et al., 2016). Different strategies have been developed to reach these population groups such as visits during weekends or evenings and dissemination of HIV self-testing kits to family members not at home during the door-to-door visits (Labhardt et al., 2019; Mulubwa et al., 2019).

2.3.2.2. Mobile outreach testing

Mobile testing is offered at locations to aid access to the community or venues where high risk individuals gather such as bars or sites of sex work or the “hotspot” settings, to aid access to the community (Chamie et al., 2021). This approach has reached higher proportions of hard-to-reach population groups (men, young adults, migrants and key populations) than other testing modalities (Bassett et al., 2015; Dememew et al., 2020; Herce et al., 2018; Parker et al., 2015;

Sharma et al., 2015). Workplace testing is another type of mobile testing that could overcome barriers involving opportunity costs, costs of time, and loss of earnings while being away from work to get tested (Chamie et al., 2021).

2.3.2.3. HIV self-testing

In HIV self-testing (HIVST), individuals collect their own oral or blood specimens for rapid testing and interpret their own results (Johnson et al., 2017; World Health Organization, 2019a). It was first recommended by WHO in 2016 as complementary to the standard HIV testing (World Health Organization, 2016). A recent systematic review and meta-analysis between 2006 and 2019 showed that HIVST doubled the uptake of HIV testing in the general population wherein the majority of the studies were done in SSA (Jamil et al., 2021). High acceptability of HIVST is due to its convenience, confidential and private nature, and the potential to overcome stigma and reduce opportunity costs when visiting a health facility (Figueroa et al., 2015; Jamil et al., 2021; Njau et al., 2019; Stevens et al., 2018). Despite the advantages of HIVST, its scale up has been hindered due to some problems such as the higher cost of oral fluid-based kits, lack of support to linkage to care for those who tested positive, lack of immediate post-test counselling and difficulties in interpreting the results (Chamie et al., 2021). In addition, while many value the painless and non-invasive nature of oral fluid-based kits, some also perceive that blood-based is more accurate (Figueroa et al., 2015).

2.3.3. HIV partner notification services or index testing

Index testing or partner notification is a type of testing whereby the exposed contacts (i.e., sexual partners, biological children and anyone with whom a needle was shared) of the HIV-positive person (i.e., index client) are offered voluntary HTS (United Nations, n.d.). The goal of index testing is to break the chain of transmission. WHO recommends that programs should also consider social network-based approaches that offer HIV testing to social contacts of key populations in addition to sexual and drug injecting partners (World Health Organization, 2019b).

We see that there are several strategies and modalities developed and implemented in SSA to target the general population and key populations. They considered the socio-behavioural aspects and the stigma that getting tested carries to scale-up testing and to finally end AIDS. Indeed, it was found that experiences during HIV testing have implications on the succeeding engagement of individuals in care and treatment (Wringe et al., 2017). These modalities have been beneficial, despite their drawbacks, and a combination of these modalities have increased their impact (Dovel et al., 2020).

2.4. UNAIDS target and SDG 10

As previously mentioned in Chapter 1, the UNAIDS set fast track targets in 2014, 90-90-90 by 2020 and 95-95-95 by 2030, to finally end the AIDS epidemic. These UNAIDS targets cause a ripple effect. The momentum and progress built from the first 90 or the first 95 is crucial for the success of the succeeding goals. Achieving the 90-90-90 would translate to about 73% of PLHIV virally suppressed in a country.

In 2015, the United Nations (UN) established the 2030 Agenda for Sustainable Development which includes the 17 SDGs urging all countries – Global North and Global South - in global partnership to act on peace and prosperity for people and the planet (United Nations, 2015). The SDG is an extension of the Millennium Development Goals which only focused on the Global South with funding coming from countries in the Global North (Kumar et al., 2016). The SDG that is particularly relevant to this thesis is the 10th SDG which refers to "reducing inequalities within and among countries".

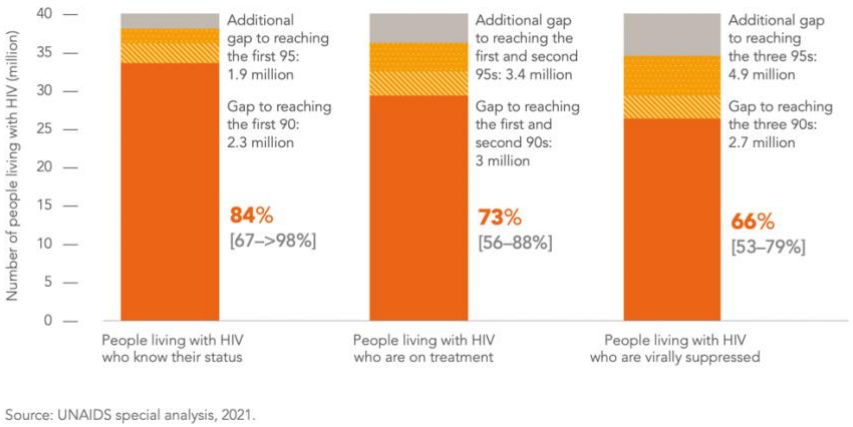
In reaching the UNAIDS targets, large efforts have been mobilized by international organizations and local governments. These two goals are not independent from one another, they are interrelated. The 2030 UNAIDS targets particularly the first 95 will be best and efficiently achieved through the lens of the 10th SDG and through lessons learnt when reaching the first 90.

2.5. Did we achieve the UNAIDS first 90 in SSA in 2020?

There has been considerable development towards achieving the UNAIDS targets in the past years as HIV testing and treatment such as ART became more available. Globally, UNAIDS

estimated that 84% of PLHIV knew their status, 73% of which were on ART and 66% were virally suppressed in 2020 (Figure 4).

Figure 4. Global estimates of HIV testing and treatment cascade, 2020.



Source: (UNAIDS, 2021b)

In SSA, knowledge of HIV status was estimated to increase from about 5.7% (95% credibility interval 4.6 – 7.0) in 2000 to 84% (82 – 86) in 2020 (Giguère et al., 2021). Overall, 12 countries reached the first 90 target including Malawi, Rwanda, Uganda, Zimbabwe and high HIV burden countries such as Botswana, Eswatini and Namibia while at least 11 countries reached the 73% target of viral suppression (United Nations, 2020). Eswatini remarkably achieved the 95-95-95 2030 targets by the end of 2019 (UNAIDS, 2020a).

Despite the increase in the proportion of HIV testing and the successful scale-up in coverage, disparities still remain, thereby weakening the progress made in subsequent targets for many countries. A gap of 2.3 million remained in reaching the first 90 globally, with an additional 1.9 million to reach the first 95 (Figure 4). A study using mathematical modelling investigated the progress made towards the first 90. They found that around 3.8 million PLHIV (all age groups) were left undiagnosed in SSA with the largest gap among men with around 701,000 still undiagnosed (aged 35-49 years) (Giguère et al., 2021). The Global Fund also reported a decline of 41% in HIV testing and 37% in diagnosis and treatment during the first COVID-19 lockdown in 2020 based on the data collected from 502 health facilities in 32 African and Asian countries (UNAIDS, 2021a).

These gaps in reaching the UNAIDS target implicitly show that there are population groups that are not being reached by large-scale HIV testing services. These gaps undermine the progress made with the developments and scale-up in HIV testing services. Monitoring the success of HIV testing only through overall national estimates is not enough to end AIDS. Without careful attention to the disadvantaged groups, such as the poor, when implementing programs, these disparities may remain, or may even generate new ones, preventing an equitable and efficient service in epidemic control. In understanding the different mechanisms of how different factors or interventions could generate systematic differences in HIV testing across different social groups, familiarizing the different concepts and theories in health inequalities is imperative.

3. Health inequality

"Health inequalities and the social determinants of health are not a footnote to the determinants of health. They are the main issue."

-Sir Michael Marmot

3.1. Common terms in health inequalities

3.1.1. Health inequality versus health inequity

To better understand inequalities in general and specifically in HIV testing, it is first essential to understand the distinction between health inequalities and health inequities. The terms are sometimes used interchangeably. However, there are subtle differences between the two especially in the field of social epidemiology[7].

According to Kawachi et al. and Arcaya et al., health inequality refers to the differences in health of individuals or population groups (Arcaya et al., 2015; Kawachi, 2002). It is also defined as "systematic differences in health of people occupying unequal positions in society". There is no moral judgment whether these differences are just or fair (Kawachi, 2002). Health inequity, on the other hand, refers to health inequalities or systematic differences that are avoidable by reasonable means or are unnecessary, which it would be unjust to allow to persist (Marmot et al., 2012; Whitehead, 1992). The WHO defines equity as "the absence of unfair and avoidable or remediable differences in health among population groups defined socially, economically, demographically or geographically" (WHO, 2022). The term inequality,

7 "Social epidemiology is a branch of epidemiology that focuses particularly on the effects of social-structural factors on states of health. Social epidemiology assumes that the distribution of advantages and disadvantages in a society reflects the distribution of health and disease."
Source: Honjo K. (2004). Social epidemiology: Definition, history, and research examples. *Environmental health and preventive medicine*, *9*(5), 193–199.

however, has a diverse interpretation which often overlaps with the concept underpinning inequities or disparities. According to WHO, the use of the term inequalities includes the fundamental concept of social justice and proportionate response to need within the Human Rights Law.

An example of health inequality which can be considered health inequity, because it can be avoided and is unjust, are racial disparities in infant mortality; for instance, in the US, black infants had 2.2-fold higher rate of infant mortality in the first year of life compared to white infants (Matthews & MacDorman, 2013). An example of inequality which, on the other hand, does not qualify as inequity, are age differences in health. For instance, people in their 20s enjoy more their health more than people in their 60s (Kawachi, 2002). Such a difference in age is mostly unavoidable and according to Arcaya et al., it is difficult to argue that differences in health between younger and older people are unfair since older people were once young, and younger people with some luck will become old, too (Arcaya et al., 2015).

In this thesis, the term health inequality was used descriptively to show observable differences in the uptake of HIV testing across socioeconomic groups. However, these systemic differences across social groups are unfair and avoidable which falls under the concept of inequity. Quantifying and monitoring health inequalities shows objective differences in a health outcome, which can be used to evaluate and improve the state of inequity in a population.

3.1.2. Socioeconomic position versus socioeconomic status

Another two words that are mostly used interchangeably but have nuanced differences are socioeconomic position (SEP) and socioeconomic status (SES). SEP refers to the "social and economic factors that affect the position individuals hold in society" such as wealth and education (Howe et al., 2012). According to Krieger, SEP is an aggregate concept that comprises both resource-based (i.e., refer to material and social resources as well as assets) and prestige-based (i.e., refer to individuals' rank or status in a social hierarchy) measures, linked to both childhood and adult social class position (Krieger, 2001b). Meanwhile, SES privileges "status" over material resources as the key determinant of SEP.

We used SEP rather than SES in the thesis because the latter implies that differences in health between social groups could be attributed to differences in status (Marmot, 2017) as mentioned

before. According to Krieger et al., SES also has the tendency to distort distinctions between two aspects of SEP – actual resources and status (i.e., prestige- or rank-related factors) (Krieger et al., 1997). Moreover, Marmot stated that SEP is more neutral in the sense that it does not make any judgment on the theoretical basis of classification (Marmot, 2017). For these reasons, hereafter, we will be using SEP. I will discuss different measures of SEP in the succeeding chapter.

3.2. "Inequality of what?"

In order to reach everyone and "leave no one behind" in the HIV response, we need strategies that could "reduce unfair inequalities and promote health of people equally" (Hepple & Nuffield Council on Bioethics, 2007). There are two ways on how to approach this – equality of health outcomes and equality of opportunity and access.

Equality of health outcomes argues that equality is achieved when measurable data such as life expectancy or HIV incidence are the same among the groups being compared (Hepple & Nuffield Council on Bioethics, 2007). On the other hand, the latter approach focuses on equality of opportunity and access to health services such as access to HTS. Although, in practice, several outcome-based approaches also put some weight to concerns about access. A good example of this scenario is the cascade of care in the HIV response. Access to HIV testing is an essential step towards prevention and viral suppression for PLHIV. This demonstrates that health outcome and access to services are interlinked and interdependent. Indeed, Marmot also argued that one should not stop at only ensuring equality of opportunity or access but also to look at the health outcomes which are often more difficult to safeguard (Marmot, 2017).

Moreover, the access-based approach has specific disadvantages. Individuals may have different capacities to make use of the benefits of access which may lead to different outcomes despite having equal access to services (Hepple & Nuffield Council on Bioethics, 2007). This is often the case in HIV testing, given its social implications and stigma surrounding HIV and testing itself.

In this thesis, we will be focusing on the socioeconomic inequalities in the uptake of and access to HIV testing. We focus on this because it is the first step in the prevention continuum and cascade of care towards prevention and viral suppression for PLHIV. The continuum warrants

that addressing inequalities in access to HIV testing could also reduce inequalities in the subsequent steps of the continuum across different socioeconomic groups.

3.3. Understanding how health inequalities are generated

Theories, in general, help us by making sense of an event or phenomenon. There are several theories that could potentially explain socioeconomic inequalities in HIV testing uptake. In the following sub-sections, I will be introducing theories explaining mechanisms behind health inequalities and how they are generated.

3.3.1. Determinants of health and health inequalities

Before commencing with the theories, knowing the determinants of health is essential to understand social inequalities in health in general. Figure 5 presents the determinants of health proposed by Dahlgen and Whitehead which is conceptualized as a rainbow-like layer of influence. It describes health determinants as interactions where individual lifestyles are embedded in social norms and networks, and in living and working conditions, which are also linked to the wider socioeconomic and cultural environment (Dahlgren & Whitehead, 2006).

Figure 5. The Main Determinants of Health.

Source: (Dahlgren & Whitehead, 1991)

In the middle, individuals possess age, sex and inherent factors that influence their health which are largely fixed. Surrounding them are influences that are theoretically modifiable through policy and programs. First, there are individual lifestyle and behavioral factors. Second, individuals interact with their social and community networks such as peers and community and are influenced by them. Third, the ability of a person to maintain their health is affected by their living and working conditions, housing and access to essential goods and services. Lastly, economic, cultural and environmental influences predominate in the overall society (Dahlgren & Whitehead, 2006).

The contributing role of different risk factors or determinants of health to the total burden of disease should be assessed so that priorities can be set, and suitable interventions and strategies can be developed (Dahlgren & Whitehead, 2006). However, in tackling inequalities in health, the determinants of health inequalities need to be understood. But, conceptually, the determinants of overall health have often been conceptually confused with the determinants of health inequalities and have been treated the same for policy considerations (Dahlgren & Whitehead, 2006). According to Dahlgen and Whitehead, the danger of such an approach is that policy tends to be very general and ineffective in reducing the "health divide".

There are different pathways described by Dahlgen and Whitehead in which inequalities can be generated such as different levels of power and resources, different levels of exposure to factors that cause or prevent disease and similar level of exposure leading to differential impacts in different socioeconomic groups. We will see in the next sub-sections how theories can determine the different pathways and mechanisms in generating inequalities in health.

3.3.2. Classic theories of inequalities in health

Below are some of the classic or foundational theories of how health inequalities may give rise to the social gradient in health outcomes. While many of these theories were used to assess inequalities in health or ill-health in the welfare states[8] of the Global North, they can also provide insights about how inequalities are generated in the Global South.

8 Welfare state is a "state that is committed to providing basic economic security for its citizens by protecting them from market risks associated with old age, unemployment, accidents, and sickness."
Source: M. Weir, Welfare State, International Encyclopedia of the Social & Behavioral Sciences, 2001.

3.3.2.1. Psychosocial theory and personal characteristics theory

As seen in the previous sub-section, individual factors are one of the determinants of health proposed by Dahlgen and Whitehead. It may also be one of the determinants of inequalities in health outcomes.

Wilkinson argues that social status can also be a determinant of inequalities in health because of its "huge impact on whether people feel valued, appreciated and needed or on the other hand looked down on, treated as insignificant, disrespected, stigmatised or humiliated" (Wilkinson, 2020). Data showed that people in low SEP experience more psychosocial stress related to financial difficulties and effort-reward imbalances on average; and experience life and work situations characterized by high demands and low control. According to Mackenbach, these types of psychosocial stressors can lead to ill health, either through biological pathways (e.g., by affecting the immune system) or behavioral pathways (e.g., by inducing risk taking behaviors).

Batty et al. and Mackenbach conceptualized that health inequalities can be explained by personal characteristics of individuals such as personal and cognitive abilities (Batty et al., 2006; Mackenbach, 2010). Batty et al. found that Intelligence Quotient (IQ) partly explained socioeconomic gradients in health with a marked reduction in inequalities after controlling for IQ (Batty et al., 2006).

While these theories may explain how inequalities in health may be generated through individual factors, they do not fully address the root causes of inequalities and how large-scale programs or interventions, such as HIV testing programs, could impact health inequalities.

3.3.2.2. Artefact, selection, behaviors and structural theories

In 1980, the Black Report was published by the Department of Health and Social Security (now the Department of Health and Social Care) in the United Kingdom reporting that, despite improvements in overall health after the introduction of the welfare state, widespread health inequalities existed. The expert committee led by Sir Douglas Black identified four key theories in explaining how health inequalities arise: artefact, selection, behavioral (including culture) and structural factors (Gray, 1982; McCartney et al., 2013). McCartney et al. in 2013 evaluated

these four theories as to how and why health inequalities arise by using epidemiological reasoning to evaluate which theories retained validity.

3.3.2.2.1. Artefact, health selection and behavioral theories

The theory of artefact proposes that the association between SEP and health outcomes is a statistical artefact in relation to the way SEP was categorized over time (McCartney et al., 2013). It also argues that health inequalities can be explained by mathematical rules or errors, instead of substantial interpretations (Huijts & Eikemo, 2009). This theory, according to McCartney et al., has been critically undermined by the abundant demonstration of inequalities in health outcomes, even when different measures of SEP (e.g., income and education) were used. McCartney et al. argued that the artefact theory can be discarded, as was also suggested in the Black Report, because it is very difficult to sustain a theory that such outcomes are unrelated to SEP.

The possibility of a health selection effect was also assessed that may explain health inequalities but, like the artefact theory, it was dismissed by the Black Report in providing sufficient explanations as to the cause of inequalities. This theory proposes that poor health causes a social selection ("social slide") which leads to the observed association between ill-health and low SEP (McCartney et al., 2013). McCartney et al. also found this theory insufficient since a large number of longitudinal studies have demonstrated that majority of the concentration of ill-health in lower SEP groups can be explained by "pre-morbid" social status rather than social slide (McCartney et al., 2013).

Behavioral and cultural theory suggests that behaviors such as smoking, diet, drinking alcohol, cultures and skills cause health inequalities and that unhealthy and risky behaviors are more prevalent in lower socioeconomic groups (Lynch et al., 1997). However, these same behaviors could also generate high negative outcomes among people in higher SEP and this theory ignores why a particular social group adopts unhealthy behaviors (Lynch et al., 1997; Nettle, 2009). Theories that focus on behavior and culture can provide some insights into how health inequalities are generated but they cannot provide sufficient explanation in relation to their principal causes (McCartney et al., 2013).

3.3.2.2.2. Structural theory

Finally, structural theory explains how differences in wealth, power, access and environment in the socioeconomic situation of social groups across different social gradients cause variations in health at all stages of life (Krieger, 2001a; McCartney et al., 2013). The theory includes upstream causes such as politics and policy. Based on this theory, the health of communities tends to improve when they have been given more resources and those with resources tend to be healthier regardless of their behaviors (Commission on Social Determinants of Health, 2008; Costello et al., 2003). Similarly, according to Link and Phelan, social factors such as SEP or social support are fundamental causes of disease because they represent access to resources which can be used to avoid disease risk and to reduce the consequences of disease (Link & Phelan, 1995). They stated that these social factors can also affect disease outcomes through multiple mechanisms despite changes in the intervening mechanisms (Link & Phelan, 1995). Groups that are more affluent usually have more power and opportunities to live a healthy life and access to health services than the less privileged giving rise to differential levels of power and resources.

According to McCartney et al, health inequalities are best explained by the structural theoretical perspective. The social gradient in health outcomes or systematic differences in health do not arise by chance, and they cannot be attributed simply to genes, "bad" behavior, or difficulties in access to health care (McCartney et al., 2013). Social and economic differences in health status also reflect social and economic inequalities in society.

3.3.3. Intervention-generated inequalities in health

Following the structural theory, some effective interventions or policies may however unintentionally increase health inequalities (Lorenc et al., 2013; Maden et al., 2018; White et al., 2009), which White et al. named as "intervention-generated inequalities" (White et al., 2009). They suggest that all processes from the planning to the delivery of an intervention have the potential to widen inequalities between different groups defined by factors such as age, ethnicity/race, gender or SEP. This may happen, for instance, when careful attention is not given to individuals with lower SEP and when people in higher SEP benefit from an intervention at an accelerated rate. This outcome has been noted in the Global North wherein studies found that cancer screening programs did not reduce inequalities across socioeconomic groups,

especially around opportunistic cancer screening programs (de Klerk et al., 2017; Kelly et al., 2017; Palencia et al., 2010). A study found that organized colorectal cancer screening programs may even have created or exacerbated existing inequalities across socioeconomic subgroups (de Klerk et al., 2017). It was also found that women's economic situation is an important determinant of national cancer screening in France (Menvielle et al., 2014). However, little is known about whether such screening, specifically the large-scale up of HIV testing programs, has the same impact on socioeconomic inequalities in SSA.

According to Maden et al., the impact of an intervention on inequalities may be negative, positive, or neutral, and result from intended or unintended effects (Maden et al., 2018). This may depend on which social group the intervention benefits most – for instance, in the example of SEP-related inequalities, an intervention may have a negative impact on inequalities if it benefits individuals in higher SEP, a positive impact if it benefits individuals in lower SEP, or no discernible impact (Maden et al., 2018).

Based on previous studies, a common attribute of interventions that often leads to the described social gradient in health is reliance on voluntary behaviors (Mechanic, 2002; White et al., 2009). For instance, although we intend that a policy screening women in health facilities for HIV is also available to men, "without compulsion to attend" (White et al., 2009), testing uptake remains voluntary and may even lead to inequality (Hepple & Nuffield Council on Bioethics, 2007). Therefore, having an opt-out policy or approach to provider-initiated testing is necessary. However, at the same time, it will only be effective if individuals seek healthcare and have the capacity and means to access health facilities.

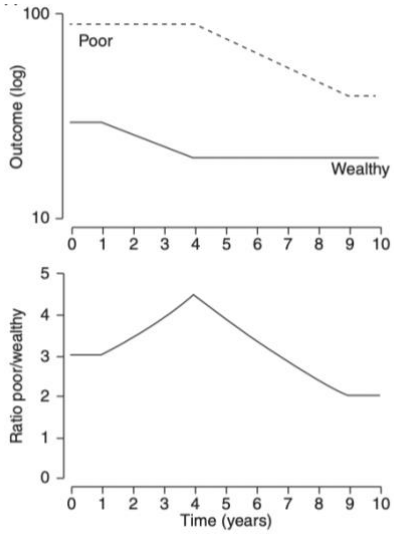
3.3.3.1. Inverse equity theory

One of the theories that may explain intervention-generated inequalities is the inverse equity theory which was proposed by C. Victora et al. in 2000. It was first used to assess inequalities in child health in the Global South, specifically in Brazil. It proposes that health interventions reach people of higher SEP first, and that only when the rich have achieved the maximum levels of utility do the poor gain greater access (Victora et al., 2000). This can lead to a widening of the relative inequalities in health.

The inverse equity theory is a corollary to the inverse care law of Tudor Hart which states that the "availability of good medical care seems to vary inversely with the need for it in the population served" (Tudor Hart, 1971). This trickle-down effect is also similar to the theory of diffusion of innovations proposed by EM Rogers in 1962 which states that new ideas, innovations or services are first adopted by a specific member of the social system and are adopted over time by other members (Dearing, 2009). The concept is that individuals tend to adopt a new idea or service if they perceive it as new or innovative. (Rogers, 1983).

Figure 6 proposes time trends for hypothetical outcomes, such as morbidity and mortality, in the richest and poorest population groups and shows corresponding inequity ratios by dividing the health outcome in the poor by that in the rich (Victora et al., 2000). At year 1, the poor is three times worse off than the rich. However, at year 2, a new intervention is initially taken up by the richer subgroup. At year 4, at the peak of the inequality ratio, the coverage among the poor then starts to increase but at a lower rate than that of the rich. By year 5, the inequity ratio reduces. Figure 6 thus demonstrates that the inverse equity theory attempts to explain why at different time periods the inequity ratio between the rich and the poor can improve, remain unchanged, or get worse (Victora et al., 2000).

Figure 6. Morbidity or mortality outcome indicators and rate ratios.



Top: Hypothetical trends in morbidity or mortality outcome indicators in poor and wealthy population groups. Bottom: Corresponding rate ratios. Source: (Victora et al., 2000)

This theory has also been proposed by Hargreaves et al. to be relevant in the HIV prevention. According to them, during the 1990s, global attention to HIV began to increase, and by the time of the 2001 UN General Assembly Special Session on HIV/AIDS huge resources were being spent on HIV prevention. Based on the inverse equity theory, these scaled-up interventions would benefit higher SEP groups faster than lower SEP groups. Thus, HIV incidence (later HIV prevalence) would decrease fastest among high SEP groups (Hargreaves et al., 2013a).

Victora and his colleagues later expanded the inverse equity theory and suggested ways as to how the poor could be disadvantaged. According to them, these could include reduced host resistance due to poor nutrition, increased exposure to risks and reduced access to services due to lower educational attainment, illiteracy and poor quality services due to lack of health care providers wanting to work in poorest regions (Schellenberg et al., 2003).

3.4. Inequalities in HIV testing in sub-Saharan Africa

While HIV testing has scaled up in SSA over the past years, with some countries even reaching the UNAIDS first 90 goal, inequalities and barriers in the uptake of and access to HIV testing had been noted in SSA. According to these studies, people with higher SEP – more affluent or with a higher educational level – who were employed and living in urban areas were more likely to have knowledge of their HIV status and were more likely to seek HIV testing (Cremin et al., 2012; Gage & Ali, 2005; Jean et al., 2012; Kim et al., 2016; Mishra et al., 2007; Mitchell et al., 2010; Mtowa et al., 2017; Peltzer et al., 2009). Studies done in Malawi found that household members in the lowest income quartile were significantly less likely to receive facility-based HTS (Helleringer et al., 2009) and men from lower SEP were more likely to receive testing after controlling for spatial effects (Kim et al., 2020). Other studies found that the likelihood of VCT was increased among individuals with higher SEP (Larose et al., 2011; Obermeyer et al., 2013) and in countries with higher Gross Domestic Product (GDP) per capita (Larose et al., 2011). It was found that wealth may be associated with greater risk awareness and reduced financial barriers to testing (Mishra et al., 2007; Parkhurst, 2010).

The study by Larose et al. tested the inverse equity theory and found that relative socioeconomic inequalities in VCT coverage appear to decline when higher SES groups reach a certain level of coverage (Larose et al., 2011). In this thesis, we also hypothesize that relative inequalities in

uptake of HIV testing would follow a similar pattern over time, most likely after the peak in relative inequalities as seen in Figure 6.

While most of the studies point to the direction of people in higher SEP reporting more uptake of and access to HIV testing, a study done in South Africa using data from 2012 found pro-poor wealth-related inequalities in early HIV testing before antenatal care among pregnant women (Ngandu et al., 2017). There was improved uptake of self-initiated testing among mothers with relatively low wealth, however, the authors mentioned that there was also a higher burden of infant HIV exposure among them. The reasons why testing uptake was higher among women with lower SEP was unknown and the authors recommended further investigation before generalizing this observation beyond the study population.

As we have seen in the previous chapter, many of the disparities in HIV are seen among women who encounter "heavy economic, legal, cultural and social" drawbacks making them economically dependent on their male partners, and sometimes leading them to engage in transactional sex (Ramjee & Daniels, 2013). However, in terms of testing, women in SSA are more likely to be tested than men (Gebregziabher et al., 2018) which is partly due to the integration of HTS in routine care such as antenatal care as part of the PMTCT programs and sexual and reproductive health services over the past years. This shows that inequalities can exist in many forms including gender inequalities.

4. Gaps and thesis objectives

4.1. What are the gaps in the literature?

Even though socioeconomic inequalities in HIV testing in SSA have been well documented in the literature, it is often challenging to compare them and to gain an overall and largescale perspective on its status. Existing studies have either investigated socioeconomic inequalities in HIV testing by quantifying inequality indicators or estimating the association between SEP and HIV testing in SSA. However, most studies were conducted in a single country (Gage & Ali, 2005; Helleringer et al., 2009; Jean et al., 2012; Kim et al., 2016, 2020; Meka et al., 2020; Mtowa et al., 2017; Ngandu et al., 2017; Peltzer et al., 2009; Teklehaimanot et al., 2016; Weiser et al., 2006; Wringe et al., 2008). They also focused on different study populations (e.g., pregnant women, adult patients, or older adults), and used different SEP indicators (e.g., income, wealth, GDP per capita, or educational attainment) and study designs. As a result, they may sometimes provide different results leading to diverging conclusions that could impact how programs and services are implemented.

To the best of our knowledge, while there were a few studies that were conducted in multiple SSA countries (Cremin et al., 2012; Larose et al., 2011; Mitchell et al., 2010; Obermeyer et al., 2013), they did not measure inequalities in HIV testing using inequality indicators typically used in the field of health inequality such as the Relative Index of Inequality and Slope Index of Inequality to quantify relative and absolute inequalities, respectively. They also did not provide pooled estimates of these inequalities across countries. Despite Larose and colleagues conducting a multi-country analysis, they did not entirely focus on SSA but on low-and-middle income countries globally (Larose et al., 2011). The limited studies that used the Concentration Index or the Erreygers Concentration Index (i.e., another inequality indicator) were only conducted in a single country (Kim et al., 2016, 2020; Ngandu et al., 2017).

In addition, based on the information we have, none of the studies have explored the temporal trends of these inequalities in HIV testing before and after the large scale-up in HIV testing. Did such large scale-up in HIV testing programs decrease, increase, or generate socioeconomic inequalities in HIV testing uptake? Cremin et al. only explored inequalities in HIV testing before the treatment era prior to 2006 (Cremin et al., 2012). Do the trends in inequalities in HIV testing follow the pattern described by the inverse equity theory? Only Larose et al. tried to assess the theory in relation to their findings; however, they also only analyzed data before the 2007 WHO international recommendation of expanded PITC.

Achieving the UNAIDS first 95 would require monitoring and addressing inequalities between and within countries measured at different geographical scales. However, there is also a lack of studies mapping these inequalities at different geographical scales and identifying inequality hotspots. In addition to measuring inequalities, it is also important to assess their determinants, as we have seen in Chapter 3, to better adapt testing strategies aimed directly at reducing inequalities between different social and population groups. But, at large, when addressing inequalities, programs often only investigate and tackle the drivers of health or disease instead of the drivers of the inequalities themselves. While many studies had investigated the determinants of HIV testing uptake, there is still sparse literature on the determinants of socioeconomic inequalities in HIV testing.

Henceforth, there is a dearth of literature on conducting comprehensive assessment and multi-country analysis of socioeconomic inequalities in HIV testing uptake in SSA that specifically uses inequality indicators. Such studies help in assessing between-country comparisons such as assessing one country's situation in contrast to another and in understanding contextual factors that may play a role in generating inequalities across countries. They also allow for within-country assessments to help in assessing inequalities at local scales and in assessing individual-level factors that contribute to such inequalities. These studies are relevant and useful to policymakers, researchers and even the public because they provide a broader insight into inequalities. They may reveal masked patterns of disparities that are useful in the implementation and prioritization of programs that would have been otherwise impossible to observe. Addressing these inequalities is necessary because they are unfair, avoidable, and it is

often easier to prevent and address them at an early stage than when they are already deeply entrenched.

4.2. Research aim and specific objectives

Thus, the main aim of this thesis is to better understand socioeconomic inequalities in HIV testing through a comprehensive multi-country analysis of population-based surveys in several SSA countries. The aim relies on the overall hypothesis that there are substantial levels of inequalities in HIV testing that deserve to be more understood, especially in terms of temporal trends, geographical distribution, contextual factors and mediating pathways, and that they may be quantified based on population-based surveys. Four specific objectives were formulated to this aim:

i) To quantify socioeconomic inequalities in HIV testing uptake and assess their trends over time,

ii) To explore the spatial distribution of socioeconomic inequalities in HIV testing uptake across various geographical scales,

iii) To identify contextual factors associated with socioeconomic inequalities in HIV testing uptake; and

iv) To understand the mediating pathways linking SEP and HIV testing uptake at the individual level.

To address these objectives, we analyzed the data within the Demographic and Health Surveys (DHS), which provide rich and free data available for academic purposes. I will present the DHS in Chapter 5 together with the different measures of SEP and measures of health inequalities.

Part Two:
Data, measures of SEP and measures of health inequalities

5. Data

"Not everything that can be counted counts and not everything that counts can be counted."

-Albert Einstein

5.1. Demographic and Health Surveys

We used data within the DHS which is a rich data source that has not systematically been used to assess inequalities in HIV testing in SSA, which this thesis proposes to do. The DHS program, funded by the US Agency for International Development, conducts nationally representative household sample surveys in over 90 countries in the Global South since 1984 (https://www.dhsprogram.com/). It collects data over a wide range of population, health, HIV and nutrition indicators to monitor the progress of health programs (Corsi et al., 2012; Rutstein & Rojas, 2006). They are population-based surveys which include a sample ranging between 5,000 and 30,000 households, where women aged 15-49 years are eligible to participate (The DHS Program, 2021a). In some DHS, men aged 15-54 years (up until 59 years in some surveys) are also eligible in all or a sub-sample of selected households depending on the survey. They are typically conducted about every five years to permit comparisons over time. Individuals who consented are interviewed face-to-face by trained interviewers who use a standardized questionnaire that includes items on sociodemographic characteristics, sexual behaviors, and reproductive health, and a specific section focusing on HIV-related issues.

The DHS use a stratified two-stage sampling method to ensure representativeness at the national and subnational levels (Corsi et al., 2012). The first stage involves clusters randomly selected with a probability selection based on the population size (Corsi et al., 2012; Rutstein & Rojas, 2006). In the second stage, households are randomly selected within these census areas and visited by trained interviewer (Corsi et al., 2012).

The standard model questionnaires, which are periodically reviewed and modified, form the basis of the survey in each country to collect data that are comparable across countries. Each survey is then adjusted to the needs of the country, while retaining the basic components (Corsi et al., 2012). The survey contains core and optional questionnaires. The core questionnaires include basic demographic and health content (i.e., marriage, fertility, family planning, reproductive health and child health); while the optional questionnaires cover specific topics (i.e., maternal mortality, men's survey, anthropometry, anemia blood testing, herpes simplex virus, HIV/AIDS, malaria, tobacco use, chronic illnesses and other biomarkers) (Corsi et al., 2012).

Through collection of blood samples from representative samples of the adult population, the DHS has played a major role in the monitoring of the HIV/AIDS epidemic in several countries in the Global South. The AIDS Indicator Survey (AIS), a type of DHS, was developed to provide countries with standard tool to collect indicators needed for effective monitoring of HIV/AIDS programs including HIV prevalence and HIV/AIDS knowledge, attitudes and behaviors.

The DHS also routinely collects geographic information in most recent surveyed countries where clusters (i.e., the groupings of the households that participated in the survey) are geo referenced. The GPS coordinates obtained from the DHS database are intentionally displaced to ensure confidentiality of the respondents. Urban clusters are displaced between 0 and 2 kilometers, while rural clusters are displaced between 0 and 5 kilometers. Since 2009, the displacement is maintained within the country's second administrative level (i.e., primary sampling unit (PSU) or cluster) where possible.

5.2. Eligible countries

Overall, we analyzed 28 SSA countries. Depending on the objective, we investigated different sets of these countries. Table 1 summarizes the specific objectives with their corresponding eligible countries.

For the first specific objective, in order to quantify socioeconomic inequalities in HIV testing and assess their trends over time, we selected SSA countries in which at least one DHS or AIS survey covering HIV indicators had been conducted before and after 2008 (i.e., before and after

the implementation of WHO international recommendations to expand provider-initiated opt-out testing) on the DHS website. For countries where several surveys were available either before or after 2008, we considered only the most recent one (as of March 2019). We analyzed the same set of countries to assess contextual factors associated with HIV testing uptake (specific objective 3).

This was later extended to two other countries based on convenience sampling (as of February 2021) to assess the potential individual-level mediating factors linking SEP and HIV testing uptake (specific objective 4).

To explore spatial variation in socioeconomic inequalities in HIV testing at different geographical scales (specific objective 2), we identified countries with a survey between 2011 and 2019 which included the HIV testing variable, HIV biomarker, GPS coordinates and spatial boundaries. For countries with more than one eligible survey, we selected the most recent (as of November 2021).

Table 1. Summary of each specific objective and their corresponding eligible countries.

Specific objective	Eligible countries
• To quantify socioeconomic inequalities in HIV testing uptake and assess their trends over time	Cameroon, Congo DR, Côte d'Ivoire, Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, Tanzania, Zambia and Zimbabwe
• To explore the spatial distribution of socioeconomic inequalities in HIV testing uptake in various geographical scales	Angola, Burundi, Cameroon, Chad, Congo DR, Côte d'Ivoire, Ethiopia, Gabon, Ghana, Guinea, Lesotho, Liberia, Malawi, Mali, Mozambique, Namibia, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia and Zimbabwe
• To identify contextual factors associated with socioeconomic inequalities in HIV testing uptake	Cameroon, Congo DR, Côte d'Ivoire, Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, Tanzania, Zambia and Zimbabwe
• To understand the mediating pathways linking socioeconomic position and HIV testing uptake at the individual level	Burkina Faso, Cameroon, Congo DR, Côte d'Ivoire, Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Senegal, Sierra Leone, Tanzania, Zambia and Zimbabwe

5.3. DHS HIV testing indicator

The indicator we used was the self-reported uptake of recent HIV testing in the previous 12 months. Participants were asked if they recently had an HIV test and, if yes, the time of their last test. We measured uptake of HIV testing regardless of the setting, service delivery modality and population group.

It should be mentioned that there are also different indicators that can be used to approximate uptake of HIV testing. Some examples are the number of health facilities that provide HIV testing and counselling (HTC) services, number of women and men aged 15 and older who received HTC in the last 12 months and know their results (World Health Organization, 2011) and lifetime HIV testing[9].

In hyperendemic areas such as SSA, repeated HIV testing is recommended for individuals at continued risk of HIV infection to support early detection and initiation of ART (Hensen et al., 2015) which makes lifetime HIV testing not sufficient. Indeed, studies found that early ART initiation is necessary to maximize individual and population-level benefits of ART such as reduced rates of sexual transmission of HIV and lower rates of severe HIV-related illness (Cohen et al., 2011; The TEMPRANO ANRS 12136 Study Group, 2015). Since early initiation of ART would require frequent or repeated testing, we focused on recent HIV testing.

9 When individuals received an HIV test in their lifetime.

6. Measures of socioeconomic position

According to Galobardes et al., most of the theoretical concepts of the use of SEP in epidemiological studies are based on the works of Karl Marx and Max Weber. Marx proposed that social class and class relations are characterized by the inherent conflict between exploited workers and exploiting capitalists or those who control the means of production (Galobardes, 2006). In contrast, Weber's theory proposes that society is hierarchically stratified along different dimensions which creates groups where members share a common market position leading to similar "life chances" (Galobardes, 2006).

There are several different measures of SEP that capture different dimensions. Their pathways in which they affect health are also likely to be different but overlapping and correlated. The social stratification in the Global South differs from the Global North due to aspects such as the lack of formal economy and welfare states in the former (Howe et al., 2012).

Here, I will present the most common measures of SEP used in epidemiological studies. These measures follow the Weberian theory.

6.1. Wealth index

The wealth index is the main measure of SEP that we used in this PhD thesis. It is a type of asset-based measure which measures household welfare in surveys in the Global South (Rutstein & Johnson, 2004). It is a composite measure of a household's cumulative living standards which are calculated based on durable assets (e.g., television, radio and car), household characteristics (e.g., material of housing roof and main cooking fuel) and access to basic services (e.g., water and electricity supplies) collected in the DHS (Howe et al., 2012). It is typically generated using the principal component analysis where it places individual households on a continuous scale of relative wealth. DHS separates interviewed households into five wealth quintiles to allow for comparisons on the influence of wealth on different population and health indicators (The DHS Program, 2021b). It allows for the identification of

problems specific to the poor, such as unequal access to health care and has allowed governments to evaluate whether public health services such as vaccination campaigns, education and other essential programs are reaching the poorest (The DHS Program, 2021b). Similarly, it is also used to assess health outcomes specific to the rich.

Since the wealth index measures household SEP, its interpretation depends on the relationship of the individual to the household (Howe et al., 2012). For instance, it may represent the SEP of the parents for children and young adults still living in the household or the SEP of the spousal household for married women living in their husband's family home (Howe et al., 2012).

Some proponents claim that the wealth index is a simple and reliable alternative to consumption expenditure (Filmer & Pritchett, 2001) and some are claiming it to be more stable because they vary less in response to fluctuations in income and expenditures and are more resistant to economic shocks (Liverpool & Winter-Nelson, 2010). The wide availability of the index in surveys in various countries is also a strength such that it facilitates comparative research (Howe et al., 2012).

However, since it is a measure of relative SEP, we cannot directly compare the bottom quintile of one country with another (Howe et al., 2012). We can only use it to assess SEP ranking within a hierarchy across a population. This is in contrast with income and consumption expenditure, where both have absolute value and can be used to compare across and within populations. This indicates that asset indices cannot be used to construct poverty lines and measure the levels of poverty within a population in a similar manner as income or consumption expenditure. There is also difficulty in determining asset quality which may result in false SEP ranking due to the inclusion of non-functioning assets (Howe et al., 2012). For instance, a household may declare that they have a car, but it might be damaged and been parked in the compound for more than five years (Howe et al., 2012). Another limitation of the wealth index is that it captures social stratification better in urban than rural settings or what is called "urban bias" (Howe et al., 2012). Urban households are more likely to have access to improved water and sanitation, have supply of electricity, and homes are made from modern materials compared with homes in rural areas. In order to address these concerns, the DHS questionnaires have included a wider range of asset indicators such as basic furniture items and windows and have developed guidelines on possible options for constructing or analyzing asset-based indices

separately for urban and rural areas and scaling these to a single index that ensures comparability between urban and rural areas (Rutstein, 2008).

Related to the urban bias, many of the items traditionally included in the construction of the index are provided at the community level – for instance, water supplies. It has been shown that the wealth index was more strongly associated with community-level infrastructure than other SEP measures (Howe et al., 2011). This implies that there may be geographical clustering of individuals or households with the same level of wealth within a community.

Asset-based measures were developed primarily for the Global South, however, household amenities have also been used in the Global North to measure early SEP when other indicators are unavailable (Dedman, 2001).

6.2. Education

Another measure of SEP is education which can be measured either for an individual, parent, or for the head of the household (Howe et al., 2012). There are several interpretations of how education is associated with the health outcome: i) education captures the transition from parents (i.e., received) SEP to adulthood (i.e., own) SEP and represents a strong determinant of future employment and income; ii) the knowledge and skills achieved through education may affect a person's cognitive functioning, making him/her more receptive to health education, or more able to communicate with and access health services; and iii) ill-health in childhood could limit educational attendance and attainment and predispose one to adult disease, generating health selection influence on health inequalities (Galobardes, 2006).

Education can be used as a continuous variable (e.g., number of school years completed) or categorical variable (e.g., highest education attainment). It can be used either in the absolute or relative scale (e.g., by ranking individuals based on highest educational attainment).

In this thesis, we used the highest educational attainment of the participants from the DHS as a measure of education. This is to measure another dimension of SEP in answering the first specific objective. The knowledge and skills learned up until the level of highest educational attainment may affect a person's receptivity to and capacity to access HIV testing and counselling services. However, this variable may be somewhat censored which means that for

a young person aged 16 years old, for instance, the educational level reported may not be the highest he or she may reach. Thus, this may not properly measure SEP, although it may measure knowledge and skills.

6.3. Other measures of socioeconomic position

Aside from asset-based index and education, there are other indicators to measure SEP, such as income, consumption expenditure, occupation and participatory wealth ranking, among others. Income, consumption expenditure and participatory wealth ranking are not available in the DHS.

In the Global South, income is more difficult to measure due to high reliance on informal economy, seasonal activity and self-employment (Howe et al., 2012). An alternative to income is consumption expenditure. It measures income by measuring how it is used – through what goods and services are purchased. It can provide a long-term assessment of SEP and the value of services by material assets. There is also a consensus among development economists of the value of using consumption expenditure rather than income especially in the Global South (Deaton & Zaidi, 2002).

Another measure is the participatory wealth ranking wherein the community members rank the wealth of households in their community. It is widely used in health and development programs but rarely used in epidemiological studies. Since it involves the participation of community members, it can capture locally relevant concepts of social stratification (Howe et al., 2012). However, the ranking system in this approach is complex and arguably nontransparent and may be difficult to implement in groups affected by conflict. It also has the challenge of ensuring that all categories within the community are heard (Laderchi et al., 2003).

Meanwhile, occupation-based measures may be similar between the Global South and the Global North. However, formal employment is rare and casual labor and small home businesses are more common in the former (Internationales Arbeitsamt, 2018). Howe and colleagues argued that relationship between occupation, and prestige and income is likely to be different in the Global South compared to that in the Global North. For these reasons, we did not use occupation despite this variable being available in the DHS.

We chose wealth index and education since they are valid measures of SEP, available in the DHS and widely used within and outside the DHS, allowing for comparisons.

7. Measures of inequalities

"As long as poverty, injustice, and gross inequality persist in our world, none of us can truly rest."
-Nelson Mandela

In Chapter 3, we saw the different theories of health inequalities. In this chapter, I will present the different indicators typically used to measure health inequalities.

7.1. Absolute versus relative inequalities

There are several indicators used to quantify inequalities in health. Most of the applications of these indicators make some forms of comparisons over time or between population groups. According to the WHO, there are two broad categories of summary measures – those that measure absolute inequality i.e., reflecting the magnitude of inequality and those that measure relative inequality i.e., reflecting proportional inequality (World Health Organization, 2017).

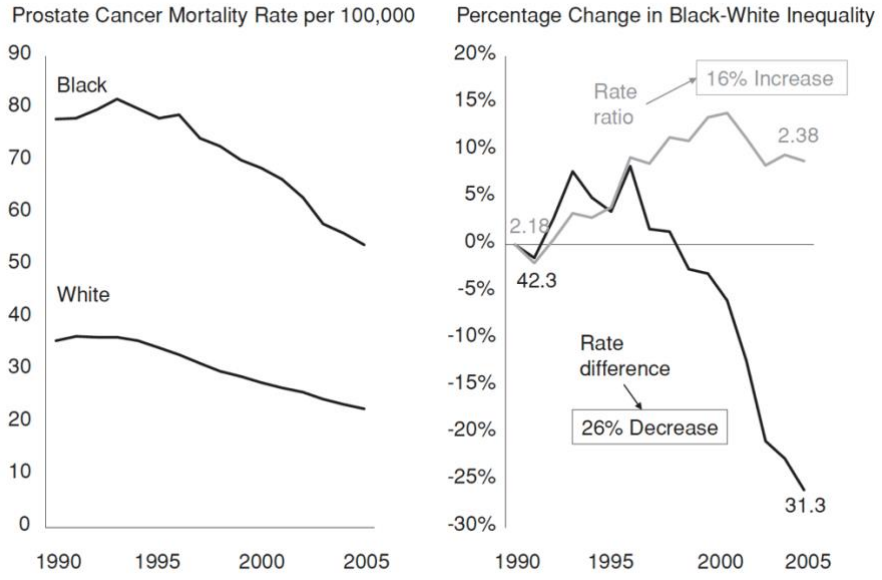
Within the two categories, there are various types of summary measures – simple measures of inequality and complex measures of inequality. Simple measures of inequality are those that draw on data from two subgroups such as difference, ratio (World Health Organization, 2017) and pairwise comparison (Oakes & Kaufman, 2017). Meanwhile, complex measures of inequality draw on data from more than two subgroups. We used complex measures of inequality in this thesis which are discussed in the succeeding sections. Common complex measures that reflect absolute and relative inequalities include the Slope Index of Inequality (SII) and Relative Index of Inequality (RII), respectively.

Indeed, there is a growing debate on which inequality measures – absolute or relative scales – should be used and evaluated. There is a normative judgment (i.e., a statement of whether

inequality is right or wrong or whether one circumstance is better than another) that involves when choosing one measure over the other (Harper et al., 2010).

Depending on the inequality scale used, the trends may change (Figure 7). The left panel of Figure 7 demonstrates trends in age-adjusted prostate cancer mortality between 1990 and 2005 for black and white men in the US. It indicates that the mortality rate for both groups decreased during this period although at different rates. The right panel shows the changes over time depending on the inequality scale used. The rate ratio indicates that black-white inequality increased by about 16% during the period. Meanwhile, the rate difference shows that inequality decreased by around 26%. Both measures are technically correct, but when considered individually, they support contrasting answers to the question of whether black-white inequality in prostate cancer is decreasing (Harper et al., 2010). It is therefore recommended to report inequalities using both scales (World Health Organization, 2017).

Figure 7. Trends in Prostate Cancer among Black and White Males, and Percentage Change in the Black-White Rate Ratio and Rate Difference between 1900 and 2005.



Source: (Harper et al., 2010)

We quantified inequalities both at the absolute and relative scales not necessarily to evaluate which measure is better and which scale to choose but to be able to provide a full context of the inequalities across multiple countries.

7.2. Slope Index of Inequality and Relative Index of Inequality

The SII and RII are the two major measures used in epidemiological studies for quantification and comparisons of the socioeconomic gradient in absolute and relative scales, respectively, providing complementary information (Moreno-Betancur et al., 2015). The central aspect to the validity of cross-population comparisons with these indicators is the use of the socioeconomic rank (i.e., defined as the proportion of the population with higher SEP) as the measure of exposure to an adverse SEP. The socioeconomic rank is a measure of relative SEP of the individual in the population, thus making valid comparisons possible across populations defined, for instance, by geographical location, time period, or birth cohort (Moreno-Betancur et al., 2015).

The SII and RII are regression-based type of indicator. This means that compared to a pairwise comparison that ignores the other groups when there are more than two subgroups, it uses all information from all groups (Oakes & Kaufman, 2017). They are also sensitive to the change in the distribution of the population over several social group over time which is an advantage over a classic regression-based measure (Oakes & Kaufman, 2017). The purpose of the SII and RII is to quantify the linear association between the socioeconomic rank and the health outcome in absolute and relative scales, respectively.

The definitions of these indices have evolved over the years. The SII was formally introduced by Preston et al. in 1981 which may be obtained by regressing the mean health variable on the mean of the relative rank variable:

$$\gamma_j = \beta_o + \beta_1 R_j \quad \text{(Eq. 1)}$$

where j indicates social group, γ_j is the average health status and R is the average relative ranking of the social group j, β_o is the estimated health status of a hypothetical individual at the bottom of the social group hierarchy (an individual whose relative rank R_j is zero), β_1 is the difference in the average health status between a hypothetical individual at the top ($R_j = 0$ versus $R_j = 1$) (Oakes & Kaufman, 2017). β_1 in Eq. 1 thus estimates the SII which is the absolute difference in health status between the bottom and top of the social group distribution. This regression can also be run on individual data where R_j is the individual's relative rank in the social group distribution.

Meanwhile, the RII, first coined by Pamuk, was firstly defined by dividing the SII by the mean population health (Pamuk, 1985, 1988). This definition of the RII was modified by Mackenbach and Kunst by dividing the estimated health of the hypothetical person at the bottom of the social group distribution by the estimated health of the hypothetical person at the top (Eq. 2) (Mackenbach & Kunst, 1997; Oakes & Kaufman, 2017):

$$RII = \frac{\beta o}{(\beta_o + \beta_1)} \text{ (Eq. 2)}$$

Thus, the RII is defined in analogy to a relative risk where it compares the health of the extremes of the social distribution but was estimated using the data on all social groups and is weighted by group size (Oakes & Kaufman, 2017). Equation 3 is based on Moreno-Betancur et al.'s representation of the definition by Mackenbach and Kunst where h(x) is the health outcome quantifying event occurrence (e.g., hazard rate, incidence rate, prevalence rate) as a function of the socioeconomic rank x, and 0 and 1 are the positions of the hypothetical best-placed and worst-placed persons, respectively (Moreno-Betancur et al., 2015). According to Moreno-Betancur and colleagues, this new definition is more appealing because all tools available can be used in estimating the relative risk and confounder adjustment is easier compared to the earlier definition by Pamuk (Pamuk, 1985).

$$RII = h(1)/\, h(0) \text{ (Eq. 3)}$$

Mackenbach and Kunst also redefined the SII as an analogy to an excess risk (Mackenbach & Kunst, 1997). Equation 4 is based on Moreno-Betancur et al.'s representation of this definition.

$$SII = h(1) - h(0) \text{ (Eq. 4)}$$

In 2015, Moreno-Betancur et al. had proposed new definitions to these indices which are based on the idea that a suitable measure of the linear association is given by the slope of the regression (Moreno-Betancur et al., 2015). They proposed the idea of fitting a linear regression to the data that possibly does not reflect the true shape of the association between socioeconomic rank *x* and health outcome *y*. In this proposed definition, "the RII and SII are the expected relative and excess risks comparing the hypothetical extremes of the scale under the log-linear and linear models, respectively, that best approximate the relation between socioeconomic status and health" (Moreno-Betancur et al., 2015). They used the logarithmic

link between the exposure and outcome to yield a relative estimate, while using an identity link will yield an absolute estimate. Thus,

$$RII = \exp(\beta^*) \text{ (Eq. 5)}$$

where $\beta^*$is the least false parameter[10] i.e., the parameter that yields the best approximation of the association between *x* and *y* through a log-linear model, and

$$SII = \alpha^* \text{ (Eq. 6)}$$

where α^* is the least false parameter i.e., the parameter that yields the best approximation of the association between *x* and *y* by a linear model. Their definition of the SII is similar to that proposed by Preston (Eq. 1).

The main asset of this definition of the indices by Moreno-Betancur et al. is that it preserves the analogies to the relative and excess risks which means that they already rely on regression models already available for estimating the relative and excess risks (Moreno-Betancur et al., 2015). They also proposed using other regressions such as Poisson and Cox models depending on the data used and the research question.

In this thesis, we used a combination of these definitions to calculate the RII and SII depending on the available data. In most of the previous examples, the formulas are designed to estimate the indices with an adverse outcome. However, throughout this thesis, we will study a favorable outcome which is the self-report of recent HIV testing uptake in the previous 12 months. To estimate the indices, we first ranked the individuals from lowest (x = 0) to highest (x = 1) in the cumulative distribution of the SEP.

We used modified Poisson regression with robust variance and a log link to estimate the prevalence ratio (PR) (Yelland et al., 2011; Zou, 2004). This method was preferred to logistic regression as it allows for risk ratio (RR) calculation (here, PR) rather than odds ratio (OR). RR

10 "The RII and SII are not true population parameters but simply summary measures of the linear association across the entire scale. In particular, these indices are not true causal parameters in studies where association can be endowed with a causal interpretation."
Source: Moreno-Betancur, M., Latouche, A., Menvielle, G., Kunst, A. E., & Rey, G. (2015). Relative Index of Inequality and Slope Index of Inequality: A Structured Regression Framework for Estimation. *Epidemiology*, *26*(4), 518–527.

is easier to interpret because it is often simpler to understand the concept of risk than odds and some people tend to misinterpret the OR as the RR leading to overestimation of the point estimate (Cummings, 2009; Lee, 1994; Yelland et al., 2011).

To estimate the RII, we followed Eq. 5 proposed by Moreno-Betancur et al., and for the SII, we used the below formula (Eq. 7) which follows the definition by Mackenbach and Kunst (Eq. 4) but with a favorable outcome:

$$SII = exp(\beta_o + \beta_1) - \exp(\beta o) \text{ (Eq. 7)}$$

Thus, an SII greater than 0 and RII greater 1 indicate inequality favoring those with the highest SEP level (here, self-reported recent HIV testing uptake in the last 12 months is more concentrated or more likely among those with the highest SEP level than those with the lowest SEP level, respectively).

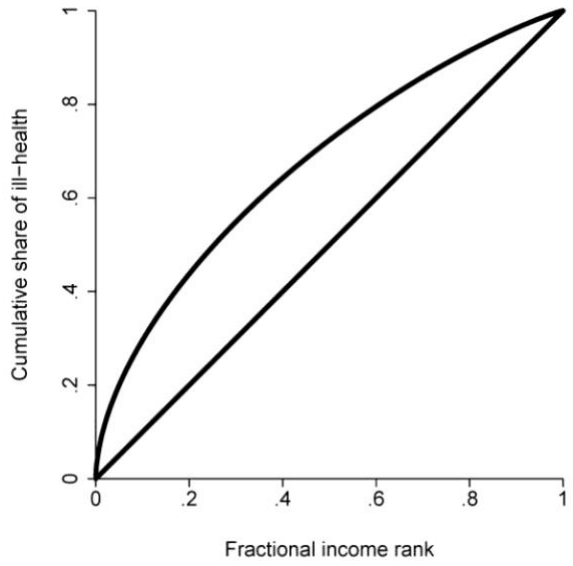
When relying on smaller sample size (mainly when measuring inequalities at small-scale), we preferred using linear regression to calculate cluster-level RII and SII since it is computationally lighter. The RII was the ratio of the predicted outcomes between the highest SEP-level and lowest SEP-level and SII was the linear regression coefficient estimating the relationship between SEP and recent HIV testing.

7.3. Erreygers Concentration Index

Another indicator commonly used to measure inequality is the Erreygers Concentration Index (ECI) which also measures absolute inequality. It is a corrected version of the Concentration Index (CI).

The CI measures the degree of inequality between socioeconomic groups with respect to a given health outcome (Kakwani et al., 1997; Wagstaff et al., 1989). It is defined in relation to the concentration curve. The concentration curve is used to identify whether socioeconomic inequality in a health outcome exists and whether it is more marked at one point in time than another or in one country or another. CI therefore is defined as twice the area between the concentration curve and the 45° line of equality (Figure 8) (Kakwani, 1980).

Figure 8. Hypothetical concentration curve.



The straight line is the 45° line of equality. Source: (O'Donnell et al., 2016).

The index takes a negative value when the curve lies above the line of equality (Figure 8) demonstrating a disproportionate concentration of the health outcome among the poor, and positive value indicate concentration of the outcome among the rich. The index is bounded between -1 and 1 with 0 indicating equality. The convenient formula for the CI is defined in terms of the covariance between the health variable (h) and the fractional rank in the living standards distribution (r) (Kakwani, 1980):

$$C = \frac{2}{\mu} cov(h, r)$$

However, it has been found that the bound of the CI depends on the mean of the health variable and therefore comparisons between populations with different mean health levels would be challenging (Erreygers, 2009). This was evident with binary health variables and any health variable with a finite upper value or positive lower value leading to varying bounds of the CI (Erreygers, 2009).

Erreygers proposed the corrected CI or the ECI to account for the bounded nature of binary health variables (0 and 1) (Erreygers, 2009) to allow for the comparison between social groups

that may be present at different levels of health (Gonzalo-Almorox & Urbanos-Garrido, 2016; Lawana & Booysen, 2018). The ECI formula is:

$$ECI = \frac{4\mu}{y^{max} - y^{min}} CI$$

where μ is the mean level of health multiplied by four, y^{max} and y^{min} are the maximum and minimum levels of health (here, HIV testing uptake with values of 1 and 0). The ECI satisfies the mirror property (i.e., the absolute value of the index is the same regardless of whether inequality in health or ill-health is being measured), scale and translation invariance (i.e., value of the index is invariant to any feasible positive linear transformation of the health variable) (Erreygers, 2009). We thus used the ECI as an additional analysis to assess the contextual factors associated with inequalities in HIV testing (i.e., ECI).

Part Three:

Findings and analyses

8. Article 1 - Socioeconomic inequalities in HIV testing and their trends over time

8.1. Summary

Global increases in HIV testing uptake in the past decades may hide disparities across various socioeconomic groups. In this first article, socioeconomic inequalities in HIV testing uptake in the last 12 months were quantified and their trends over time before and after 2008 were assessed. We analyzed data from 16 SSA countries where at least one DHS was done before and after 2008 (i.e., the year after the release of the recommendation for expanded PITC). Country-level absolute and relative socioeconomic inequalities in recent HIV testing were estimated using the SII and RII, respectively. The SII difference and RII ratio between the pre- and post-2008 surveys were estimated to assess trends over time. Estimates across countries were pooled using random-effect meta-analysis.

Uptake of recent HIV testing increased between surveys before and after 2008 in the 16 countries. Before 2008, recent HIV testing uptake was almost similar between women and men, however, after 2008, women were more likely to be tested for HIV in 14 of 16 countries. Overall relative inequalities in recent HIV testing decreased for both genders. Meanwhile, absolute inequalities increased in men and plateaued in women. Despite the decrease in relative inequalities, pro-rich inequalities persisted in majority of the countries in both genders. We observed higher magnitudes of both absolute and relative inequalities in men compared to women after 2008. Important between-country heterogeneities in the magnitude of inequalities were also observed for both genders. The findings were consistent when repeating analysis using highest educational attainment as the measure of SEP and when conducting a subgroup analysis of participants aged 15-24 years. In this work, we demonstrate that overall increases in HIV testing uptake until 2016 hid differential progress across socioeconomic groups. The findings of this article show the need to monitor inequalities in both absolute and relative scales. Without specific focus on equity, it is unlikely that HIV testing programs will reach everyone especially the disadvantaged groups. This article was published in the Lancet Global Health.

Temporal trends in socioeconomic inequalities in HIV testing: an analysis of cross-sectional surveys from 16 sub-Saharan African countries

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Summary

Background Overall increases in the uptake of HIV testing in the past two decades might hide discrepancies across socioeconomic groups. We used data from population-based surveys done in sub-Saharan Africa to quantify socioeconomic inequalities in uptake of HIV testing, and to establish trends in testing uptake in the past two decades.

Methods We analysed data from 16 countries in sub-Saharan Africa where at least one Demographic and Health Survey was done before and after 2008. We assessed the country-specific and sex-specific proportions of participants who had undergone HIV testing in the previous 12 months across wealth and education groups, and quantified socioeconomic inequalities with both the relative and slope indices of inequalities. We assessed time trends in inequalities, and calculated mean results across countries with random-effects meta-analyses.

Findings We analysed data for 537 784 participants aged 15–59 years (most aged 15–49 years) from 32 surveys done between 2003 and 2016 (16 before 2008, and 16 after 2008) in Cameroon, Côte d'Ivoire, DR Congo, Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, Tanzania, Zambia, and Zimbabwe. A higher proportion of female participants than male participants reported uptake of HIV testing in the previous 12 months in five of 16 countries in the pre-2008 surveys, and in 14 of 16 countries in the post-2008 surveys. After 2008, in the overall sample, the wealthiest female participants were 2·77 (95% CI 1·42–5·40) times more likely to report HIV testing in the previous 12 months than were the poorest female participants, whereas the richest male participants were 3·55 (1·85–6·81) times more likely to report HIV testing than in the poorest male participants. The mean absolute difference in uptake of HIV testing between the richest and poorest participants was 11·1 (95% CI 4·6–17·5) percentage points in female participants and 15·1 (9·6–20·6) in male participants. Over time (ie, when pre-2008 and post-2008 data were compared), socioeconomic inequalities in the uptake of HIV testing in the previous 12 months decreased in male and female participants, whereas absolute inequalities remained similar in female participants and increased in male participants.

Interpretation Although relative socioeconomic inequalities in uptake of HIV testing in sub-Saharan Africa has decreased, absolute inequalities have persisted or increased. Greater priority should be given to socioeconomic equity in assessments of HIV-testing programmes.

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See **Comment** page e744

For a French translation of the Article see **Online** for appendix 1

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Introduction

As the gateway to many HIV prevention and care services, including antiretroviral therapy (ART), HIV testing has a central role in the HIV response. Testing strategies have evolved as ART became increasingly available in most countries, from a cautious approach that focused on counselling and confidentiality to a push to increase routine access to testing in clinical settings and through large-scale community approaches.[1,2] This evolution has resulted in substantial increases in access to, and uptake of, HIV testing in many countries.

The proportion of people living with HIV who know their HIV status increased from 10% in 2005, to 85% in eastern and southern Africa and 64% in western and central Africa in 2018.[3] However, an estimated 1·1 million people with HIV in eastern and southern Africa, and 1·3 million in western and central Africa, remain unaware of their HIV status. Thus, efforts are still needed to reach the target of 90% of people with HIV knowing their status by 2020—the first 90 of the global 90-90-90 target adopted by UNAIDS.[4] Ensuring that no specific group of the population is left behind in efforts to achieve these objectives is essential.

Several cross-sectional studies[5–8] done in sub-Saharan Africa have shown low uptake of HIV testing in the poorest and least educated population groups, and whether these inequalities increased or decreased during the intensification of HIV testing activities remains unknown. Scale-up of health interventions

Research in context

Evidence before this study

We searched PubMed with the search terms ("inequality" OR "inequity" OR "equity") AND ("HIV testing") AND ("Africa") for articles published in any language up to Oct 15, 2019. We also screened the reference lists of relevant articles returned by our search to identify other potentially relevant papers. Many studies documented socioeconomic inequalities in access to HIV treatment and to specific HIV prevention services, such as HIV testing, prevention of mother-to-child transmission, and voluntary medical male circumcision. Most of the studies assessed socioeconomic inequalities in specific subgroups of the population (eg, pregnant women), or specifically focused on other forms of inequalities, such as gender or age inequalities. Among studies focusing on wealth-related or education-related inequalities, most focused on one country only. All of these studies showed that wealth or education, or both, were predictors of HIV testing. A study of the relation between socioeconomic status and knowledge of one's HIV status in 13 sub-Saharan African countries, which was done in the pre-treatment era (ie, before 2006), showed a general trend of greater knowledge of HIV status among wealthier and more educated individuals compared with among poorer and less educated people. One grey-literature report based on Demographic and Health Survey data up to 2011 described the demographic characteristics associated with HIV testing in several sub-Saharan African countries. In gender-specific univariate analyses, uptake of HIV testing tended to increase monotonically with wealth. There were a few exceptions, however, especially in countries with very high or very low overall levels of testing. Although socioeconomic inequalities in HIV testing in sub-Saharan Africa have been detailed in many studies, no pooled estimate of the effect was available. Furthermore, whether these inequalities were decreasing or worsening was not reported in any study.

Added value of this study

We analysed data from the standardised, population-based Demographic and Health Surveys to identify the magnitude of the effect of wealth-related and education-related inequalities on uptake of HIV testing in 16 sub-Saharan African countries. We also investigated how this effect changed over time, by comparing data from surveys done before and after 2008 (when international recommendations to expand provider-initiated opt-out testing were released, and by when antiretroviral therapy in sub-Saharan Africa had been scaled up). We report both relative and absolute inequalities based on indicators that are widely used for the quantification and comparison of socioeconomic gradients in health, and also calculated mean overall estimates for the 16 countries included. In the most recent surveys (ie, those done after 2008), we noted a general trend of inequalities that disfavoured poor and less educated people (ie, these groups were less likely to have undergone an HIV test in the previous 12 months). Relative socioeconomic inequalities were sharper in male than in female participants: overall, in the post-2008 surveys, the wealthiest male participants were roughly 3·6 times more likely to report HIV testing in the previous 12 months than were the poorest participants; the corresponding ratio among female participants was roughly 2·8. Relative inequalities tended to be greater in western and central African countries than in eastern and southern African countries. When we contrasted the pre-2008 and post-2008 surveys, relative inequalities in HIV testing uptake had decreased in both sexes, whereas absolute inequalities remained similar among female participants and increased among male participants.

Implications of all the available evidence

Socioeconomic inequalities in the uptake of HIV testing remain substantial in many countries, despite reductions in relative inequalities. Our results highlight the need to monitor not only overall progress in HIV testing uptake, but also progress in socioeconomic subgroups. A better understanding of the drivers of these inequalities is needed to ensure that current and future HIV testing policies reach every part of the population, especially the poorest and the least educated groups.

does not necessarily translate into reduced health inequalities, and could even exacerbate inequalities. For instance, data from high-income countries suggest that programmes that increased cancer screening services did not reduce the effect of socioeconomic inequalities on uptake of these services.[9,10] Monitoring of temporal trends in socioeconomic inequalities in response to expanded HIV testing is thus essential to assess and ensure equity of HIV programmes in line with the Sustainable Development Goals. In this study, we used data from population-based surveys in several sub-Saharan African countries to assess temporal trends relative and absolute socioeconomic inequalities in the uptake of HIV testing during the era of HIV testing progression and ART scale-up.

For the **Demographic and Health Surveys** see https://dhsprogram.com/

Methods

Study design and data sources

In this cross-sectional study, we analysed data from Demographic and Health Surveys (DHS) from 16 sub-Saharan African countries to quantify socioeconomic inequalities in uptake of HIV testing in the previous 12 months. DHS are nationally representative cross-sectional surveys in which data are collected for a wide range of health indicators. DHS have a multistage design: households are sampling units, and generally all people aged 15–59 years from selected households are eligible for inclusion. However, the bulk of the surveys were done in participants aged 15–49 years, and depending on the survey, data for men or for HIV indicators and biomarkers, or both, might be collected in

only a subsample of selected households. Consenting adults are interviewed face-to-face by trained interviewers, who use a standardised questionnaire that includes items on sociodemographic characteristics, sexual behaviours, and reproductive health, and a specific section focusing on HIV-related issues.[11]

For our analysis, we selected sub-Saharan African countries where at least two DHS including questions about HIV indicators and biomarkers had been done—one before 2008 and one after 2008. In 2007, international recommendations to expand provider-initiated opt-out testing were released,[12] and the recommendation of provider-initiated testing might have caused the profile of HIV-testing users to broaden from a small self-selecting group.[5] For countries where multiple surveys were available either before or after 2008, we considered only the most recently done one (as of March, 2019). Pre-2008 and post-2008 surveys were thereafter termed earlier and later surveys, respectively.

Data

In the DHS, each included household was classified as rural or urban according to nationally defined boundaries. There are many ways to measure socioeconomic position in low-income and middle-income countries, and each method has both strengths and limitations. Asset-based measures and education are commonly used complementarily and are often highly correlated, although they rely on different theoretical bases.[13] Individual sociodemographic characteristics collected as part of the DHS included age, level of school attended (ie, none, primary, or secondary or higher) and marital status (ie, married or cohabiting, single, or widowed or separated). Household wealth was assessed with the DHS's wealth index—a composite measure of living standards that is based on the household's assets (eg, televisions, refrigerators) and characteristics (eg, type of water access, type of flooring).[14] In the DHS, participants were asked whether they had ever been tested for HIV, and if so, the time since their last test. The outcome of interest was self-reporting of undergoing an HIV test in the past 12 months.

Statistical analysis

For each survey, we calculated the proportion of participants reporting an HIV test in the past 12 months. In the calculation, we accounted for survey design and sampling weights. For each survey round (ie, the pre-2008 and post-2008 surveys), we assessed within-country inequalities on the basis of participants' relative rank in the cumulative distribution of the wealth index. Inequalities were then measured both on relative and absolute scales. The reporting of inequalities on both scales is highly recommended, especially when monitoring changes, because conclusions can be skewed when only one or the other is used.[15] Furthermore, the choice of a relative scale over an absolute scale—or vice versa—carries an implicit normative judgment on what a

	Sierra Leone				Guinea				Liberia				Côte d'Ivoire			
	2008		2013		2005		2012		2007		2013		2005		2011–12	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Response rate* (%)	94%	93%	97%	96%	97%	95%	98%	97%	95%	93%	98%	95%	90%	88%	93%	91%
n	7374	3280	16658	7262	7954	3174	9142	3782	7092	6009	9239	4118	5183	4503	10060	5135
Living in rural area (%)	64%	63%	64%	63%	69%	61%	64%	61%	58%	60%	39%	41%	53%	53%	49%	50%
Age, years (%)																
15–24	32%	28%	39%	34%	35%	36%	40%	36%	38%	37%	40%	39%	46%	41%	40%	34%
25–34	36%	25%	31%	25%	30%	20%	30%	24%	30%	28%	30%	30%	31%	32%	34%	29%
≥35	31%	47%	30%	41%	35%	44%	30%	40%	32%	36%	29%	31%	24%	28%	26%	37%
Marital status																
Married or cohabiting	75%	63%	66%	57%	79%	59%	74%	55%	64%	57%	58%	54%	59%	44%	63%	53%
Single	19%	33%	28%	39%	17%	37%	23%	43%	26%	38%	31%	43%	32%	50%	30%	42%
Widowed or separated	6%	3%	6%	4%	4%	4%	4%	2%	10%	5%	11%	4%	9%	6%	7%	5%
Education level																
None	66%	50%	56%	43%	78%	51%	67%	43%	42%	18%	33%	13%	54%	34%	53%	36%
Attended primary	13%	14%	14%	12%	11%	17%	14%	18%	33%	33%	31%	29%	27%	25%	25%	26%
Attended secondary or higher	21%	36%	30%	45%	11%	32%	19%	39%	25%	49%	36%	58%	20%	41%	21%	38%
HIV prevalence	2%	1%	2%	1%	2%	1%	2%	1%	2%	1%	2%	2%	6%	3%	5%	3%
Uptake of HIV testing in previous 12 months	5%	5%	18%	8%	1%	3%	5%	5%	2%	3%	22%	14%	5%	4%	15%	10%

The DHS data, on which these percentages are based, are available online. *Based on each country's United States Agency for International Development Demographic and Health Survey final report.

Table 1: **Survey and population characteristics in Sierra Leone, Guinea, Liberia, and Côte d'Ivoire**

	Mali				Niger				Cameroon				DR Congo			
	2006		2012–13		2006		2012		2004		2011		2007		2013–14	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Response rate* (%)	97%	91%	96%	93%	96%	92%	95%	88%	94%	93%	97%	96%	97%	95%	99%	97%
n	14583	4207	10424	4399	9223	3549	11160	3928	10656	5280	15426	7191	9995	4757	18827	8656
Living in rural area (%)	66%	64%	75%	75%	80%	74%	81%	75%	45%	43%	47%	45%	55%	57%	62%	63%
Age, years (%)																
15–24	40%	36%	36%	29%	37%	31%	34%	28%	46%	41%	43%	39%	43%	39%	41%	36%
25–34	32%	23%	36%	24%	34%	25%	37%	25%	29%	27%	30%	26%	30%	26%	33%	26%
≥35	29%	41%	28%	47%	29%	44%	29%	47%	25%	32%	27%	34%	27%	35%	26%	37%
Marital status																
Married or cohabiting	85%	65%	85%	68%	86%	67%	89%	70%	67%	51%	63%	50%	66%	57%	64%	58%
Single	12%	31%	14%	32%	10%	31%	8%	29%	24%	40%	28%	45%	24%	38%	26%	38%
Widowed or separated	3%	4%	2%	1%	4%	2%	4%	2%	9%	9%	9%	5%	9%	5%	10%	4%
Education level																
None	78%	60%	76%	62%	84%	69%	80%	63%	22%	12%	21%	10%	21%	6%	15%	4%
Attended primary	11%	19%	9%	14%	10%	17%	11%	19%	39%	37%	33%	33%	39%	30%	37%	22%
Attended secondary or higher	10%	21%	15%	24%	6%	14%	9%	18%	39%	52%	46%	57%	41%	64%	48%	74%
HIV prevalence	2%	1%	1%	1%	1%	1%	<1%	<1%	7%	4%	6%	3%	2%	1%	2%	1%
Uptake of HIV testing in previous 12 months	3%	4%	7%	7%	1%	2%	8%	3%	5%	8%	24%	21%	5%	5%	9%	8%

The Demographic and Health Surveys data, on which these percentages are based, are available online. *Based on each country's United States Agency for International Development Demographic and Health Survey final report.

Table 2: **Survey and population characteristics in Mali, Niger, Cameroon, and DR Congo**

fair and socially just distribution of health should be.[16] We used the relative index of inequality (RII) as our relative scale and the slope index of inequality (SII) as our absolute scale.[17] The former expresses the ratio of the predicted outcomes between the richest and the poorest people in the wealth distribution, whereas the latter represents the absolute difference in the predicted proportions of these two extremes. Both indicators were obtained by fitting a modified Poisson regression, with robust variance and a log link function to estimate the association between participants' relative wealth rank and HIV testing in the past 12 months, and by using generalised estimating equations to account for the clustering of observations.[18] We used the Wilcoxon rank-sum test to compare indices of inequalities between west and central versus eastern and southern African countries.

We also assessed temporal trends in relative and absolute inequalities in uptake of HIV testing in the previous 12 months. For each country, we computed the ratio of RIIs between the later and the earlier surveys:

$$RII\ ratio = \frac{RII_{after\ 2008}}{RII_{before\ 2008}}$$

For the SII, we calculated the difference between the later and earlier surveys:

$$SII\ difference = SII_{after\ 2008} - SII_{before\ 2008}$$

We also calculated 95% CIs for both the RII ratio and the SII difference. Both indicators were standardised on the basis of the number of years elapsed between the earlier and the later surveys (appendix 2 p 2). An RII ratio value greater than 1 reflects increasing relative inequalities, whereas a value less than 1 suggests decreasing relative inequalities. An SII difference of greater than 0 shows increasing absolute inequalities, whereas a difference of less than 0 shows decreasing absolute inequalities.

We averaged inequality estimates across countries for each survey round, as well as trends indicators, by using random-effects meta-analyses.[19] Between-country heterogeneity was assessed with I^2 statistics. To track socioeconomic inequalities in access to HIV testing in young people—a vulnerable population who generally lack access to HIV prevention services—we did a subgroup analysis in participants aged 15–24 years. Because inequalities can differ according to the dimension measured, we repeated all our analyses but used the relative rank in the cumulative distribution of educational attainment instead of wealth as the measure of socioeconomic position. All analyses were also stratified according to sex. We used R (version 3.6.0) for all analyses.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of

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

Results

The 16 sub-Saharan African countries included in the analyses were Cameroon, Côte d'Ivoire, DR Congo, Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, Tanzania, Zambia, and Zimbabwe. The earlier surveys were done between 2003 and 2008, and the later surveys were done between 2008–09 and 2016, with the inter-survey period ranging from 5 years to 11 years across countries (tables 1–4).

90–100% of women and girls approached participated, and 82–100% of men and boys (tables 1–4). Overall, data were collected from 537784 people, 354431 female participants and 183353 male participants. In the surveys done after 2008, most participants in most countries were living in rural areas (except for Cameroon, Côte d'Ivoire, and Liberia) and most were married or cohabiting (except for male participants in Cameroon and Lesotho; tables 1–4). Across all surveys, HIV prevalence was lowest in Niger (0·7% in the pre-2008 survey and 0·4% in the post-2008 survey) and highest in Lesotho (23·0% in the pre-2008 survey and 25·0% in the later survey; appendix 2 p 3).

The uptake of HIV testing improved in all countries between the pre-2008 survey and the post-2008 survey (figure 1). Overall, uptake of HIV testing in the past 12 months was lowest in Niger (1·3%) in the pre-2008 surveys and in Guinea (5·0%) in the post-2008 surveys (figure 1; appendix 2 p 3). It was highest in Zambia (17·0%) in the pre-2008 surveys and in Lesotho (52·6%) in the post-2008 surveys (figure 1; appendix 2 p 4). In the pre-2008 surveys (table 1), a higher proportion of female participants than male participants took an HIV test in five of the 16 countries, whereas in the post-2008 surveys, female participants reported higher uptake than male participants in 14 of 16 countries (tables 1–4). With some exceptions, uptake of HIV testing in the previous 12 months was more frequently reported in urban than in rural areas (appendix 2 pp 4–10).

Figure 2 presents, for each country, the proportions of people who underwent HIV testing in the previous 12 months per survey round and by sex among the richest and poorest wealth quintiles. Among both sexes, we noted a pattern of higher uptake of testing in the richest quintile than in the poorest quintile across survey rounds (figure 2).

Relative and absolute inequalities in uptake of HIV testing in the previous 12 months based on wealth distribution are shown in tables 5 (female participants) and 6 (male participants). In the pre-2008 surveys, relative inequalities that favoured the richest participants over the poorest were noted in all 16 countries, for both male and female participants (all RII values >1; tables 5, 6). Before 2008, the wealthiest female

	Zambia				Lesotho				Zimbabwe				Rwanda			
	2007		2013–14		2004		2014		2005–06		2015		2005		2014–15	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Response rate* (%)	97%	91%	96%	91%	94%	85%	97%	94%	90%	82%	96%	92%	98%	97%	100%	100%
n	7146	6500	16411	14773	7095	2797	6621	2931	8907	7175	9955	8396	11321	4820	13497	6217
Living in rural area (%)	58%	57%	54%	54%	76%	79%	64%	66%	61%	60%	62%	64%	83%	83%	81%	80%
Age, years (%)																
15–24	41%	38%	40%	38%	45%	45%	42%	43%	46%	47%	39%	41%	44%	43%	39%	37%
25–34	34%	30%	32%	26%	26%	24%	31%	25%	30%	27%	33%	27%	28%	24%	33%	30%
≥35	25%	32%	27%	35%	29%	31%	27%	32%	24%	26%	28%	32%	28%	34%	28%	33%
Marital status																
Married or cohabiting	62%	56%	60%	55%	52%	43%	55%	40%	58%	48%	62%	52%	49%	52%	52%	54%
Single	26%	39%	28%	41%	33%	51%	33%	52%	27%	48%	25%	43%	38%	46%	38%	44%
Widowed or separated	12%	5%	12%	4%	14%	7%	12%	9%	15%	5%	13%	5%	14%	3%	11%	2%
Education level																
None	10%	5%	8%	4%	2%	17%	1%	10%	4%	2%	1%	1%	23%	17%	12%	11%
Attended primary	54%	46%	47%	40%	59%	55%	39%	45%	33%	27%	26%	23%	67%	70%	64%	65%
Attended secondary or higher	35%	49%	45%	56%	39%	28%	60%	45%	63%	71%	73%	76%	10%	12%	23%	24%
HIV prevalence	16%	12%	15%	12%	26%	19%	30%	20%	21%	15%	17%	11%	4%	2%	4%	3%
Uptake of HIV testing in previous 12 months	21%	13%	48%	39%	8%	6%	59%	38%	8%	8%	49%	37%	13%	12%	40%	37%

The Demographic and Health Surveys data, on which these percentages are based, are available online. *Based on each country's United States Agency for International Development Demographic and Health Survey final report.

Table 3: **Survey and population characteristics in Zambia, Lesotho, Zimbabwe, and Rwanda**

	Malawi				Tanzania				Kenya				Ethiopia			
	2004		2015–16		2003–04		2011–12		2003		2008–09		2005		2016	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Response rate* (%)	96%	86%	98%	95%	96%	91%	96%	89%	94%	86%	96%	89%	96%	89%	95%	86%
n	11 698	3261	24 562	7478	6863	5659	10 967	8352	8195	3578	8444	3465	14 070	6033	15 683	12 688
Living in rural area (%)	82%	80%	82%	82%	69%	70%	73%	74%	75%	75%	75%	74%	82%	85%	78%	80%
Age, years (%)																
15–24	45%	38%	42%	43%	42%	42%	39%	42%	43%	43%	41%	41%	41%	40%	39%	35%
25–34	31%	34%	31%	26%	33%	31%	31%	26%	30%	26%	32%	27%	31%	25%	34%	29%
≥35	24%	28%	27%	31%	25%	27%	30%	32%	27%	31%	27%	32%	28%	36%	27%	36%
Marital status																
Married or cohabiting	71%	64%	66%	58%	64%	53%	63%	53%	60%	51%	58%	51%	64%	57%	65%	59%
Single	17%	33%	21%	38%	25%	41%	25%	42%	30%	45%	31%	44%	25%	40%	26%	39%
Widowed or separated	12%	3%	13%	4%	12%	6%	12%	5%	10%	4%	10%	5%	11%	3%	9%	3%
Education level																
None	23%	11%	12%	6%	22%	11%	18%	9%	13%	6%	9%	4%	66%	43%	48%	30%
Attended primary	62%	63%	62%	59%	69%	78%	65%	67%	58%	57%	57%	52%	22%	37%	35%	47%
Attended secondary or higher	16%	26%	26%	36%	8%	11%	18%	24%	29%	37%	34%	44%	12%	20%	17%	23%
HIV prevalence	14%	10%	11%	7%	8%	6%	6%	4%	9%	5%	8%	5%	2%	1%	1%	1%
Uptake of HIV testing in previous 12 months	8%	8%	44%	42%	6%	8%	33%	28%	8%	8%	31%	23%	4%	2%	21%	20%

The Demographic and Health Surveys data, on which these percentages are based, are available online. *Based on each country's United States Agency for International Development Demographic and Health Survey final report.

Table 4: **Survey and population characteristics in Malawi, Tanzania, Kenya, and Ethiopia**

participants were nearly ten times more likely to report an HIV test in the previous 12 months than the poorest (mean RII for all 16 countries 9·79 [95% CI 4·24–22·60]). By comparison, the equivalent RII after 2008 was 2·77 (95% CI 1·42–5·40), and thus the standardised mean RII ratio was 0·85 per yr^{-1} (95% CI 0·80–0·90). However, in the post-2008 surveys, inequalities between the richest and poorest female participants persisted in 13 of 16 countries (table 5). This pattern was similar in male participants, with large relative inequalities favouring the richest over the poorest in the pre-2008 surveys, inequalities which decreased in the post-2008 surveys (standardised mean RII ratio for all 16 countries 0·91 per yr^{-1} [95% CI 0·86–0·96]; table 6). However, inequalities persisted in the post-2008 surveys in 14 of the 16 countries, and overall the richest male participants were 3·55 times more likely to report HIV testing in the previous 12 months than the poorest male participants (mean overall RII 3·55 [95% CI 1·85–6·81]). In the post-2008 surveys, relative inequalities were more marked in the countries in west and central Africa than in those in eastern and southern Africa among both female (p=0·0070) and male participants (Wilcoxon rank-sum test p<0·0001). Notably, socioeconomic inequalities in testing uptake persisted even when other variables, such as urban versus rural location, were accounted for in multivariate analyses (appendix 2 pp 11–18).

Inequalities favouring the richest participants over the poorest were also noted on the absolute scale among both male and female participants in all countries in the pre-2008 surveys (tables 5, 6). However, we identified no changes in the absolute inequalities in female participants between the pre-2008 surveys and the post-2008 surveys (standardised mean SII difference 0·001 per yr^{-1} [95% CI –0·006 to 0·008]). In the post-2008 surveys, a difference of more than 10 percentage points persisted between the wealthiest and poorest female participants in uptake of HIV testing in the previous 12 months (mean SII 0·111 [95% CI [0·046 to 0·176]). Among male participants, absolute inequalities increased between the pre-2008 and post-2008 surveys (standardised mean SII difference 0·007 per yr^{-1} [95% CI 0·001 to 0·014]; table 6). When results were averaged in the random-effects meta-analysis, important heterogeneity (I^2>75%) was noted for all inequality estimates.

In Malawi, Rwanda, Zambia, and Zimbabwe, relative and absolute inequalities were reduced in the post-2008 data compared with the pre-2008 data in both male and female participants (tables 5, 6). A subgroup analysis in participants aged 15–24 years (144 165 women and girls, and 69 597 men and boys) had similar results to those obtained in the overall sample, in terms of both magnitude and temporal trends (appendix 2 pp 19–20).

When inequalities were based on educational attainment rather than wealth, similar results were noted. Mean relative inequalities decreased in both female (standardised RII ratio 0·86 per yr^{-1} [95% CI 0·81 to 0·92]) and male

(0·91 per yr^{-1} [0·87 to 0·96]) participants, whereas mean absolute inequalities plateaued in female participants (standardised mean SII difference 0·003 per yr^{-1} [95% CI –0·002 to 0·007]) and increased in male participants (0·009 per yr^{-1} [0·004 to 0·014]; appendix 2 pp 22, 23).

Discussion

We analysed repeated cross-sectional population-based surveys to provide a comprehensive assessment of socioeconomic inequalities in uptake of HIV testing in sub-Saharan Africa and to measure temporal trends in the past two decades. Uptake of HIV testing in the previous 12 months increased between surveys done before and after 2008 in the 16 countries included in the analysis. HIV testing was more frequent in urban than in rural areas in nearly all countries both before and after 2008. Before 2008, testing uptake was roughly equivalent between the sexes, but after 2008, women were more likely to have been tested for HIV during the previous 12 months in 14 of the 16 countries. Overall, we noted large relative and absolute inequalities favouring the richest participants over the poorest participants both before and after 2008. Relative inequalities decreased with time in both sexes, whereas absolute inequalities plateaued in female participants but increased in male participants. Results were similar in a subgroup analysis of participants aged 15–24 years, in whom testing uptake is known to be a particular challenge. In the most recent surveys, important relative and absolute inequalities persisted in most countries.

We consistently noted increases over time in uptake of HIV testing in both sexes, as has been previously documented.[7] Indeed, funding for HIV programmes, including funding for HIV counselling and testing, increased substantially during the era of treatment scale-up in sub-Saharan Africa.[20] Concomitantly, the development and spread of new approaches for HIV outreach and testing allowed the intensification of testing programmes—notably the expansion of provider-initiated HIV testing after 2007,[21] and the subsequent development of community-based HIV testing.[2] Despite encouraging increases in the availability and uptake of HIV testing in the past decades, efforts are still required to fulfil the target of 90% of people living with HIV knowing their status, especially in western and central Africa.[22]

We noted that, after 2008, during the time of ART scale-up, higher proportions of female participants than male participants reported HIV testing in the past 12 months in most included countries—a pattern that was not apparent before 2008. Our analysis did not distinguish across HIV testing settings, but a global push on prevention of mother-to-child transmission of HIV via provider-initiated routine testing and the provision of ART in antenatal clinics could have largely contributed to the overall increase in testing among female participants.[21] The apparent absence of efforts to pursue the integration of HIV testing services into other relevant clinical settings could partly explain why fewer men and boys seem to have access to HIV testing and treatment, and could contribute to the HIV prevention blind spot in men and boys.[23] Provider-initiated testing has been suggested to reduce socioeconomic inequalities in the uptake of HIV testing.[6] The higher levels of both relative and absolute inequalities that we noted in male compared with female participants in the post-2008 DHS could thus also be linked to the differing opportunities for provider-initiated testing between sexes. Integration of HIV testing into a wider range of clinical settings could help to reduce the effect of socioeconomic inequalities on HIV testing uptake in men and boys, but would probably not be sufficient to close the gap with women and girls because of the low level of health-seeking behaviours in men and boys. Innovative approaches to HIV testing, such as HIV self-testing, assisted partner notification, and index partner testing, have improved the availability and uptake of HIV testing in key populations and partners of people with HIV.[24] However, few data are available about the relation between such approaches and socioeconomic inequalities in terms of HIV testing uptake. We recommend the inclusion of socioeconomic inequality in future assessments of these approaches.

The trends in inequalities we noted diverged according to whether we used relative or absolute measures of inequalities, and thus we can draw different conclusions about the effect of the scale-up of HIV testing on socioeconomic inequalities in uptake of HIV testing. Such a situation is quite common in the study of health inequalities, and shows the importance of using both absolute and relative effect measures when reporting inequalities.[15] Relative inequalities tend to be larger at low overall levels of the considered outcome, whereas

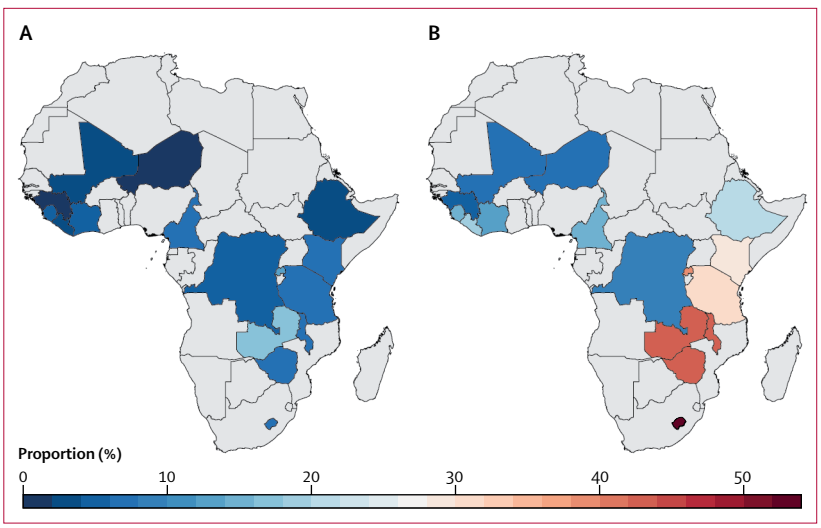

Figure 1: **Proportion of participants who underwent HIV testing during the previous 12 months in 16 sub-Saharan African countries before (A) and after (B) 2008**
Percentages were estimated from the Demographic and Health Surveys. Countries shown in grey were not included in the analyses.

See Online for appendix 2

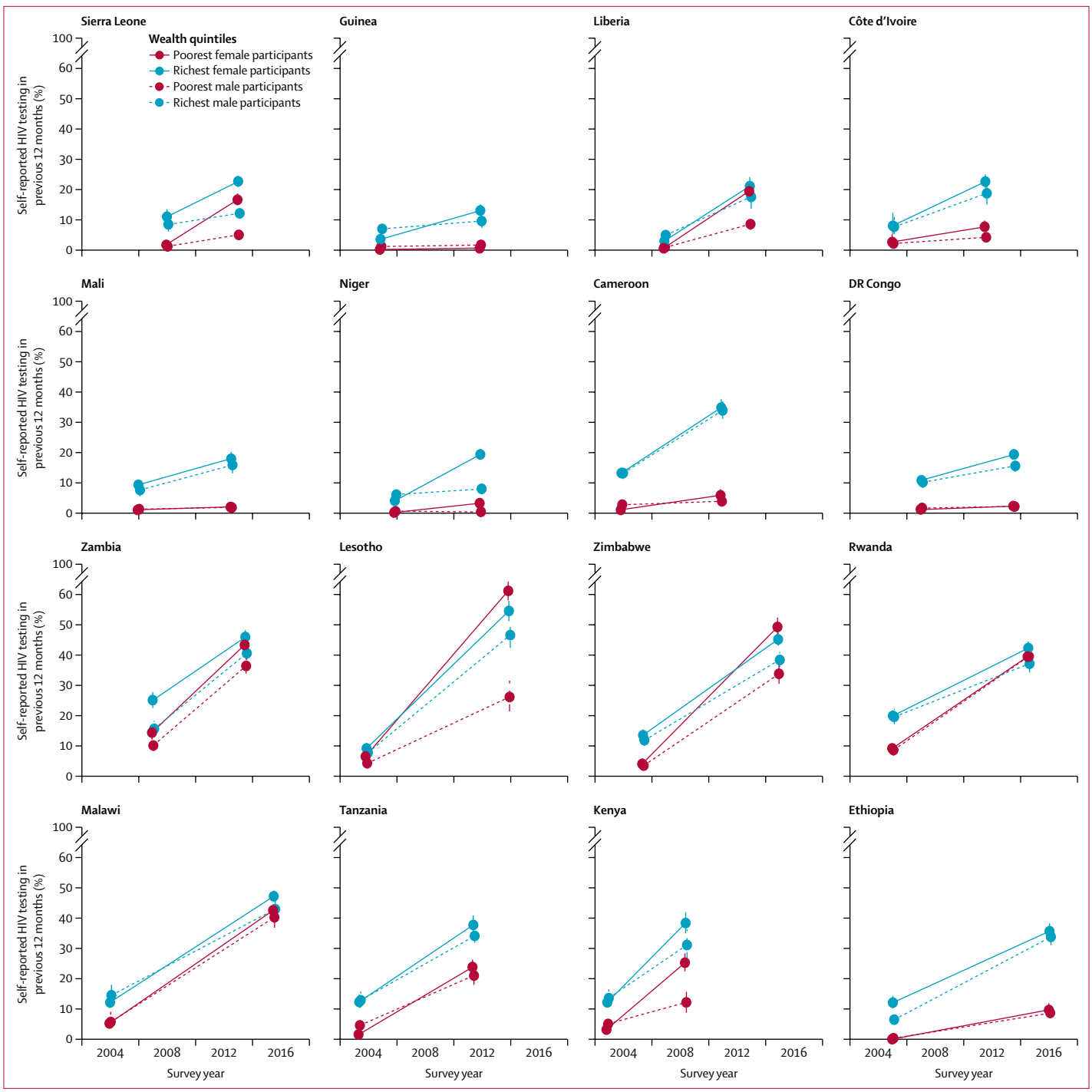

Figure 2: **Proportion of participants in the richest and poorest wealth quintiles who self-reported an HIV test in the previous 12 months in 16 sub-Saharan African countries**

absolute inequalities tend to be larger at intermediate levels of the considered outcome.[25] Thus, an increase in overall level of HIV testing uptake from low to intermediate between survey rounds is consistent with the inequality trends described here, especially the finding of increasing absolute inequalities in some western and central African countries. A corollary is that the overall coverage of HIV testing should be considered when comparing different countries in terms of socioeconomic inequalities, especially when using an absolute scale. For example, for female participants in the post-2008 surveys, it would be correct to interpret

	Relative index of inequality (95% CI)			Slope index of inequality (95% CI)		
	Before 2008 DHS	After 2008 DHS	Standardised ratio	Before 2008 DHS	After 2008 DHS	Standardised difference
Western and central Africa						
Sierra Leone	7·2 (4·5 to 11·4)	1·4 (1·2 to 1·7)	0·72 (0·66 to 0·80)	0·12 (0·09 to 0·14)	0·06 (0·03 to 0·09)	–0·011 (–0·019 to –0·003)
Guinea	135·6 (37·1 to 496·1)	49·0 (29·2 to 82·1)	0·87 (0·71 to 1·06)	0·05 (0·04 to 0·07)	0·17 (0·14 to 0·21)	0·017 (0·012 to 0·022)
Liberia	3·9 (2·0 to 7·6)	1·2 (1·0 to 1·4)	0·82 (0·73 to 0·92)	0·03 (0·01 to 0·04)	0·04 (0·00 to 0·07)	0·001 (–0·005 to 0·008)
Côte d'Ivoire	5·4 (2·6 to 11·0)	3·5 (2·8 to 4·4)	0·94 (0·83 to 1·05)	0·05 (0·03 to 0·08)	0·19 (0·16 to 0·22)	0·021 (0·014 to 0·027)
Mali	34·3 (18·8 to 62·5)	25·8 (17·5 to 38·1)	0·96 (0·86 to 1·07)	0·11 (0·08 to 0·13)	0·23 (0·20 to 0·26)	0·019 (0·013 to 0·025)
Niger	58·3 (26·1 to 130·2)	9·4 (7·1 to 12·5)	0·74 (0·64 to 0·85)	0·07 (0·05 to 0·09)	0·23 (0·20 to 0·26)	0·027 (0·021 to 0·033)
Cameroon	29·0 (18·8 to 44·9)	3·8 (3·1 to 4·7)	0·75 (0·70 to 0·80)	0·18 (0·15 to 0·2)	0·15 (0·13 to 0·17)	–0·003 (–0·008 to 0·002)
DR Congo	14·7 (9·4 to 22·9)	12·9 (8·8 to 18·9)	0·98 (0·90 to 1·07)	0·14 (0·11 to 0·17)	0·17 (0·14 to 0·19)	0·003 (–0·003 to 0·009)
Southern and eastern Africa						
Zambia	1·8 (1·4 to 2·2)	1·1 (1·0 to 1·1)	0·92 (0·89 to 0·96)	0·12 (0·08 to 0·16)	0·03 (–0·01 to 0·06)	–0·014 (–0·023 to –0·006)
Lesotho	1·4 (1·1 to 1·9)	0·9 (0·8 to 0·9)	0·95 (0·92 to 0·98)	0·03 (0·01 to 0·05)	–0·10 (–0·14 to –0·05)	–0·012 (–0·018 to –0·007)
Zimbabwe	5·6 (4·1 to 7·5)	0·9 (0·9 to 1·0)	0·83 (0·80 to 0·86)	0·14 (0·11 to 0·17)	–0·04 (–0·08 to 0·00)	–0·019 (–0·024 to –0·014)
Rwanda	2·0 (1·6 to 2·4)	1·1 (1·0 to 1·2)	0·94 (0·92 to 0·96)	0·09 (0·07 to 0·12)	0·02 (–0·01 to 0·06)	–0·007 (–0·012 to –0·003)
Malawi	2·3 (1·7 to 3·1)	1·0 (0·9 to 1·0)	0·93 (0·91 to 0·95)	0·06 (0·04 to 0·08)	–0·01 (–0·03 to 0·02)	–0·005 (–0·008 to –0·003)
Tanzania	9·2 (5·6 to 15·3)	1·4 (1·2 to 1·6)	0·79 (0·74 to 0·84)	0·12 (0·09 to 0·15)	0·10 (0·07 to 0·14)	–0·002 (–0·008 to 0·004)
Kenya	5·5 (4·0 to 7·5)	1·6 (1·3 to 1·8)	0·80 (0·75 to 0·85)	0·13 (0·11 to 0·16)	0·14 (0·09 to 0·18)	0·001 (–0·009 to 0·010)
Ethiopia	295·9 (170·9 to 512·6)	4·6 (4·0 to 5·4)	0·69 (0·65 to 0·72)	0·38 (0·33 to 0·43)	0·39 (0·35 to 0·43)	0·001 (–0·005 to 0·007)
Within-sample mean estimates from random-effects meta-analysis	9·8 (4·2 to 22·6)	2·8 (1·4 to 5·4)	0·85 (0·80 to 0·90)	0·11 (0·07 to 0·15)	0·11 (0·05 to 0·18)	0·001 (–0·006 to 0·008)
I^2	97·75%	99·00%	94·19%	95·72%	97·68%	95·36%

Relative index of inequality ratios and slope index of inequality differences are standardised based on the number of years elapsed between both survey rounds. DHS=Demographic and Health Survey.

Table 5: **Relative and absolute wealth-related inequalities in female participants who self-reported HIV testing in the previous 12 months in 16 sub-Saharan African countries**

that Sierra Leone is more equitable (SII 0·06) than Côte d'Ivoire (SII 0·19) because the overall proportion of the population who underwent HIV testing in the previous 12 months is roughly similar in both countries (18% *vs* 15%). Conversely, it would be inaccurate to deduce that Sierra Leone is more equitable than Kenya (SII 0·14) because the overall proportion of the population who underwent testing in the previous 12 months is substantially higher in Kenya (31%).

Despite progress, especially in terms of relative socioeconomic inequalities, inequalities remained substantial in the post-treatment era, especially in male participants. A better understanding of the sources of heterogeneity in the level of inequalities is required to address this issue. The inequalities we noted were not caused solely by differential access to HIV testing services in urban and rural areas: socioeconomic inequalities in testing uptake persisted even when urban versus rural location was accounted for in multivariate analyses (appendix 2 pp 12–19). The burden of the HIV epidemic seemed to play a role in the pattern we identified. In countries with a high HIV prevalence, such as Lesotho, Malawi, Zambia, and Zimbabwe, the difference in uptake of HIV testing between the richest and poorest participants was less substantial than that in countries with low HIV prevalence (eg DR Congo, Ethiopia, Mali, Niger). Countries with high HIV prevalence also prioritised ambitious HIV testing programmes, and HIV prevalence has been associated with HIV spending.[26] Thus, low-to-moderate efforts to promote and offer HIV testing might perpetuate socioeconomic inequalities in testing uptake, whereas larger efforts might decrease these inequalities, even when they are not specifically targeted at socioeconomically disadvantaged populations.

Our analysis had several limitations. Our results rely on a self-reported outcome. Assessment of the validity of self-reports of HIV testing is challenging, notably because accuracy might differ depending on HIV status.[27] Because inequality measurements rely on the quantification of an association, differential accuracy in self-reporting between socioeconomic groups might have biased our results. To our knowledge, little evidence is available about how the sensitivity and specificity of self-reported HIV testing are affected by socioeconomic status. However, evidence for other conditions (eg, cancer) suggest that over-reporting of self-reported screening is common among disadvantaged groups (eg, racial minorities).[28] If such over-reporting also applies to people self-reporting HIV testing, then the pro-rich inequalities in terms of testing uptake that we noted could be an under-estimation. Over-reporting of HIV testing uptake might also have contributed to the findings in some countries (eg, among female participants in Lesotho and Zimbabwe) that poorer people had higher uptake than wealthier people. Contextual factors such as the community-level stigma towards people with HIV could also affect the validity of

	Relative index of inequality (95% CI)			Slope index of inequality (95% CI)		
	Before 2008 DHS	After 2008 DHS	Standardised ratio	Before 2008 DHS	After 2008 DHS	Standardised difference
Western and central Africa						
Sierra Leone	7·5 (3·1 to 18·0)	2·8 (1·9 to 4·2)	0·82 (0·68 to 1·00)	0·09 (0·05 to 0·13)	0·09 (0·06 to 0·13)	0·001 (–0·010 to 0·012)
Guinea	32·4 (11·0 to 95·2)	10·3 (5·3 to 20·3)	0·85 (0·71 to 1·02)	0·10 (0·06 to 0·14)	0·12 (0·08 to 0·16)	0·002 (–0·006 to 0·011)
Liberia	10·7 (5·5 to 20·9)	3·4 (2·4 to 4·8)	0·83 (0·73 to 0·94)	0·06 (0·04 to 0·09)	0·15 (0·11 to 0·20)	0·015 (0·007 to 0·023)
Côte d'Ivoire	5·5 (2·5 to 12·0)	6·6 (4·3 to 10·1)	1·03 (0·90 to 1·18)	0·04 (0·02 to 0·07)	0·17 (0·13 to 0·21)	0·020 (0·013 to 0·027)
Mali	20·7 (8·7 to 49·1)	20·4 (11·5 to 36·3)	1·00 (0·85 to 1·17)	0·10 (0·06 to 0·13)	0·20 (0·15 to 0·25)	0·016 (0·007 to 0·025)
Niger	33·4 (12·6 to 88·6)	138·3 (47·9 to 399·4)	1·27 (1·00 to 1·61)	0·11 (0·07 to 0·14)	0·17 (0·12 to 0·21)	0·01 (0·001 to 0·019)
Cameroon	5·9 (4·1 to 8·4)	5·5 (4·5 to 6·7)	0·99 (0·94 to 1·05)	0·14 (0·11 to 0·17)	0·35 (0·31 to 0·39)	0·031 (0·024 to 0·038)
DR Congo	8·9 (5·2 to 15·3)	13·8 (8·7 to 21·9)	1·07 (0·96 to 1·19)	0·12 (0·09 to 0·15)	0·17 (0·13 to 0·20)	0·007 (0·000 to 0·014)
Southern and eastern Africa						
Zambia	1·9 (1·5 to 2·5)	1·2 (1·1 to 1·4)	0·93 (0·89 to 0·97)	0·09 (0·05 to 0·13)	0·06 (0·03 to 0·09)	–0·004 (–0·012 to 0·003)
Lesotho	2·7 (1·6 to 4·7)	1·9 (1·6 to 2·2)	0·96 (0·91 to 1·02)	0·05 (0·02 to 0·08)	0·23 (0·17 to 0·29)	0·018 (0·011 to 0·025)
Zimbabwe	4·8 (3·4 to 6·7)	1·2 (1·1 to 1·4)	0·87 (0·83 to 0·90)	0·11 (0·09 to 0·14)	0·07 (0·03 to 0·11)	–0·004 (–0·009 to 0·001)
Rwanda	3·2 (2·3 to 4·3)	0·9 (0·8 to 1·1)	0·88 (0·85 to 0·91)	0·14 (0·10 to 0·18)	–0·02 (-0·07 to 0·02)	–0·017 (–0·024 to –0·011)
Malawi	3·4 (2·1 to 5·5)	1·0 (0·9 to 1·1)	0·90 (0·86 to 0·94)	0·09 (0·05 to 0·13)	0·00 (–0·05 to 0·04)	–0·008 (–0·013 to –0·003)
Tanzania	3·2 (2·3 to 4·6)	1·7 (1·4 to 1·9)	0·92 (0·88 to 0·96)	0·09 (0·06 to 0·12)	0·13 (0·10 to 0·17)	0·005 (–0·001 to 0·011)
Kenya	5·3 (3·4 to 8·3)	2·3 (1·7 to 3·0)	0·86 (0·78 to 0·94)	0·14 (0·10 to 0·18)	0·20 (0·13 to 0·26)	0·011 (–0·003 to 0·024)
Ethiopia	127·6 (56·3 to 289·2)	4·3 (3·7 to 5·1)	0·74 (0·68 to 0·79)	0·16 (0·13 to 0·20)	0·33 (0·30 to 0·37)	0·015 (0·011 to 0·020)
Within-sample mean estimates from random-effects meta-analysis	7·3 (4·1 to 13·1)	3·6 (1·9 to 6·8)	0·91 (0·86 to 0·96)	0·10 (0·08 to 0·12)	0·15 (0·10 to 0·21)	0·007 (0·001 to 0·014)
I^2	91·41%	98·27%	80·72%	79·47%	96·02%	92·69%

Relative index of inequality ratios and slope index of inequality differences are standardised based on the number of years elapsed between both survey rounds. DHS=Demographic and Health Survey.

Table 6: **Relative and absolute wealth-related inequalities in male participants who self-reported HIV testing in the previous 12 months in 16 sub-Saharan African countries**

self-reported HIV testing, although evidence is scant about the probable direction of such a bias.

Our research work relied on data collected up to 2016. Thus, it might not capture the most recent changes in HIV testing patterns in response to UNAIDS' 90-90-90 objective. Another limitation was the heterogeneity noted in the results of the meta-analyses, which prevented us from generalising our results beyond the subset of countries that we included in our analysis (appendix 2 p 24). Further research should be done to identify the drivers of such heterogeneity, and especially to understand the possible interplay between community-level and country-level drivers.

To our knowledge, our study is the first to describe trends in relative and absolute socioeconomic inequalities in the uptake of HIV testing in the previous 12 months across a large number of sub-Saharan African countries in a variety of regional and epidemiological contexts. Furthermore, our analysis was based on large, representative surveys with a high proportion of responses, and the patterns we described were consistent across different measures of socioeconomic inequalities.

In conclusion, this study shows that overall increases in the uptake of HIV testing up to 2016 hid differential progress across socioeconomic groups. Without specific focus on equity, HIV programmes are unlikely to reach every part of the population, and are especially unlikely to reach the poorest and least educated citizens. Persisting socioeconomic inequalities in the uptake of HIV testing could go beyond equity if those least likely to be tested are at greatest risk of HIV infection. Indeed, in some settings, poverty was associated with an increased risk of incident HIV infection.[29,30] Our results show the need to monitor and address socioeconomic inequalities, as well as inequalities related to sex, age, and geography, to ensure an equitable distribution of the benefits and successes in epidemic control of HIV programmes.

Contributors

PAA-T and KJ conceived and planned the study with input from TB and LT. PAA-T collated and processed DHS data. PAA-T and KJ conducted the analysis and produced output figures and tables with input from LT. All authors contributed to the interpretation of the results. PAA-T and KJ wrote the first draft of the report and all authors contributed to subsequent revisions.

Declaration of interests

We declare no competing interests.

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Supplementary appendix 2

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Ante-Testard PA, Benmarhnia T, Bekelynck A, et al. Temporal trends in socioeconomic inequalities in HIV testing: an analysis of cross-sectional surveys from 16 sub-Saharan African countries. *Lancet Glob Health* 2020; **8:** e808–18.

Appendix 2: Supplementary material to "Temporal trends in socioeconomic inequalities in HIV testing: an analysis of cross-sectional surveys in 16 sub-Saharan African countries"

Pearl Anne Ante-Testard, Tarik Benmarhnia, Anne Bekelynck, Rachel Baggaley, Eric Ouattara, Laura Temime, Kévin Jean

Appendix 2A: Standardization formulas for trends indicators

Trends in relative and absolute inequalities were measured using the ratio of the relative index of inequalities (RII ratio) and the difference in the slope index of inequalities (SII difference) between the later and the earlier surveys. To allow a better comparability between countries, these trends indicators were standardized on the number of years elapsed between the earlier and the later surveys, based on the following formulas. In these formulas, σ represents the standard error of the corresponding estimate and n_y represents the number of years elapsed between the earlier and the later country.

Relative index of inequalities

$$RII\ ratio = \exp\left(\frac{\log\left(RII_{post-2008}\right) - \log\left(RII_{pre-2008}\right)}{n_y}\right)$$

$$\sigma_{RII\ ratio} = \sqrt{\left(\sigma^2_{RII_{post-2008}} + \sigma^2_{RII_{pre-2008}}\right)}/n_y$$

Slope index of inequalities

$$SII\ difference = \frac{SII_{post-2008} - SII_{pre-2008}}{n_y}$$

$$\sigma_{SII\ difference} = \sqrt{\left(\sigma^2_{SII_{post-2008}} + \sigma^2_{SII_{pre-2008}}\right)}/n_y$$

Appendix 2B: Descriptive statistics per country and survey year

Supplementary Table 1: Descriptive statistics per country and survey year, overall adult population

West-Central Africa	Sierra Leone		Guinea		Liberia		Côte d'Ivoire		Mali		Niger		Cameroon		Congo DR	
Survey Year	**2008**	**2013**	**2005**	**2012**	**2007**	**2013**	**2005**	**2011-12**	**2006**	**2012-13**	**2006**	**2012**	**2004**	**2011**	**2007**	**2013-14**
***Household response rate (%)**	98	99.3	99	99.5	97	99	96	98	99	98	98	98	98	99	99	99.9
Sample size (n)	10,654	23,920	11,128	12,924	13,101	13,357	9,686	15,195	18,790	14,823	12,772	15,088	15,936	22,617	14,752	27,483
Living in rural area (%)	63.6	63.9	66.8	62.8	58.6	39.8	52.8	49.0	65.7	75.1	78.7	79.7	44.4	45.8	55.4	62.0
Age (%): *15-24 years*	31.1	37.8	35.5	38.8	37.2	39.7	43.3	37.6	38.8	33.8	35.1	32.6	44.6	42.2	41.8	39.7
25-34 years	32.9	29.1	26.9	28.6	29.0	30.4	31.2	32.5	29.6	32.5	31.7	33.8	28.4	28.9	28.6	30.7
≥ 35 years	36.0	33.1	37.6	32.6	33.8	29.9	25.4	29.9	31.6	33.7	33.3	33.6	26.9	29.0	29.6	29.6
Family situation (%): *Living in union*	71.4	62.9	73.4	68.1	60.7	56.9	52.2	59.3	80.4	79.6	80.7	83.7	61.8	59.3	63.1	62.4
Single	23.4	31.7	22.2	28.6	31.5	34.6	40.4	34.3	16.2	18.9	15.9	13.3	29.3	33.3	28.8	29.6
Widowed/ separated	5.3	5.4	4.4	3.3	7.8	8.5	7.4	6.4	3.4	1.5	3.5	3.0	8.9	7.4	8.0	8.0
Wealth index (%): *Poorest*	18.9	18.5	19.7	17.6	17.7	17.4	16.9	18.1	18.3	18.9	17.5	17.2	17.3	16.0	17.8	18.1
Poorer	18.5	18.3	18.4	19.3	19.2	17.8	18.5	17.0	19.1	18.6	19.0	18.5	16.7	17.4	19.3	19.0
Middle	19.0	18.7	18.9	18.6	19.3	18.8	19.3	18.1	18.4	19.1	19.6	19.6	19.1	18.8	21.4	19.3
Richer	20.0	19.7	19.8	20.7	20.9	21.8	21.1	21.2	19.9	20.1	20.5	20.5	21.9	22.6	18.9	19.8
Richest	23.6	24.7	23.3	23.8	22.9	24.2	24.2	25.6	24.3	23.4	23.4	24.2	25.0	25.2	22.6	23.9
HIV prevalence (%)	1.4	1.5	1.5	1.8	1.6	2.1	4.6	3.9	1.3	1.1	0.7	0.4	5.2	4.3	1.3	1.1
Recent uptake of HIV testing (%)	5.2	14.7	1.9	5.0	2.4	19.1	4.7	13.5	3.4	6.8	1.3	6.9	6.2	14.6	4.6	8.6
Eastern-Southern Africa	**Zambia**		**Lesotho**		**Zimbabwe**		**Rwanda**		**Malawi**		**Tanzania**		**Kenya**		**Ethiopia**	
Survey Year	**2007**	**2013-14**	**2004**	**2014**	**2005-06**	**2015**	**2005**	**2014-15**	**2004**	**2015-16**	**2003-04**	**2011-12**	**2003**	**2008-09**	**2005**	**2016**
***Household response rate (%)**	98	98	95	99	95	99	99.7	99.9	98	99	99	98	96	98	99	98
Sample size (n)	13,646	31,184	9,892	9,552	16,082	18,351	16,141	19,714	14,959	32,040	12,522	19,319	11,773	11,909	20,103	28,371
Living in rural area (%)	57.4	53.9	76.9	64.3	60.2	62.6	82.9	80.4	81.6	81.7	69.4	73.6	74.8	74.4	83.0	78.9
Age (%): *15-24 years*	39.8	39.5	44.7	42.1	46.4	40.1	43.3	38.0	43.4	42.6	41.8	40.6	43.2	41.0	40.8	37.4
25-34 years	31.9	29.4	25.7	29.3	28.9	30.2	26.9	32.1	31.8	29.9	32.1	28.9	28.8	30.3	28.9	31.4
≥ 35 years	28.4	31.2	29.6	28.7	24.7	29.7	29.8	29.9	24.8	27.5	26.1	30.5	28.0	28.7	30.2	31.2
Family situation (%): *Living in union*	58.8	57.7	49.5	50.1	53.2	57.1	49.6	52.5	69.5	63.9	58.8	58.7	57.2	56.3	62.1	62.4
Single	32.3	33.9	38.3	38.7	36.1	33.4	40.0	39.6	20.4	25.1	32.2	32.8	34.4	34.9	29.5	31.5
Widowed/ separated	8.8	8.4	12.1	11.2	10.6	9.5	10.4	7.9	10.1	11.0	9.0	8.5	8.3	8.8	8.3	6.2
Wealth index (%): *Poorest*	18.0	16.3	14.7	14.4	16.5	16.2	20.4	17.6	16.4	18.5	16.9	16.7	16.2	15.9	17.5	16.4
Poorer	16.4	17.8	18.3	16.4	16.7	17.5	19.9	19.0	19.5	19.0	18.5	18.1	17.7	17.5	19.0	18.1
Middle	18.1	18.8	18.4	19.3	17.3	18.4	19.1	19.5	20.6	19.1	18.7	18.5	18.3	18.7	19.0	19.1
Richer	22.3	22.1	22.4	23.7	24.7	23.0	19.4	20.5	20.5	19.4	20.2	20.7	21.3	21.1	19.1	20.5
Richest	25.2	24.9	26.2	26.2	24.8	24.9	21.2	23.4	23.0	24.0	25.8	26.0	26.5	26.8	25.3	25.9
HIV prevalence (%)	14.2	13.4	23.0	25.0	18.3	14.2	3.0	3.1	12.3	9.2	6.9	5.2	6.9	6.5	1.3	0.9
Recent uptake of HIV testing (%)	17.0	43.5	7.4	52.6	7.9	43.6	12.5	38.8	7.6	43.9	7.0	30.4	7.8	28.4	3.2	20.6

*Based on each country's USAID DHS Final Report

Appendix 2C: Bivariate and multivariate analysis of recent (<12 months) HIV testing.

Supplementary Table 1: Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	Sierra Leone								Guinea							
Survey Year	2008				2013				2005				2012			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	9.4	ref.	7.2	ref.	20.8	ref.	11.1	ref.	3.0	ref.	6.2	ref.	10.5	ref.	8.6	ref.
Rural	3.0	0.34 [0.26;0.45]	3.1	0.50 [0.33;0.75]	15.7	0.75 [0.68;0.84]	6.5	0.57 [0.45;0.72]	0.5	0.16 [0.09;0.27]	1.4	0.18 [0.11;0.31]	1.8	0.15 [0.11; 0.21]	2.9	0.29 [0.20;0.42]
Age *15-24 years*	5.7	ref.	2.3	ref.	17.3	ref.	6.9	ref.	1.6	ref.	2.3	ref.	4.8	ref.	3.4	ref.
25-34 years	6.9	1.35 [1.11;1.64]	6.5	3.19 [1.69;6.03]	22.8	1.30 [1.20;1.40]	8.4	1.37 [1.11;1.70]	1.4	1.00 [0.65;1.56]	5.2	2.78 [1.41;5.46]	6.3	1.39 [1.11; 1.75]	8.0	2.42 [1.65;3.55]
≥ 35 years	3.2	0.65 [0.50;0.84]	5.4	2.67 [1.48;4.83]	12.6	0.74 [0.67;0.81]	9.2	1.38 [1.13;1.70]	0.8	0.60 [0.35;1.02]	3.1	1.64 [0.92;2.92]	3.7	0.80 [0.62; 1.04]	4.9	1.67 [1.10;2.54]
Family situation *Living in union*	5.0	ref.	5.9	ref.	19.5	ref.	8.7	ref.	1.0	ref.	3.7	ref.	4.6	ref.	5.0	ref.
Single	7.1	0.93 [0.71;1.21]	2.9	0.53 [0.34;0.83]	14.1	0.65 [0.59;0.71]	7.4	0.74 [0.62;0.89]	2.0	1.36 [0.77;2.37]	2.4	0.62 [0.38;1.01]	5.9	0.77 [0.56; 1.04]	5.1	0.79 [0.57;1.09]
Widowed/ separated	3.3	0.66 [0.41;1.06]	2.8	0.68 [0.25;1.84]	13.3	0.62 [0.52;0.74]	9.2	0.85 [0.56;1.27]	4.3	3.15 [1.62;6.12]	4.2	1.25 [0.55;2.85]	4.7	0.75 [0.41; 1.36]	9.4	1.83 [0.86;3.92]
Wealth Index *Poorest*	1.7	ref.	1.2	ref.	16.6	ref.	5.0	ref.	0.2	ref.	1.1	ref.	0.6	ref.	1.6	ref.
Poorer	3.5	1.81 [1.19;2.77]	4.4	3.37 [1.45;7.82]	13.6	0.84 [0.73;0.96]	6.5	1.39 [1.04;1.85]	0.3	1.59 [0.39;6.58]	1.2	1.20 [0.34;4.29]	1.2	1.32 [0.74; 2.35]	2.9	1.47 [0.70;3.11]
Middle	3.2	2.52 [1.58;4.01]	3.6	2.46 [1.02;5.94]	16.2	0.92 [0.81;1.04]	7.5	1.38 [0.96;1.99]	0.3	0.97 [0.20;4.71]	1.3	1.77 [0.56;5.59]	2.2	2.06 [1.16; 3.65]	3.2	1.29 [0.59;2.82]
Richer	6.0	3.39 [2.18;5.27]	4.0	2.57 [0.99;6.66]	17.3	1.00 [0.89;1.13]	8.4	1.71 [1.21;2.41]	1.8	6.43 [1.96;21.12]	3.2	4.05 [1.49;11.02]	5.5	5.73 [3.37; 9.76]	6.4	3.07 [1.64;5.75]
Richest	10.9	4.97 [3.15;7.84]	8.4	6.06 [2.50;14.66]	22.6	1.24 [1.09;1.40]	12.1	2.23 [1.60;3.10]	3.5	17.14 [5.49; 53.59]	7.0	9.15 [3.49;23.98]	13.0	13.48 [8.09; 22.44]	9.6	5.12 [2.72;9.64]
Educational level *None*	2.8	ref.	2.0	ref.	15.3	ref.	6.0	ref.	0.4	ref.	1.7	ref.	2.4	ref.	2.2	ref.
Primary	6.5	1.77 [1.29;2.42]	4.6	1.84 [0.93;3.63]	19.6	1.20 [1.08;1.33]	6.3	1.04 [0.78;1.38]	3.0	6.50 [3.52; 12.00]	2.0	1.16 [0.58;2.29]	5.6	1.82 [1.34; 2.48]	3.9	1.58 [0.96;2.61]
Secondary/higher	12.4	2.91 [2.28;3.72]	7.9	3.62 [2.21;5.94]	20.7	1.22 [1.12;1.33]	10.9	1.60 [1.32;1.94]	5.4	11.39 [6.32; 20.50]	6.3	3.58 [2.24;5.73]	13.1	3.32 [2.53; 4.36]	8.9	3.40 [2.22;5.19]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	Liberia								Côte d'Ivoire							
Survey Year	2007				2013				2005				2011-12			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	3.3	ref.	4.6	ref.	21.8	ref.	16.9	ref.	6.1	ref.	5.9	ref.	20.0	ref.	14.1	ref.
Rural	1.1	0.30 [0.19;0.48]	1.5	0.26 [0.16; 0.43]	21.2	0.89 [0.80;0.99]	9.2	0.54 [0.45;0.65]	3.6	0.43 [0.29;0.64]	3.1	0.42 [0.28;0.64]	10.5	0.54 [0.47;0.62]	5.7	0.53 [0.42; 0.66]
Age *15-24 years*	2.3	ref.	2.2	ref.	20.4	ref.	7.1	ref.	3.8	ref.	2.9	ref.	14.7	ref.	8.2	ref.
25-34 years	2.2	1.00 [0.69;1.44]	3.5	1.86 [1.16; 2.99]	27.9	1.30 [1.19;1.42]	18.5	2.70 [2.13;3.42]	6.9	1.46 [1.01;2.11]	7.4	2.06 [1.29;3.28]	19.4	1.40 [1.26;1.56]	10.9	1.49 [1.17;1.90]
≥ 35 years	1.6	0.82 [0.53;1.25]	2.9	1.66 [1.09; 2.53]	16.6	0.71 [0.63;0.79]	17.2	2.37 [1.88;2.99]	4.1	0.69 [0.44;1.10]	3.4	1.16 [0.68;1.99]	11.1	0.80 [0.70;0.91]	10.7	1.34 [1.05;1.70]
Family situation *Living in union*	1.8	ref.	3.2	ref.	24.5	ref.	17.0	ref.	5.5	ref.	3.4	ref.	16.2	ref.	10.2	ref.
Single	2.4	1.18 [0.76;1.83]	2.0	0.59 [0.39; 0.90]	16.9	0.71 [0.64;0.78]	8.8	0.44 [0.36;0.53]	3.9	0.77 [0.52;1.15]	4.6	1.30 [0.87;1.96]	14.0	0.72 [0.64;0.80]	9.0	0.80 [0.65;0.98]
Widowed/ separated	2.8	1.50 [0.89;2.53]	4.4	1.56 [0.93; 2.64]	19.3	0.85 [0.73;0.98]	22.0	1.02 [0.71;1.47]	4.3	0.83 [0.38;1.82]	10.8	1.35 [0.56;3.22]	14.2	0.73 [0.59;0.91]	15.0	1.17 [0.78;1.76]
Wealth Index *Poorest*	0.5	ref.	0.8	ref.	19.4	ref.	8.5	ref.	2.6	ref.	2.1	ref.	7.6	ref.	4.2	ref.
Poorer	0.8	1.64 [0.79;3.41]	1.1	1.22 [0.50; 2.96]	20.2	1.02 [0.91;1.16]	8.4	1.18 [0.89;1.57]	1.3	0.83 [0.41;1.70]	1.8	0.60 [0.27;1.35]	9.6	1.25 [1.01;1.53]	7.1	1.39 [0.95;2.03]
Middle	2.2	3.22 [1.53;6.81]	2.0	2.61 [1.17; 5.79]	25.6	1.18 [1.04;1.34]	13.0	1.66 [1.26;2.21]	4.9	2.07 [1.10;3.90]	4.8	1.41 [0.71;2.78]	11.9	1.57 [1.27;1.95]	5.2	1.43 [0.99;2.08]
Richer	3.3	3.65 [1.73;7.67]	4.3	4.86 [2.30; 10.29]	21.4	1.12 [0.96;1.30]	18.9	2.47 [1.87;3.26]	5.2	2.56 [1.42;4.63]	4.4	1.67 [0.82;3.40]	20.7	2.22 [1.78;2.76]	11.1	2.33 [1.64;3.32]
Richest	2.9	3.79 [1.77;8.13]	4.9	5.95 [2.85; 12.45]	21.0	1.08 [0.92;1.26]	17.5	2.37 [1.79;3.14]	8.0	3.25 [1.79;5.89]	7.6	2.57 [1.40;4.72]	22.5	2.64 [2.14;3.25]	18.7	3.90 [2.75;5.51]
Educational level *None*	0.6	ref.	0.5	ref.	19.1	ref.	7.3	ref.	2.5	ref.	2.8	ref.	11.3	ref.	4.2	ref.
Primary	2.0	2.28 [1.36;3.80]	1.3	1.38 [0.63; 3.00]	19.9	1.16 [1.06;1.27]	6.4	0.97 [0.68;1.38]	5.5	1.64 [1.11;2.42]	2.6	1.00 [0.53;1.87]	16.0	1.41 [1.25;1.60]	7.9	1.65 [1.24;2.19]
Secondary/higher	4.7	5.99 [3.63;9.87]	4.4	5.58 [2.85; 10.93]	25.4	1.51 [1.36;1.67]	18.8	2.42 [1.76;3.33]	9.3	3.06 [2.01;4.65]	6.7	2.31 [1.46;3.66]	24.7	1.84 [1.61;2.10]	16.8	3.31 [2.60;4.21]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	Mali								Niger							
Survey Year	2006				2012-13				2005				2012			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	7.4	ref.	6.6	ref.	17.3	ref.	14.4	ref.	4.3	ref.	6.3	ref.	20.7	ref.	8.9	ref.
Rural	1.4	0.15 [0.11;0.20]	1.7	0.25 [0.16;0.37]	3.5	0.19 [0.15;0.23]	3.9	0.27 [0.20;0.36]	0.2	0.04 [0.02;0.08]	0.5	0.12 [0.06;0.24]	5.6	0.29 [0.25;0.34]	0.7	0.10 [0.06;0.17]
Age *15-24 years*	4.2	ref.	3.5	ref.	6.8	ref.	3.9	ref.	1.2	ref.	1.7	ref.	8.1	ref.	2.3	ref.
25-34 years	4.1	1.18 [0.96;1.46]	4.2	1.29 [0.81;2.06]	8.6	1.55 [1.33;1.82]	9.3	2.58 [1.77;3.78]	1.0	1.43 [0.94;2.17]	2.9	2.45 [1.35;4.46]	10.2	1.44 [1.25;1.65]	4.0	2.06 [1.22;3.46]
≥ 35 years	1.7	0.55 [0.42;0.72]	3.1	1.04 [0.68;1.60]	5.0	0.93 [0.76;1.14]	6.7	1.97 [1.40;2.78]	0.7	0.91 [0.56;1.49]	1.8	1.83 [1.02;3.28]	6.6	0.84 [0.71;1.00]	2.3	1.38 [0.83;2.30]
Family situation *Living in union*	3.5	ref.	3.7	ref.	6.8	ref.	6.8	ref.	0.8	ref.	1.5	ref.	8.8	ref.	2.5	ref.
Single	3.1	0.42 [0.25;0.69]	2.7	0.67 [0.43;1.04]	7.6	0.51 [0.34;0.78]	5.9	0.71 [0.54;0.94]	2.1	0.50 [0.19;1.32]	3.0	1.06 [0.65;1.72]	4.3	0.24 [0.14;0.42]	3.3	0.91 [0.58;1.42]
Widowed/ separated	3.2	0.61 [0.30;1.26]	5.0	1.12 [0.48;2.62]	6.4	0.45 [0.19;1.08]	7.7	1.31 [0.38;4.46]	1.4	0.45 [0.12;1.71]	6.0	2.27 [0.92;5.57]	9.2	0.71 [0.50;0.99]	3.6	2.13 [0.76;5.95]
Wealth Index *Poorest*	1.0	ref.	1.1	ref.	1.9	ref.	1.7	ref.	0	ref.	0.5	ref.	3.1	ref.	0.2	ref.
Poorer	1.0	1.04 [0.61;1.78]	1.4	1.23 [0.47;3.18]	1.4	0.66 [0.42;1.04]	2.9	1.82 [0.89;3.70]	0.1	1.67 [0.40;7.05]	0.3	0.99 [0.17;5.93]	4.3	1.40 [1.01;1.95]	0.5	4.32 [0.57;32.54]
Middle	1.2	0.95 [0.57;1.60]	2.4	2.16 [0.99;4.73]	2.7	1.25 [0.83;1.87]	2.9	1.66 [0.83;3.29]	0.1	2.08 [0.48;9.06]	0.3	1.17 [0.21;6.42]	5.7	1.62 [1.22;2.15]	0.4	1.47 [0.14;15.80]
Richer	3.3	2.77 [1.75;4.39]	2.7	3.19 [1.35;7.50]	8.3	3.30 [2.26;4.81]	6.9	3.63 [1.96;6.72]	0.5	7.11 [2.21;22.87]	1.0	3.70 [0.75;18.13]	7.6	2.40 [1.80;3.21]	1.6	9.44 [1.37;64.89]
Richest	9.2	7.95 [5.19;12.17]	7.5	7.46 [3.39;16.38]	17.8	6.57 [4.61;9.38]	15.7	8.43 [4.71;15.08]	3.9	31.39 [10.06;97.93]	6.0	10.59 [2.61;42.87]	19.2	4.75 [3.58;6.30]	7.8	36.37 [5.74;230.54]
Educational level *None*	2.0	ref.	1.5	ref.	4.4	ref.	3.1	ref.	0.6	ref.	1.0	ref.	6.7	ref.	1.0	ref.
Primary	5.9	2.03 [1.51;2.73]	3.4	1.86 [1.11;3.12]	9.0	1.39 [1.04;1.85]	6.6	2.44 [1.70;3.51]	2.2	1.40 [0.75;2.62]	2.4	2.40 [1.45;3.97]	13.7	1.55 [1.32;1.82]	3.0	2.54 [1.44;4.48]
Secondary/higher	11.3	3.89 [2.94;5.15]	8.7	4.72 [3.04;7.35]	18.7	2.39 [1.88;3.03]	15.3	4.23 [3.28;5.46]	5.0	1.61 [0.69;3.75]	6.5	4.21 [2.39;7.39]	18.0	1.63 [1.34;1.99]	8.7	7.16 [4.53;11.30]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	Zambia								Lesotho							
Survey Year	**2007**				**2013-14**				**2004**				**2014**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	%	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**	**%**	**PR [95% CI]**
Area of residence *Urban*	26.0	ref.	14.4	ref.	48.9	ref.	40.5	ref.	9.5	ref.	7.5	ref.	58.0	ref.	47.2	ref.
Rural	16.8	0.66 [0.58 ;0.75]	11.7	0.74 [0.63;0.87]	46.4	0.91 [0.87;0.96]	37.9	0.89 [0.84;0.93]	7.5	0.78 [0.66;0.92]	5.3	0.82 [0.58;1.15]	59.7	1.08 [1.02;1.13]	33.1	0.70 [0.63;0.77]
Age *15-24 years*	19.0	ref.	11.0	ref.	43.8	ref.	31.0	ref.	6.7	ref.	2.7	ref.	54.8	ref.	29.6	ref.
25-34 years	24.3	1.21 [1.09;1.35]	15.5	1.48 [1.29;1.71]	56.1	1.30 [1.25;1.35]	49.4	1.61 [1.53;1.70]	10.3	1.52 [1.25;1.84]	8.6	2.94 [1.84;4.68]	67.7	1.25 [1.19;1.31]	46.1	1.49 [1.31;1.68]
≥ 35 years	18.4	0.97 [0.86;1.10]	12.7	1.19 [1.01;1.40]	43.1	1.01 [0.97;1.06]	40.3	1.32 [1.25;1.39]	7.7	1.14 [0.92;1.43]	8.1	2.56 [1.66;3.94]	55.8	1.03 [0.98;1.09]	42.5	1.46 [1.30;1.65]
Family situation *Living in union*	22.7	ref.	13.7	ref.	53.5	ref.	46.0	ref.	9.4	ref.	8.1	ref.	67.7	ref.	47.2	ref.
Single	15.5	0.65 [0.57;0.73]	11.5	0.79 [0.68;0.92]	34.7	0.64 [0.61;0.68]	29.6	0.63 [0.60;0.67]	5.2	0.64 [0.53;0.77]	3.7	0.47 [0.33;0.67]	44.2	0.64 [0.60;0.68]	30.1	0.61 [0.56;0.68]
Widowed/ separated	21.6	0.85 [0.74;0.99]	14.9	1.16 [0.90;1.48]	47.9	0.88 [0.83;0.92]	39.9	0.87 [0.79;0.95]	9.5	0.99 [0.78;1.25]	5.4	0.86 [0.47;1.57]	60.9	0.88 [0.83;0.93]	41.4	0.87 [0.74;1.03]
Wealth Index *Poorest*	14.4	ref.	10.1	ref.	43.2	ref.	36.3	ref.	6.5	ref.	4.2	ref.	61.0	ref.	26.1	ref.
Poorer	15.6	1.11 [0.93;1.33]	10.6	1.05 [0.83;1.34]	49.0	1.09 [1.02;1.16]	38.2	1.03 [0.96;1.11]	7.5	1.12 [0.82;1.52]	4.6	1.32 [0.68;2.55]	62.6	1.01 [0.95;1.08]	34.8	1.33 [1.10;1.61]
Middle	18.2	1.24 [1.03;1.51]	13.5	1.30 [1.03;1.64]	48.4	1.08 [1.01;1.15]	39.0	1.07 [1.00;1.16]	7.2	1.13 [0.83;1.52]	4.6	1.25 [0.66;2.37]	60.4	0.98 [0.91;1.04]	36.1	1.32 [1.10;1.59]
Richer	26.9	1.63 [1.36;1.97]	13.0	1.38 [1.08;1.76]	51.1	1.13 [1.06;1.20]	40.3	1.16 [1.07;1.24]	8.3	1.26 [0.93;1.71]	7.0	1.91 [1.07;3.41]	59.7	0.96 [0.89;1.02]	40.2	1.52 [1.27;1.83]
Richest	25.0	1.58 [1.30;1.93]	15.6	1.58 [1.25;2.00]	45.8	1.05 [0.98;1.13]	40.5	1.12 [1.04;1.21]	9.1	1.33 [1.00;1.77]	7.7	2.03 [1.17;3.55]	54.4	0.89 [0.83;0.95]	46.5	1.77 [1.48;2.11]
Educational level *None*	16.5	ref.	8.3	ref.	42.7	ref.	33.9	ref.	6.5	ref.	3.9	ref.	37.8	ref.	33.7	ref.
Primary	18.5	1.12 [0.94;1.34]	9.8	1.09 [0.75;1.56]	46.5	1.08 [1.01;1.15]	35.1	1.02 [0.90;1.16]	7.0	1.22 [0.57;2.58]	5.0	1.28 [0.71;2.28]	60.3	1.58 [1.17;2.14]	32.4	0.91 [0.77;1.08]
Secondary/higher	25.3	1.44 [1.20;1.74]	16.2	1.82 [1.26;2.62]	49.6	1.17 [1.09;1.25]	42.3	1.24 [1.09;1.41]	9.4	1.70 [0.80;3.62]	8.4	2.28 [1.29;4.04]	58.6	1.56 [1.16;2.11]	44.3	1.24 [1.05;1.46]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	Zimbabwe								Rwanda							
Survey Year	2005-06				2015				2005				2014-15			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	*12.1*	ref.	11.1	ref.	47.3	ref.	38.4	ref.	25.0	ref.	21.7	ref.	43.7	ref.	40.6	ref.
Rural	*5.8*	0.46 [0.38; 0.56]	5.0	0.43 [0.35;0.52]	50.6	1.04 [0.99;1.09]	35.8	0.90 [0.84;0.96]	10.4	0.43 [0.37; 0.49]	9.6	0.45 [0.38; 0.54]	38.8	0.90 [0.85; 0.95]	36.0	0.92 [0.85;1.00]
Age *15-24 years*	*8.6*	ref.	6.3	ref.	42.5	ref.	27.5	ref.	11.5	ref.	9.0	ref.	38.3	ref.	32.7	ref.
25-34 years	*9.5*	1.09 [0.93; 1.28]	9.7	1.46 [1.20;1.78]	59.2	1.35 [1.29;1.42]	47.7	1.67 [1.55;1.80]	18.0	1.63 [1.47; 1.81]	17.2	1.91 [1.59; 2.30]	46.0	1.21 [1.15; 1.27]	45.2	1.34 [1.24;1.46]
≥ 35 years	*6.4*	0.77 [0.64; 0.92]	7.2	1.16 [0.94;1.44]	47.2	1.10 [1.04;1.16]	39.4	1.43 [1.32;1.54]	10.0	0.96 [0.85; 1.09]	11.2	1.28 [1.04; 1.57]	34.4	0.91 [0.86; 0.97]	34.0	1.03 [0.95;1.12]
Family situation *Living in union*	*8.7*	ref.	7.7	ref.	57.1	ref.	44.8	ref.	15.9	ref.	12.6	ref.	44.3	ref.	40.5	ref.
Single	*7.6*	0.84 [0.70; 1.01]	7.0	0.89 [0.75;1.07]	27.4	0.51 [0.47;0.55]	26.2	0.60 [0.56;0.64]	9.1	0.50 [0.44; 0.57]	10.4	0.77 [0.65; 0.92]	33.9	0.77 [0.73; 0.80]	32.2	0.80 [0.75;0.86]
Widowed/ separated	*8.3*	0.91 [0.74; 1.12]	10.2	1.37 [0.97;1.94]	55.0	0.94 [0.89;0.99]	45.0	1.02 [0.91;1.14]	12.8	0.76 [0.66; 0.89]	15.9	1.14 [0.78; 1.67]	38.2	0.86 [0.80; 0.93]	43.0	1.01 [0.83;1.23]
Wealth Index *Poorest*	*4.0*	ref.	3.4	ref.	49.1	ref.	33.7	ref.	9.1	ref.	8.6	ref.	39.3	ref.	39.5	ref.
Poorer	*4.8*	1.35 [0.94; 1.93]	5.1	1.67 [1.15;2.43]	49.7	1.02 [0.95;1.09]	37.0	1.09 [0.98;1.20]	9.8	1.06 [0.91; 1.23]	7.3	0.82 [0.62; 1.08]	38.8	0.99 [0.92; 1.06]	37.8	0.93 [0.83;1.04]
Middle	*6.3*	1.91 [1.38; 2.63]	6.3	2.06 [1.40;3.05]	51.0	1.05 [0.98;1.13]	35.8	1.11 [0.99;1.23]	12.0	1.24 [1.07; 1.44]	10.2	1.11 [0.84; 1.46]	39.3	1.00 [0.94; 1.08]	35.9	0.93 [0.84;1.04]
Richer	*9.8*	2.92 [2.15; 3.98]	8.2	2.52 [1.74;3.66]	52.4	1.09 [1.01;1.17]	37.7	1.18 [1.07;1.31]	13.9	1.45 [1.26; 1.67]	11.3	1.26 [0.97; 1.64]	38.6	0.97 [0.91; 1.05]	35.4	0.91 [0.82;1.01]
Richest	*13.5*	4.01 [2.97; 5.41]	11.8	3.92 [2.73;5.62]	45.1	0.94 [0.88;1.01]	38.3	1.19 [1.08;1.32]	19.9	1.57 [1.33; 1.84]	19.5	2.01 [1.57; 2.58]	42.2	1.05 [0.98; 1.13]	37.1	0.92 [0.83;1.03]
Educational level *None*	*3.0*	ref.	1.9	ref.	38.8	ref.	32.7	ref.	10.6	ref.	8.6	ref.	34.5	ref.	33.2	ref.
Primary	*4.4*	1.19 [0.71; 2.01]	3.4	1.46 [0.51;4.14]	47.6	1.25 [0.97;1.62]	30.9	0.89 [0.61;1.29]	12.5	1.08 [0.96; 1.22]	10.4	1.21 [0.95; 1.54]	38.7	1.10 [1.02; 1.18]	35.9	1.08 [0.96;1.21]
Secondary/higher	*10.7*	2.69 [1.63; 4.44]	9.1	3.19 [1.14;8.88]	50.1	1.34 [1.04;1.72]	38.6	1.14 [0.79;1.63]	21.6	1.55 [1.30; 1.84]	23.6	2.53 [1.91; 3.36]	45.2	1.27 [1.17; 1.38]	41.5	1.22 [1.08;1.38]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	Malawi								Tanzania							
Survey Year	2004				2015-16				2003-04				2011-12			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	11.5	ref.	14.3	ref.	49.4	ref.	44.3	ref.	11.6	ref.	12.6	ref.	39.7	ref.	33.4	ref.
Rural	6.6	0.58 [0.46;0.72]	6.4	0.44 [0.32;0.60]	43.3	0.97 [0.93;1.02]	41.8	0.95 [0.89;1.02]	3.3	0.31 [0.24;0.41]	6.6	0.55 [0.44;0.68]	29.9	0.79 [0.73;0.85]	25.7	0.74 [0.68;0.81]
Age *15-24 years*	8.7	ref.	7.4	ref.	42.7	ref.	34.6	ref.	6.1	ref.	6.8	ref.	31.0	ref.	21.6	ref.
25-34 years	8.0	0.95 [0.82;1.10]	9.4	1.26 [0.90;1.76]	50.4	1.17 [1.13;1.21]	53.5	1.51 [1.42;1.61]	6.5	1.12 [0.89;1.40]	9.8	1.55 [1.23;1.96]	39.2	1.28 [1.20;1.37]	32.8	1.76 [1.60;1.93]
≥ 35 years	4.5	0.61 [0.50;0.75]	7.1	1.05 [0.76;1.45]	40.3	0.94 [0.91;0.98]	43.5	1.25 [1.18;1.34]	4.2	0.77 [0.59;1.01]	9.3	1.49 [1.18;1.88]	27.6	0.87 [0.81;0.93]	31.6	1.60 [1.45;1.75]
Family situation *Living in union*	8.0	ref.	7.9	ref.	49.8	ref.	50.3	ref.	5.1	ref.	9.4	ref.	35.2	ref.	33.2	ref.
Single	5.7	0.70 [0.56;0.87]	8.3	0.97 [0.73;1.30]	27.9	0.56 [0.54;0.59]	29.6	0.61 [0.57;0.65]	6.5	1.09 [0.84;1.41]	7.0	0.66 [0.54;0.82]	25.0	0.59 [0.55;0.65]	20.7	0.56 [0.51;0.61]
Widowed/ separated	7.1	0.92 [0.75;1.14]	7.3	1.00 [0.52;1.93]	44.1	0.88 [0.85;0.92]	48.4	0.90 [0.79;1.03]	7.5	1.30 [0.96;1.77]	8.9	0.94 [0.64;1.39]	34.5	0.89 [0.81;0.97]	28.6	0.84 [0.70;1.00]
Wealth Index *Poorest*	5.4	ref.	5.9	ref.	42.6	ref.	40.4	ref.	1.7	ref.	4.8	ref.	23.9	ref.	21.2	ref.
Poorer	5.7	1.14 [0.89;1.46]	4.4	0.83 [0.48;1.44]	43.9	1.01 [0.96;1.05]	43.4	1.06 [0.96;1.17]	2.1	1.29 [0.72;2.34]	5.5	1.10 [0.77;1.58]	29.9	1.12 [1.01;1.25]	24.9	1.16 [1.00;1.34]
Middle	5.9	1.18 [0.92;1.51]	7.7	1.36 [0.83;2.23]	42.3	0.97 [0.93;1.02]	40.5	0.99 [0.90;1.09]	3.3	1.90 [1.12;3.21]	7.3	1.42 [1.01;2.00]	31.2	1.14 [1.03;1.27]	26.3	1.18 [1.03;1.35]
Richer	7.1	1.34 [1.06;1.70]	5.3	1.04 [0.64;1.70]	45.4	1.01 [0.96;1.06]	43.5	1.03 [0.94;1.13]	6.5	3.27 [1.95;5.49]	9.1	1.68 [1.20;2.36]	36.2	1.24 [1.12;1.38]	28.5	1.30 [1.13;1.50]
Richest	12.3	2.08 [1.62;2.68]	14.7	2.73 [1.70;4.39]	47.3	1.00 [0.96;1.05]	43.0	1.02 [0.93;1.12]	12.5	5.67 [3.40;9.45]	13.0	2.35 [1.68;3.31]	37.8	1.35 [1.21;1.49]	34.2	1.57 [1.37;1.80]
Educational level *None*	4.8	ref.	4.9	ref.	39.1	ref.	37.4	ref.	1.8	ref.	3.9	ref.	24.0	ref.	19.2	ref.
Primary	6.9	1.28 [1.05;1.55]	5.9	1.53 [0.87;2.67]	43.4	1.09 [1.04;1.14]	39.6	1.07 [0.94;1.22]	5.9	2.37 [1.68;3.34]	8.3	1.91 [1.31;2.79]	33.4	1.22 [1.13;1.33]	27.5	1.28 [1.11;1.49]
Secondary/higher	13.7	2.33 [1.86;2.94]	14.2	3.74 [2.18;6.41]	49.4	1.19 [1.13;1.25]	47.6	1.27 [1.12;1.45]	14.7	5.03 [3.20;7.89]	13.5	2.92 [1.86;4.56]	37.8	1.28 [1.16;1.41]	31.7	1.35 [1.15;1.58]

Supplementary Table 1 (followed): Proportion of recent (<12 months) HIV testing across various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	Kenya								Ethiopia							
Survey Year	2003				2008-09				2005				2016			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]	%	PR [95% CI]
Area of residence *Urban*	12.4	ref.	26.9	ref.	38.6	ref.	26.9	ref.	16.4	ref.	8.8	ref.	37.2	ref.	34.8	ref.
Rural	6.1	0.49 [0.41; 0.59]	22.1	0.69 [0.59;0.80]	27.8	0.75 [0.68;0.83]	22.1	0.69 [0.59;0.80]	1.2	0.07 [0.05; 0.09]	1.3	0.13 [0.09; 0.18]	16.7	0.43 [0.39; 0.47]	16.0	0.46 [0.42; 0.51]
Age *15-24 years*	7.4	ref.	19.8	ref.	29.4	ref.	19.8	ref.	5.7	ref.	3.1	ref.	19.4	ref.	15.6	ref.
25-34 years	10.6	1.49 [1.26; 1.76]	30.0	1.43 [1.25;1.65]	39.7	1.31 [1.23;1.40]	30.0	1.43 [1.25;1.65]	3.4	0.98 [0.76; 1.25]	3.2	1.31 [0.96; 1.80]	25.4	1.33 [1.25; 1.42]	27.1	1.61 [1.48; 1.75]
≥ 35 years	4.8	0.79 [0.64; 0.97]	22.1	1.09 [0.94;1.26]	21.8	0.81 [0.74;0.89]	22.1	1.09 [0.94;1.26]	2.2	0.66 [0.49; 0.89]	1.2	0.64 [0.45; 0.91]	18.7	1.00 [0.92; 1.07]	17.9	1.14 [1.05; 1.23]
Family situation *Living in union*	8.1	ref.	25.3	ref.	34.5	ref.	25.3	ref.	2.2	ref.	1.6	ref.	23.3	ref.	20.8	ref.
Single	6.3	0.74 [0.61; 0.89]	21.8	0.86 [0.76;0.98]	22.9	0.62 [0.57;0.68]	21.8	0.86 [0.76;0.98]	7.7	1.46 [1.13; 1.89]	3.5	1.75 [1.29; 2.38]	14.9	0.57 [0.52; 0.62]	17.5	0.82 [0.77; 0.88]
Widowed/ separated	8.9	1.05 [0.83; 1.33]	16.5	0.65 [0.44;0.97]	31.7	0.88 [0.79;0.98]	16.5	0.65 [0.44;0.97]	5.6	1.30 [0.94; 1.80]	3.9	2.18 [1.18; 4.00]	23.9	0.79 [0.72; 0.88]	30.4	1.20 [1.01; 1.42]
Wealth Index *Poorest*	3.4	ref.	12.3	ref.	25.4	ref.	12.3	ref.	0.2	ref.	0.5	ref.	9.9	ref.	8.8	ref.
Poorer	5.6	1.80 [1.20; 2.71]	22.6	1.45 [1.13;1.87]	28.3	1.11 [0.98;1.26]	22.6	1.45 [1.13;1.87]	0.5	2.66 [0.52; 13.66]	0.8	1.44 [0.46; 4.53]	13.7	1.54 [1.35; 1.76]	12.1	1.39 [1.19; 1.63]
Middle	5.9	2.20 [1.49; 3.24]	22.2	1.45 [1.10;1.91]	28.9	1.15 [1.01;1.31]	22.2	1.45 [1.10;1.91]	0.9	5.72 [1.29; 25.38]	1.3	2.30 [0.82; 6.47]	16.1	1.69 [1.46; 1.96]	15.4	1.49 [1.28; 1.74]
Richer	8.5	2.98 [2.03; 4.38]	22.0	1.49 [1.14;1.95]	28.0	1.17 [1.03;1.33]	22.0	1.49 [1.14;1.95]	2.3	9.94 [2.31; 42.82]	1.6	2.87 [1.04; 7.92]	23.1	2.20 [1.92; 2.53]	21.7	1.94 [1.67; 2.26]
Richest	12.3	4.30 [2.99; 6.17]	31.3	2.10 [1.63;2.70]	38.5	1.44 [1.27;1.64]	31.3	2.10 [1.63;2.70]	12.2	69.03 [17.28; 275.83]	6.6	16.63 [7.02; 39.41]	35.8	3.27 [2.88; 3.73]	33.9	2.91 [2.52; 3.36]
Educational level *None*	3.4	ref.	13.6	ref.	21.7	ref.	13.6	ref.	0.6	ref.	0.9	ref.	15.2	ref.	12.9	ref.
Primary	6.4	2.08 [1.46; 2.96]	20.1	1.74 [1.13;2.70]	28.7	1.28 [1.10;1.49]	20.1	1.74 [1.13;2.70]	4.2	4.55 [3.23; 6.39]	1.5	2.88 [1.59; 5.22]	22.1	1.30 [1.21; 1.40]	16.3	1.39 [1.25; 1.55]
Secondary/higher	11.8	3.93 [2.73; 5.68]	28.1	2.46 [1.58;3.83]	35.8	1.50 [1.29;1.76]	28.1	2.46 [1.58;3.83]	20.5	15.45 [11.00; 21.68]	7.5	10.26 [5.97; 17.64]	36.2	1.83 [1.68; 2.00]	35.7	2.36 [2.09; 2.65]

Supplementary Table 2: Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	**Sierra Leone**								**Guinea**							
Survey Year	**2008**				**2013**				**2005**				**2012**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	0.58	[0.41;0.83]	0.98	[0.57;1.70]	0.75	[0.65;0.86]	0.75	[0.54;1.03]	0.93	[0.45;1.91]	0.53	[0.21;1.31]	0.50	[0.31;0.82]	0.63	[0.36;1.12]
Age *25-34 years*	1.27	[1.00;1.61]	3.09	[1.58;6.07]	0.96	[0.88;1.04]	1.22	[0.93;1.60]	1.07	[0.63;1.81]	2.65	[1.38;5.09]	1.18	[0.91;1.53]	2.38	[1.56;3.63]
≥ 35 years	0.61	[0.44;0.84]	2.76	[1.38;5.52]	0.54	[0.49;0.60]	1.18	[0.88;1.59]	0.66	[0.34;1.27]	1.57	[0.76;3.25]	0.69	[0.51;0.93]	1.74	[1.01;2.98]
Family situation *Single*	0.73	[0.54;0.99]	0.77	[0.45;1.33]	0.51	[0.45;0.57]	0.79	[0.61;1.02]	0.89	[0.48;1.65]	0.68	[0.38;1.23]	0.65	[0.48;0.87]	0.96	[0.63;1.47]
Widowed/ separated	0.68	[0.43;1.09]	0.60	[0.22;1.65]	0.69	[0.58;0.82]	0.83	[0.55;1.24]	2.67	[1.51;4.71]	0.82	[0.35;1.91]	0.74	[0.46;1.18]	1.71	[0.84;3.47]
***Wealth rank**	4.69	[2.64;8.34]	10.77	[3.16;36.73]	1.26	[1.02;1.55]	2.44	[1.41;4.21]	101.38	[17.08;601.88]	16.14	[2.21;117.99]	21.27	[9.30;48.65]	6.00	[2.07;17.36]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	Liberia								Côte d'Ivoire							
Survey Year	2007				2013				2005				2011-12			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	0.38	[0.21;0.70]	0.47	[0.26;0.85]	0.93	[0.82;1.05]	0.72	[0.58;0.91]	0.67	[0.44;1.01]	0.68	[0.42;1.10]	0.80	[0.67;0.96]	1.17	[0.90;1.51]
Age *25-34 years*	0.93	[0.62;1.41]	1.37	[0.73;2.56]	1.02	[0.92;1.12]	1.99	[1.44;2.75]	1.24	[0.86;1.81]	2.90	[1.74;4.84]	1.18	[1.05;1.33]	1.36	[1.04;1.80]
≥ 35 years	0.77	[0.47;1.28]	1.09	[0.53;2.26]	0.54	[0.48;0.61]	1.65	[1.18;2.30]	0.59	[0.37;0.95]	2.03	[1.06;3.91]	0.66	[0.56;0.76]	1.16	[0.84;1.61]
Family situation *Single*	0.90	[0.55;1.47]	0.55	[0.28;1.06]	0.57	[0.51;0.64]	0.58	[0.43;0.78]	0.64	[0.42;0.97]	1.84	[1.13;3.01]	0.61	[0.54;0.70]	0.82	[0.62;1.09]
Widowed/ separated	1.45	[0.87;2.42]	1.38	[0.81;2.33]	0.91	[0.79;1.04]	1.03	[0.72;1.46]	0.86	[0.42;1.74]	1.37	[0.60;3.12]	0.74	[0.61;0.91]	1.15	[0.78;1.68]
***Wealth rank**	1.79	[0.73;4.42]	6.76	[3.01;15.19]	1.21	[1.00;1.47]	3.18	[2.11;4.79]	4.24	[1.80;10.00]	3.73	[1.41;9.89]	3.30	[2.46;4.42]	8.33	[4.96;13.97]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	**Mali**								**Niger**							
Survey Year	**2006**				**2012-13**				**2006**				**2012**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	0.31	[0.22;0.44]	0.61	[0.37;1.01]	0.44	[0.32;0.62]	0.77	[0.53;1.11]	0.07	[0.03;0.16]	0.34	[0.12;0.97]	0.50	[0.40;0.63]	0.41	[0.21;0.80]
Age *25-34 years*	1.00	[0.81;1.22]	0.89	[0.56;1.41]	1.24	[1.06;1.44]	2.72	[1.83;4.05]	1.05	[0.69;1.60]	2.85	[1.69;4.82]	1.09	[0.96;1.24]	1.80	[1.05;3.07]
≥ 35 years	0.47	[0.35;0.63]	0.72	[0.44;1.18]	0.74	[0.60;0.91]	2.22	[1.43;3.46]	0.63	[0.38;1.02]	2.69	[1.32;5.50]	0.63	[0.54;0.75]	1.26	[0.67;2.38]
Family situation *Single*	0.34	[0.23;0.50]	0.49	[0.30;0.78]	0.51	[0.38;0.67]	1.08	[0.76;1.53]	0.38	[0.21;0.68]	1.39	[0.75;2.55]	0.25	[0.18;0.33]	0.75	[0.44;1.26]
Widowed/ separated	0.62	[0.37;1.03]	0.87	[0.39;1.93]	0.50	[0.29;0.86]	0.96	[0.36;2.56]	0.47	[0.20;1.07]	1.84	[0.82;4.16]	0.74	[0.58;0.94]	2.10	[0.78;5.63]
***Wealth rank**	9.62	[5.10;18.15]	10.95	[3.64;32.93]	11.58	[6.19;21.68]	14.85	[7.05;31.28]	5.82	[1.82;18.62]	10.82	[1.61;72.83]	5.39	[3.67;7.92]	49.48	[10.91;224.38]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

West-Central Africa	Cameroon								Democratic Republic of Congo							
Survey Year	2004				2011				2007				2013-14			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]
Area of residence *Rural*	0.99	[0.72;1.36]	0.85	[0.65;1.11]	0.90	[0.78;1.04]	1.11	[0.95;1.30]	0.44	[0.28;0.68]	0.54	[0.30;0.95]	0.43	[0.33;0.55]	0.72	[0.53;0.98]
Age *25-34 years*	1.17	[0.91;1.50]	1.98	[1.43;2.74]	1.06	[0.95;1.17]	1.87	[1.61;2.17]	1.14	[0.92;1.41]	1.51	[1.06;2.13]	1.24	[1.09;1.42]	1.71	[1.27;2.30]
≥ 35 years	1.08	[0.83;1.41]	1.58	[1.10;2.28]	0.68	[0.60;0.78]	1.47	[1.24;1.74]	0.67	[0.52;0.86]	1.14	[0.77;1.70]	0.74	[0.62;0.87]	1.28	[0.91;1.82]
Family situation *Single*	0.63	[0.48;0.83]	0.70	[0.52;0.95]	0.58	[0.51;0.65]	0.80	[0.69;0.92]	0.50	[0.39;0.65]	0.72	[0.50;1.03]	0.47	[0.39;0.56]	0.52	[0.39;0.71]
Widowed/ separated	1.31	[1.01;1.71]	0.76	[0.55;1.05]	0.98	[0.86;1.13]	0.95	[0.77;1.16]	1.07	[0.82;1.41]	0.82	[0.50;1.33]	0.89	[0.74;1.07]	0.68	[0.45;1.02]
***Wealth rank**	33.50	[18.83;59.59]	5.85	[3.67;9.30]	3.50	[2.77;4.42]	6.45	[4.96;8.38]	7.75	[4.11;14.60]	5.08	[2.17;11.88]	7.47	[4.83;11.54]	12.05	[6.73;21.59]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	**Zambia**								**Lesotho**							
Survey Year	**2007**				**2013-14**				**2004**				**2014**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	0.70	[0.59;0.84]	0.95	[0.76;1.18]	0.91	[0.86;0.96]	0.92	[0.87;0.99]	0.84	[0.68;1.02]	1.36	[0.92;2.02]	0.99	[0.93;1.05]	0.85	[0.75;0.96]
Age *25-34 years*	0.97	[0.87;1.08]	1.31	[1.07;1.59]	1.01	[0.97;1.05]	1.13	[1.05;1.22]	1.17	[0.93;1.49]	2.76	[1.44;5.28]	1.02	[0.97;1.06]	1.15	[0.99;1.33]
≥ 35 years	0.77	[0.67;0.88]	1.02	[0.82;1.27]	0.77	[0.74;0.81]	0.86	[0.79;0.92]	0.85	[0.65;1.12]	2.19	[1.12;4.29]	0.82	[0.77;0.87]	1.04	[0.88;1.23]
Family situation *Single*	0.57	[0.50;0.64]	0.82	[0.66;1.02]	0.59	[0.56;0.62]	0.59	[0.55;0.64]	0.61	[0.48;0.78]	0.79	[0.46;1.34]	0.61	[0.57;0.65]	0.64	[0.55;0.73]
Widowed/ separated	0.87	[0.76;1.01]	1.14	[0.90;1.45]	0.91	[0.87;0.96]	0.87	[0.80;0.95]	1.04	[0.83;1.31]	0.96	[0.52;1.77]	0.92	[0.87;0.98]	0.90	[0.76;1.05]
***Wealth rank**	1.42	[1.05;1.92]	1.90	[1.30;2.79]	1.12	[1.03;1.22]	1.24	[1.12;1.38]	1.33	[0.94;1.88]	3.78	[2.03;7.02]	0.93	[0.84;1.02]	1.63	[1.32;2.02]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	**Zimbabwe**								**Rwanda**							
Survey Year	**2005-06**				**2015**				**2005**				**2014-15**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	1.09	[0.79;1.50]	0.73	[0.53;0.98]	1.06	[0.98;1.15]	1.08	[0.97;1.19]	0.45	[0.39;0.52]	0.57	[0.47;0.70]	0.92	[0.86;0.98]	0.89	[0.81;0.98]
Age *25-34 years*	0.87	[0.72;1.06]	1.50	[1.14;1.98]	0.99	[0.94;1.04]	1.17	[1.06;1.31]	0.95	[0.85;1.08]	1.67	[1.30;2.14]	0.95	[0.89;1.01]	1.07	[0.96;1.19]
≥ 35 years	0.60	[0.48;0.75]	1.18	[0.85;1.64]	0.77	[0.73;0.82]	0.91	[0.82;1.02]	0.54	[0.47;0.63]	1.09	[0.80;1.49]	0.69	[0.64;0.74]	0.76	[0.67;0.87]
Family situation *Single*	0.60	[0.49;0.74]	1.07	[0.81;1.42]	0.47	[0.43;0.51]	0.59	[0.54;0.66]	0.40	[0.34;0.47]	0.83	[0.64;1.08]	0.66	[0.62;0.70]	0.71	[0.64;0.79]
Widowed/ separated	0.97	[0.79;1.19]	1.45	[1.03;2.04]	0.97	[0.92;1.03]	1.02	[0.91;1.14]	0.88	[0.76;1.03]	1.17	[0.81;1.69]	0.93	[0.87;1.00]	1.02	[0.83;1.24]
Wealth rank	7.20	[4.12;12.57]	3.17	[1.81;5.53]	1.17	[1.03;1.32]	1.40	[1.18;1.66]	1.44	[1.17;1.76]	2.20	[1.54;3.12]	1.07	[0.98;1.17]	0.95	[0.83;1.09]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	Malawi								Tanzania							
Survey Year	2004				2015-16				2003-04				2011-12			
Gender	Female		Male		Female		Male		Female		Male		Female		Male	
	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]	PR	[95% CI]
Area of residence *Rural*	0.76	[0.61;0.95]	0.59	[0.42;0.84]	0.98	[0.93;1.03]	0.96	[0.89;1.04]	0.59	[0.42;0.82]	0.78	[0.59;1.04]	0.85	[0.78;0.94]	0.88	[0.79;0.98]
Age *25-34 years*	0.78	[0.67;0.91]	1.22	[0.79;1.89]	0.90	[0.87;0.93]	1.00	[0.92;1.08]	1.05	[0.81;1.37]	1.27	[0.91;1.78]	0.93	[0.86;0.99]	1.25	[1.10;1.42]
≥ 35 years	0.50	[0.41;0.61]	1.04	[0.66;1.62]	0.72	[0.69;0.75]	0.78	[0.72;0.85]	0.71	[0.52;0.96]	1.18	[0.81;1.70]	0.61	[0.57;0.66]	1.05	[0.91;1.21]
Family situation *Single*	0.52	[0.42;0.64]	0.95	[0.63;1.44]	0.49	[0.47;0.52]	0.53	[0.49;0.58]	0.87	[0.65;1.17]	0.73	[0.52;1.02]	0.48	[0.44;0.53]	0.59	[0.51;0.68]
Widowed/ separated	1.10	[0.89;1.37]	0.98	[0.50;1.91]	0.92	[0.89;0.96]	0.88	[0.77;1.01]	1.36	[1.00;1.85]	0.92	[0.62;1.36]	0.94	[0.86;1.03]	0.83	[0.70;0.99]
***Wealth rank**	2.40	[1.78;3.25]	2.61	[1.51;4.52]	1.12	[1.06;1.19]	1.14	[1.01;1.27]	5.42	[2.95;9.99]	2.72	[1.71;4.33]	1.41	[1.25;1.60]	1.69	[1.42;2.00]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Supplementary Table 2 (followed): Multivariate analysis of the association between the proportion of recent (<12 months) HIV testing and various socio-demographic factors per gender, country and survey year. PR: Prevalence Ratio, CI: Confidence Interval.

Eastern-Southern Africa	**Kenya**								**Ethiopia**							
Survey Year	**2003**				**2008-09**				**2005**				**2016**			
Gender	**Female**		**Male**		**Female**		**Male**		**Female**		**Male**		**Female**		**Male**	
	PR	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**	**PR**	**[95% CI]**
Area of residence *Rural*	0.97	[0.77;1.23]	0.83	[0.62;1.10]	0.89	[0.78;1.00]	0.97	[0.80;1.18]	0.36	[0.23;0.56]	0.68	[0.41;1.13]	0.77	[0.68;0.88]	0.86	[0.74;0.99]
Age *25-34 years*	1.18	[0.97;1.43]	1.28	[0.88;1.86]	1.00	[0.93;1.08]	1.37	[1.14;1.65]	1.04	[0.81;1.33]	1.34	[0.92;1.95]	1.00	[0.93;1.07]	1.38	[1.24;1.53]
≥ 35 years	0.63	[0.49;0.80]	0.94	[0.60;1.48]	0.60	[0.54;0.67]	1.06	[0.85;1.32]	0.66	[0.47;0.91]	0.70	[0.40;1.22]	0.73	[0.67;0.79]	0.93	[0.83;1.05]
Family situation *Single*	0.65	[0.52;0.81]	0.89	[0.60;1.32]	0.54	[0.49;0.59]	0.97	[0.80;1.18]	0.94	[0.71;1.23]	1.11	[0.69;1.79]	0.49	[0.45;0.54]	0.79	[0.72;0.88]
Widowed/ separated	1.10	[0.87;1.38]	1.40	[0.87;2.26]	0.95	[0.85;1.06]	0.67	[0.45;0.99]	1.18	[0.91;1.54]	1.68	[0.96;2.94]	0.82	[0.75;0.90]	1.16	[0.99;1.37]
***Wealth rank**	5.25	[3.44;8.01]	4.22	[2.36;7.55]	1.43	[1.18;1.74]	2.09	[1.46;2.99]	59.83	[24.76;144.53]	57.86	[17.37;192.66]	4.18	[3.36;5.20]	3.93	[3.06;5.05]

*Wealth rank (continuous variable): participants' relative rank in the cumulative distribution of the wealth index (from 0 to 1, poorest to richest, respectively)

Appendix 2D. Relative and absolute wealth-related inequalities among those aged less than 25 years old

Supplementary Table 1: Relative and absolute wealth-related inequalities in self-reported recent (<12 months) HIV testing in women aged less than 25 years old in 16 sub-Saharan African countries. RII: relative index of inequalities, SII: slope index of inequalities, RE: random-effect. RII ratios and SII differences are standardised on the number of years elapsed between both survey rounds. Countries are ordered west to east.

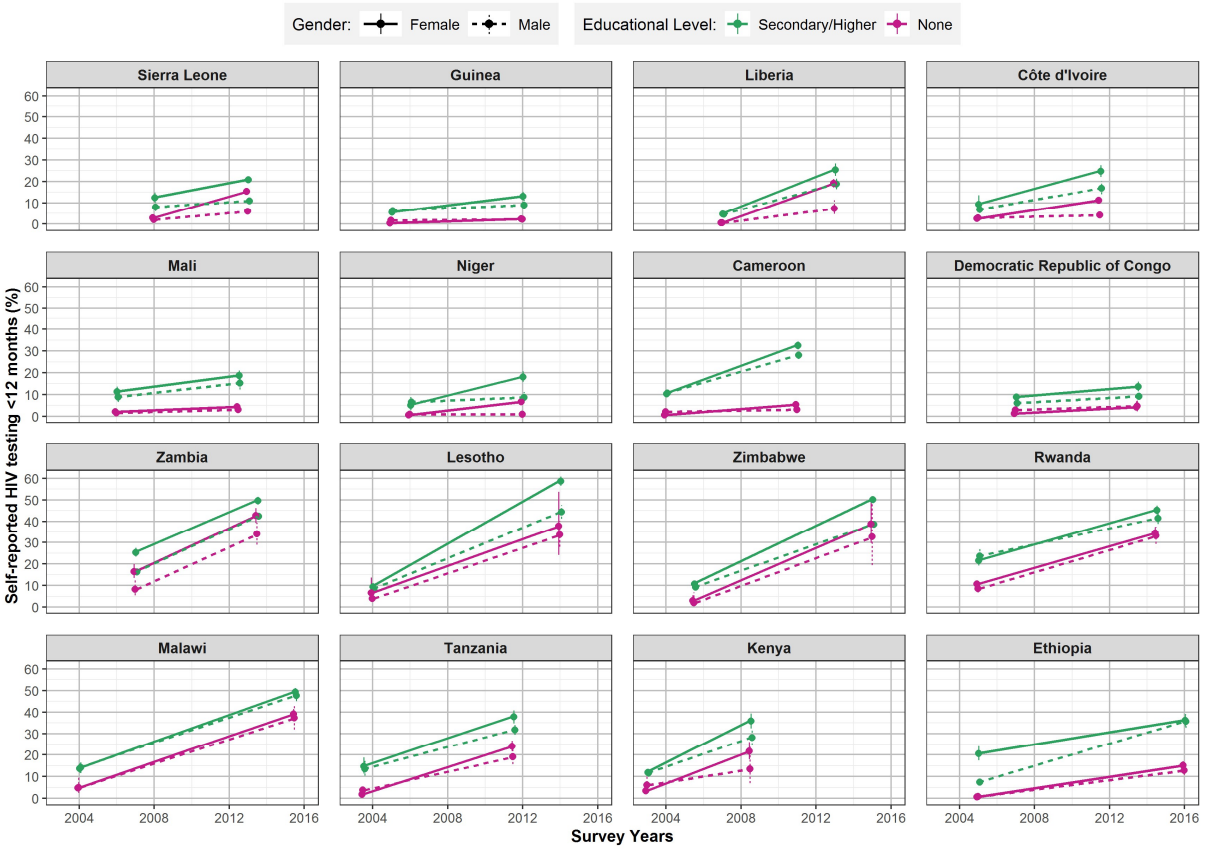
Country		Relative inequalities			Absolute inequalities		
		Pre-2008 Survey RII	Post-2008 Survey RII	Standardised RII Ratio (.yr^{-1})	Pre-2008 Survey SII	Post-2008 Survey SII	Standardised SII Difference (.yr^{-1})
Western and Central Africa	**Sierra Leone**	4.2 (2.4;7.5)	1.2 (1.0;1.5)	0.78 (0.69;0.88)	0.09 (0.05;0.13)	0.03 (-0.01;0.07)	-0.012 (-0.022;-0.001)
	Guinea	43.7 (11.2;169.9)	24.0 (12.7;45.3)	0.92 (0.74;1.14)	0.05 (0.03;0.07)	0.15 (0.11;0.19)	0.014 (0.008;0.021)
	Liberia	4.0 (1.8;8.8)	0.9 (0.7;1.1)	0.78 (0.68;0.90)	0.03 (0.01;0.05)	-0.02 (-0.07;0.03)	-0.009 (-0.018;0.000)
	Côte d'Ivoire	4.1 (1.7;9.9)	2.5 (1.8;3.3)	0.92 (0.80;1.07)	0.04 (0.02;0.07)	0.13 (0.08;0.17)	0.013 (0.005;0.021)
	Mali	24.4 (13.1;45.6)	19.6 (12.0;32.2)	0.97 (0.86;1.09)	0.12 (0.09;0.15)	0.21 (0.17;0.25)	0.015 (0.007;0.023)
	Niger	51.3 (17.6;149.7)	9.0 (5.8;14.1)	0.75 (0.62;0.91)	0.07 (0.04;0.10)	0.21 (0.16;0.26)	0.024 (0.015;0.033)
	Cameroon	19.8 (10.9;36.0)	2.9 (2.2;3.8)	0.76 (0.69;0.83)	0.14 (0.11;0.17)	0.12 (0.09;0.15)	-0.003 (-0.009;0.003)
	Congo DR	10.4 (5.4;20.1)	13.6 (8.3;22.3)	1.04 (0.92;1.18)	0.12 (0.08;0.15)	0.15 (0.12;0.18)	0.005 (-0.002;0.013)
Southern and Eastern Africa	**Zambia**	1.9 (1.4;2.5)	0.9 (0.81;1.0)	0.89 (0.85;0.93)	0.13 (0.07;0.18)	-0.05 (-0.09;0.00)	-0.027 (-0.038;-0.015)
	Lesotho	0.7 (0.4;1.1)	0.8 (0.7;0.9)	1.01 (0.96;1.06)	-0.03 (-0.06;0.01)	-0.12 (-0.19;-0.06)	-0.010 (-0.017;-0.002)
	Zimbabwe	5.6 (3.7;8.3)	0.8 (0.7;0.9)	0.81 (0.78;0.85)	0.15 (0.11;0.18)	-0.11 (-0.17;-0.05)	-0.026 (-0.034;-0.019)
	Rwanda	1.8 (1.4;2.4)	1.1 (0.9;1.2)	0.95 (0.91;0.98)	0.07 (0.04;0.11)	0.02 (-0.03;0.07)	-0.005 (-0.012;0.001)
	Malawi	2.9 (2.0;4.2)	0.9 (0.8;1.0)	0.90 (0.87;0.93)	0.08 (0.05;0.11)	-0.05 (-0.08;-0.02)	-0.011 (-0.015;-0.007)
	Tanzania	15.9 (8.5;30.0)	1.1 (1.0;1.4)	0.72 (0.66;0.78)	0.16 (0.12;0.20)	0.04 (-0.01;0.09)	-0.015 (-0.023;-0.007)
	Kenya	4.7 (2.9;7.6)	1.8 (1.5;2.2)	0.84 (0.77;0.92)	0.11 (0.08;0.15)	0.18 (0.11;0.24)	0.011 (-0.002;0.025)
	Ethiopia	41.1 (23.6;71.6)	3.4 (2.8;4.2)	0.80 (0.76;0.84)	0.30 (0.25;0.36)	0.29 (0.24;0.34)	-0.002 (-0.008;0.005)
Within-sample pooled estimate from RE meta-analysis		**6.98 (3.55;13.73)**	**2.21 (1.20;4.09)**	**0.86 (0.81;0.92)**	**0.099 (0.062;0.136)**	**0.074 (0.009;0.139)**	**-0.002 (-0.010;0.006)**
I^2		81.97%	87.86%	88.41%	91.80%	95.94%	92.10%

Supplementary Table 2: Relative and absolute wealth-related inequalities in self-reported recent (<12 months) HIV testing in men aged less than 25 years old in 16 sub-Saharan African countries. RII: relative index of inequality, SII: slope index of inequality, RE: random-effect. RII ratios and SII differences are standardised on the number of years elapsed between both survey rounds. Countries are ordered west to east.

Country		Relative inequalities			Absolute inequalities		
		Pre-2008 Survey RII	Post-2008 Survey RII	Standardised RII Ratio (.yr^{-1})	Pre-2008 Survey SII	Post-2008 Survey SII	Standardised SII Difference (.yr^{-1})
Western and Central Africa	**Sierra Leone**	13.2 (1.1;156.3)	1.1 (0.6;1.9)	0.61(0.37;1.01)	0.05 (-0.00;0.10)	0.01 (-0.04;0.05)	-0.009 (-0.022;0.005)
	Guinea	4.8 (1.2;18.3)	5.2 (1.7;15.9)	1.01 (0.79;1.30)	0.03 (0.00;0.06)	0.06 (0.01;0.10)	0.004 (-0.004;0.011)
	Liberia	6.2 (2.2;17.0)	2.8 (1.5;5.3)	0.88 (0.72;1.07)	0.04 (0.01;0.06)	0.07 (0.02;0.11)	0.005 (-0.003;0.014)
	Côte d'Ivoire	3.4 (0.8;13.6)	6.5 (3.3;12.9)	1.11 (0.87;1.41)	0.02 (-0.00;0.05)	0.14 (0.09;0.19)	0.018 (0.009;0.027)
	Mali	6.1 (2.0;18.4)	23.1 (6.4;82.5)	1.23 (0.95;1.59)	0.06 (0.02;0.09)	0.12 (0.06;0.18)	0.010 (-0.001;0.020)
	Niger	4.1 (0.8;22.6)	132.1 (29.1;599.0)	1.78 (1.22;2.61)	0.03 (-0.01;0.07)	0.14 (0.07;0.20)	0.018 (0.006;0.030)
	Cameroon	4.7 (2.3;9.7)	5.8 (4.1;8.2)	1.03 (0.92;1.16)	0.07 (0.04;0.11)	0.24 (0.19;0.29)	0.023 (0.014;0.032)
	Congo DR	4.1 (1.9;8.7)	10.7 (5.2;22.3)	1.16 (0.99;1.36)	0.06 (0.03;0.09)	0.09 (0.06;0.13)	0.005 (-0.002;0.012)
Southern and Eastern Africa	**Zambia**	2.1 (1.4;3.1)	1.5 (1.3;1.7)	0.95 (0.89;1.01)	0.09 (0.04;0.13)	0.13 (0.08;0.17)	0.007 (-0.004;0.017)
	Lesotho	2.0 (0.6;6.5)	2.6 (1.9;3.6)	1.03 (0.91;1.17)	0.02 (-0.02;0.05)	0.28 (0.18;0.38)	0.026 (0.016;0.036)
	Zimbabwe	6.5 (3.8;10.9)	1.2 (0.9;1.4)	0.83 (0.79;0.89)	0.11 (0.08;0.15)	0.04 (-0.02;0.10)	-0.007 (-0.015;0.000)
	Rwanda	2.6 (1.5;4.5)	0.9 (0.7;1.1)	0.89 (0.84;0.95)	0.09 (0.04;0.14)	-0.05 (-0.12;0.02)	-0.015 (-0.024;-0.006)
	Malawi	6.5 (2.6;16.1)	1.1 (0.9;1.3)	0.86 (0.79;0.93)	0.13 (0.06;0.20)	0.04 (-0.03;0.10)	-0.008 (-0.016;0.000)
	Tanzania	3.6 (1.9;6.7)	2.0 (1.5;2.6)	0.93 (0.85;1.01)	0.08 (0.04;0.12)	0.13 (0.08;0.18)	0.007 (-0.002;0.015)
	Kenya	4.1 (1.9;8.7)	2.0 (1.3;3.0)	0.88 (0.75;1.03)	0.10 (0.04;0.15)	0.14 (0.06;0.22)	0.008 (-0.010;0.026)
	Ethiopia	183.9 (55.0;614.8)	3.9 (3.0;5.0)	0.70 (0.63;0.79)	0.19 (0.13;0.26)	0.25 (0.21;0.30)	0.006 (-0.002;0.013)
Within-sample pooled estimate from RE meta-analysis		**5.09 (3.00;8.64)**	**3.05 (1.63;5.71)**	**0.94 (0.86;1.04)**	**0.067 (0.044;0.090)**	**0.112 (0.065;0.159)**	**0.006 (0.000;0.012)**
I^2		49.72%	78.87%	79.44%	74.70%	89.19%	83.22%

Appendix 2E: Quantification and time trends of education-based inequalities in recent (<12 months) uptake of HIV testing

Supplementary Figure 1: Gender-specific percentage of recent (<12 months) HIV testing per educational level (secondary /higher and none) between the earlier and later surveys in 16 sub-Saharan African countries. Countries are ordered west to east.



Supplementary Table 1**:** Relative and absolute education-related inequalities in self-reported recent (<12 months) HIV testing in women in 16 sub-Saharan African countries. RII: relative index of inequality, SII: slope index of inequality. RE: random-effect. RII ratios and SII differences are standardised on the number of years elapsed between both survey rounds. Countries are orders west to east.

Country		Relative inequalities			Absolute inequalities		
		Pre-2008 Survey RII	Post-2008 Survey RII	Standardised RII ratio (.yr^{-1})	Pre-2008 Survey SII	Post-2008 Survey SII	Standardised SII difference (.yr^{-1})
Western and Central Africa	**Sierra Leone**	6.8 (4.4;10.6)	1.5 (1.3;1.8)	0.74 (0.68;0.81)	0.11 (0.08;0.14)	0.08 (0.05;0.1)	-0.008 (-0.015;0)
	Guinea	82.9 (28.5;241)	8.8 (5.4;14.4)	0.73 (0.61;0.86)	0.06 (0.04;0.07)	0.09 (0.07;0.12)	0.005 (0.001;0.01)
	Liberia	16.2 (7.6;34.6)	1.8 (1.6;2.1)	0.7 (0.61;0.79)	0.06 (0.04;0.08)	0.13 (0.1;0.17)	0.012 (0.006;0.019)
	Côte d'Ivoire	5.8 (2.8;11.8)	2.7 (2.2;3.4)	0.89 (0.79;1)	0.06 (0.03;0.08)	0.15 (0.12;0.18)	0.014 (0.008;0.021)
	Mali	9.3 (5.7;15.2)	4.5 (2.9;6.8)	0.89 (0.81;0.99)	0.07 (0.05;0.09)	0.1 (0.07;0.13)	0.005 (0;0.011)
	Niger	2.3 (0.7;7.7)	2.5 (1.8;3.3)	1.01 (0.82;1.24)	0.01 (-0.01;0.03)	0.09 (0.06;0.12)	0.013 (0.007;0.019)
	Cameroon	21.6 (13.8;33.9)	4 (3.3;4.9)	0.79 (0.73;0.84)	0.17 (0.14;0.2)	0.16 (0.13;0.18)	-0.001 (-0.007;0.004)
	Congo DR	8.8 (5.5;14.2)	4.2 (3.1;5.8)	0.89 (0.82;0.98)	0.11 (0.09;0.14)	0.09 (0.07;0.11)	-0.003 (-0.009;0.002)
Southern and Eastern Africa	**Zambia**	1.8 (1.5;2.1)	1.2 (1.2;1.3)	0.95 (0.92;0.98)	0.12 (0.08;0.16)	0.1 (0.07;0.13)	-0.002 (-0.01;0.005)
	Lesotho	2.1 (1.5;3)	1 (0.9;1.1)	0.93 (0.9;0.96)	0.06 (0.03;0.09)	0.01 (-0.03;0.06)	-0.005 (-0.01;0.001)
	Zimbabwe	6.2 (4.2;9)	1.2 (1.1;1.3)	0.84 (0.81;0.88)	0.15 (0.12;0.19)	0.08 (0.03;0.12)	-0.008 (-0.014;-0.002)
	Rwanda	1.6 (1.3;2)	1.4 (1.2;1.5)	0.98 (0.96;1.01)	0.07 (0.04;0.1)	0.12 (0.09;0.16)	0.006 (0.001;0.011)
	Malawi	3 (2.2;4.2)	1.2 (1.2;1.3)	0.93 (0.9;0.95)	0.08 (0.05;0.1)	0.09 (0.07;0.12)	0.002 (-0.001;0.005)
	Tanzania	6.8 (3.9;11.7)	1.3 (1.2;1.5)	0.81 (0.76;0.87)	0.11 (0.07;0.14)	0.09 (0.05;0.12)	-0.002 (-0.009;0.004)
	Kenya	1.7 (1.2;2.2)	1.7 (1.4;1.9)	1 (0.94;1.06)	0.04 (0.02;0.06)	0.16 (0.12;0.21)	0.022 (0.013;0.031)
	Ethiopia	113.4 (62.2;206.6)	2.5 (2.2;2.9)	0.71 (0.67;0.75)	0.3 (0.25;0.35)	0.23 (0.2;0.26)	-0.007 (-0.012;-0.001)
Within-sample average estimate from RE meta-analysis		**6.74 (3.40;13.35)**	**2.00 (1.47;2.72)**	**0.86 (0.81;0.92)**	**0.095 (0.060;0.130)**	**0.112 (0.087;0.137)**	**0.003 (-0.002;0.007)**
I²		96.44%	96.94%	93.16%	92.90%	87.33%	85.30%

Supplementary Table 2**:** Relative and absolute education-related inequalities in self-reported recent (<12 months) HIV testing in men in 16 sub-Saharan African countries. RII: relative index of inequality, SII: slope index of inequality. RE: random-effect meta-analyses. RII ratios and SII differences are standardised on the number of years elapsed between both survey rounds. Countries are orders west to east.

Country		Relative inequalities			Absolute inequalities		
		Pre-2008 Survey RII	Post-2008 Survey RII	Standardised RII ratio (.yr^{-1})	Pre-2008 Survey SII	Post-2008 Survey SII	Standardised SII difference (.yr^{-1})
Western and Central Africa	**Sierra Leone**	13.4 (5.3;34.1)	3.1 (2.1;4.5)	0.75 (0.61;0.91)	0.11 (0.07;0.16)	0.1 (0.07;0.13)	-0.003 (-0.014;0.008)
	Guinea	12.2 (4.9;30.6)	12.5 (5.8;27)	1 (0.85;1.19)	0.07 (0.04;0.11)	0.13 (0.08;0.17)	0.008 (0;0.016)
	Liberia	24.4 (9.9;60.3)	6.4 (4.5;9.3)	0.8 (0.68;0.94)	0.09 (0.06;0.12)	0.24 (0.19;0.29)	0.025 (0.015;0.035)
	Côte d'Ivoire	6.4 (2.6;16)	7.5 (5.1;10.9)	1.02 (0.88;1.19)	0.05 (0.02;0.07)	0.19 (0.15;0.22)	0.021 (0.014;0.028)
	Mali	16.4 (7;38.1)	14.4 (9.2;22.5)	0.98 (0.85;1.14)	0.09 (0.06;0.13)	0.18 (0.14;0.22)	0.014 (0.005;0.022)
	Niger	12.2 (4.7;31.4)	28.2 (12.6;63)	1.15 (0.94;1.41)	0.07 (0.04;0.1)	0.11 (0.08;0.15)	0.006 (-0.001;0.014)
	Cameroon	5.2 (3.5;7.9)	4.3 (3.5;5.4)	0.97 (0.91;1.04)	0.13 (0.09;0.17)	0.3 (0.26;0.35)	0.025 (0.017;0.033)
	Congo DR	6.1 (3.3;11.4)	11.7 (7.5;18.3)	1.11 (0.98;1.24)	0.1 (0.06;0.14)	0.16 (0.13;0.2)	0.01 (0.002;0.018)
Southern and Eastern Africa	**Zambia**	2.7 (2.2;3.5)	1.5 (1.4;1.6)	0.91 (0.88;0.95)	0.14 (0.11;0.17)	0.16 (0.13;0.2)	0.004 (-0.003;0.011)
	Lesotho	3.7 (1.9;7.3)	1.7 (1.4;2)	0.92 (0.86;0.99)	0.07 (0.03;0.11)	0.2 (0.13;0.26)	0.013 (0.005;0.02)
	Zimbabwe	4.7 (3.2;6.7)	1.6 (1.4;1.8)	0.89 (0.86;0.93)	0.11 (0.08;0.14)	0.18 (0.14;0.23)	0.007 (0.002;0.013)
	Rwanda	3.5 (2.4;5.2)	1.3 (1.1;1.5)	0.9 (0.86;0.94)	0.16 (0.1;0.21)	0.1 (0.05;0.15)	-0.006 (-0.014;0.001)
	Malawi	6.7 (4;11.1)	1.4 (1.3;1.6)	0.87 (0.84;0.91)	0.15 (0.1;0.19)	0.15 (0.11;0.19)	0 (-0.005;0.006)
	Tanzania	3.1 (2;4.7)	1.3 (1.1;1.5)	0.9 (0.85;0.95)	0.09 (0.05;0.13)	0.06 (0.02;0.1)	-0.003 (-0.01;0.004)
	Kenya	4.8 (2.9;8)	2.3 (1.8;3)	0.88 (0.79;0.97)	0.13 (0.09;0.18)	0.2 (0.15;0.26)	0.013 (0;0.026)
	Ethiopia	45 (20.8;97.5)	3.5 (2.9;4)	0.79 (0.74;0.85)	0.13 (0.1;0.16)	0.28 (0.24;0.31)	0.014 (0.009;0.018)
Within-sample average estimate from RE meta-analysis		**6.94 (4.56;10.55)**	**3.53 (2.12;5.87)**	**0.91 (0.87;0.96)**	**0.104 (0.087;0.120)**	**0.171 (0.136;0.206)**	**0.009 (0.004;0.014)**
I^2		84.46%	97.27%	68.60%	69.66%	89.80%	82.85%

Appendix 2F: Central estimates, confidence intervals and prediction intervals of average estimates from random-effect meta-analyses of socio-economic inequalities in recent (<12 months) uptake of HIV testing.

Supplementary Table 1: Comparison of the 95% confidence and prediction intervals of the random-effect meta-analyses of wealth-related inequalities in women.

Metric	Average central estimate	95% confidence interval	95% prediction interval
RII – Survey 1	9.792	4.244;22.597	0.619;154.884
RII – Survey 2	2.767	1.418;5.397	0.677;11.301
RII ratio	0.846	0.795;0.901	0.684;1.047
SII – Survey 1	0.110	0.068;0.153	-0.019;0.239
SII- Survey 2	0.111	0.046;0.175	-0.125;0.346
SII difference	0.001	-0.006;0.008	-0.027;0.029

Supplementary Table 2: Comparison of the 95% confidence and prediction intervals of the random-effect meta-analyses of wealth-related inequalities in men.

Metric	Average central estimate	95% confidence interval	95% prediction interval
RII – Survey 1	7.320	4.086;13.114	1.227;43.676
RII – Survey 2	3.551	1.851;6.813	0.760;16.586
RII ratio	0.911	0.861;0.964	0.783.1.061
SII – Survey 1	0.101	0.083;0.119	0.032;0.170
SII- Survey 2	0.151	0.096;0.206	-0.075;0.377
SII difference	0.007	0.001;0.014	-0.02;0.035

Supplementary Table 3: Comparison of the 95% confidence and prediction intervals of the random-effect meta-analyses of education-related inequalities in women.

Metric	Average central estimate	95% confidence interval	95% prediction interval
RII – Survey 1	6.737	3.398;13.354	0.667;68.002
RII – Survey 2	2.001	1.471;2.722	0.921;4.348
RII ratio	0.859	0.805;0.916	0.693;1.064
SII – Survey 1	0.095	0.060;0.130	-0.011;0.201
SII- Survey 2	0.112	0.087;0.137	0.023;0.201
SII difference	0.003	-0.002;0.007	-0.012;0.018

Supplementary Table 4: Comparison of the 95% confidence and prediction intervals of the random-effect meta-analyses of education-related inequalities in men.

Metric	Average central estimate	95% confidence interval	95% prediction interval
RII – Survey 1	6.938	4.563;10.550	1.986;22.906
RII – Survey 2	3.526	2.118;5.871	0.685;17.265
RII ratio	0.912	0.869;0.957	0.808;1.029
SII – Survey 1	0.104	0.087;0.120	0.044;0.163
SII- Survey 2	0.171	0.136;0.206	0.033;0.310
SII difference	0.009	0.004;0.014	-0.009;0.027

9. Article 2 - Spatial distribution of socioeconomic inequalities in HIV testing

9.1. Summary

In Chapter 8, we quantified socioeconomic inequalities in HIV testing uptake in the last 12 months and assessed their trends over time in SSA. Aside from quantifying these inequalities, mapping their spatial variation, and localizing their hotspots at smaller scales is essential to better tailor and localize HIV testing efforts at a time of decreasing international support. In recent years, studying infectious diseases including HIV and assessing health programs using spatial analysis has gathered interest (Mosser et al., 2019; Rice et al., 2021). However, it has not often been used to assess and monitor inequalities in HIV programs particularly in HIV testing. It is also still ambiguous whether the level of HIV prevalence drives the level of HIV testing uptake at smaller scales. Thus, in this paper, we assessed the absolute and relative inequalities in recent HIV testing uptake and their spatial variation by estimating the SII and RII, respectively, across different geographical scales, based on DHS data between 2011 and 2019. We conducted a spatial cluster analysis to assess the spatial clustering of high and low SII and RII values at subnational levels. We assessed the efficiency of HIV testing services (i.e., whether uptake of HIV testing matches the level of HIV prevalence) through Pearson correlation.

Aside from confirming the existence of pro-rich inequalities in most countries at the national level, both in absolute and relative scales, as documented in Chapter 8, the present chapter describes their subnational distributions. Within- and between-country variations in inequality estimates in both scales and their spatial distributions varied between gender. Hotspots of SII and RII values were mostly observed in countries in WCA with few countries in ESA. We show that at the national level, HIV testing services presented a positive correlation with the level of risk. Meanwhile, at subnational levels, there was a lack of correlation between testing and the level of risk in most countries. In conclusion, our results may help policymakers and organizations to prioritize areas and groups that are most in need. There is also a need to monitor disparities at smaller scales besides national-level

estimates. Lastly, our results show that important efforts to match HIV testing levels to the actual risk of HIV (as measured by local HIV prevalence) have yet to be implemented. This paper is in finalization and the abstract has been accepted for a poster presentation in the ANRS Scientific Days.

Investigating inequalities in HIV testing in sub-Saharan Africa: insights from a spatial analysis of 25 countries

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Abstract

Background

We aim to explore spatial variations in socioeconomic inequalities in self-reported HIV testing uptake in the previous 12 months in sub-Saharan Africa (SSA) at different geographical scales, identify geographical hotspots in such inequalities at fine scale, and assess the efficiency of HIV testing programs in several SSA countries.

Methods

We analyzed data from 25 countries in SSA with Demographic and Health Surveys between 2011 and 2019 (most recent survey per country). We quantified socioeconomic inequalities in self-reported HIV testing in the last 12 months with both the slope index of inequality (SII) and relative index of inequality (RII) in different geographical scales to capture gender-specific within-country spatial variations. We also conducted sampling cluster-level analyses based on Local Indicator of Spatial Association to consider the autocorrelation in SII and RII across SSA countries. To assess the efficiency of HIV testing programs, we assessed the correlation between recent HIV testing uptake and HIV prevalence through Pearson correlation at each geographical scale.

Results

We observed pro-rich inequalities at both absolute and relative scales in recent HIV testing in majority of the SSA countries in female and male participants at the national level. We also identified existing inequalities at subnational levels. Within- and between-country heterogeneities in gender-specific inequalities in both inequality scales and their respective spatial distributions varied depending on the scale used. Clustering of high absolute and relative inequalities were mostly observed in Western and Central Africa with a few regions in Eastern and Southern Africa. We also revealed that HIV testing programs seemed to be efficient at the national level, but less efficient at subnational levels in the majority of the countries.

Conclusion

These findings may help policymakers and local and international organizations to prioritize areas and population groups in need of HIV testing services and to localize their responses while gaining efficiency. Our results also show the need to monitor efficiency of HIV testing

programs in relation to the HIV risk at subnational levels as a complementary to monitoring national estimates.

Keywords: socioeconomic inequality, HIV, HIV testing, spatial analysis, sub-Saharan Africa, efficiency

Introduction

The role of HIV testing in the fight against HIV/AIDS is crucial since it is the gateway to HIV prevention and care, especially in sub-Saharan Africa (SSA), the global epicenter of the disease. Over the years, testing has scaled up due to the increasing availability of antiretroviral therapy (ART) and in response to the UNAIDS 90-90-90 and 95-95-95 targets by 2020 and 2030, respectively [1,2].

Socioeconomic inequalities have been reported in HIV testing uptake in SSA. In particular, earlier studies found that people in higher socioeconomic position (SEP) were more likely to seek HIV testing or know their HIV status [3–8]. However, most of these studies assessed testing inequalities at the national level. Very few studies have analyzed the spatial distribution of these inequalities. To the best of our knowledge, such a local analysis has only been performed within a single country at a time [9].

Spatial analysis at local scales has proved useful for studying infectious diseases such as malaria [10,11], or assessing the coverage of vaccines such as the Diphtheria-Pertussis-Tetanus vaccine [12]. Regarding HIV, it has helped identify high transmission areas [13] and understand access difficulties to healthcare facilities in underserved areas in Africa [14]. However, it has not been frequently utilized in monitoring inequalities in the HIV response, particularly in HIV testing. Notably, based on reports, uptake of HIV testing tends to be higher in countries with the greatest HIV burden at the national level. Nevertheless, the existence of such a phenomenon at a finer scale has not been empirically assessed. Observing such spatial variations is important not only for ensuring equity in epidemic control but also for prioritizing areas with the greatest burden where a small portion of the population contributes a disproportionately large part of the infections [15] or inequalities. The geographical units with relatively higher disease or outcome rates are often called “hotspots”, and control efforts can be more efficient and effective when targeting such hotspots [10,16]. With decreasing international funding in the HIV response in past years, mapping HIV testing uptake and their inequalities across different geographical scales and identifying their local hotspots has never been more important.

There are various criteria for health programs that can be used to evaluate their public benefit

which include equity and efficiency. While equity is an important characteristic of health programs to ensure an equitable epidemic control across different social groups with specific needs, programs should also be efficient in reaching their objectives. Efficiency of a health program is concerned with the optimal production and distribution of scarce health resources and is critical for sustainability and maximizing health gains [17].

Here, we explore spatial variations in socioeconomic inequalities in HIV testing uptake in SSA across geographical scales, identify geographical hotspots for such inequalities and assess the efficiency of HIV testing programs related to HIV prevalence at the national and subnational levels in several SSA countries.

Methods

Study design and data sources

We conducted a multi-country analysis of cross-sectional surveys in sub-Saharan African countries, namely the Demographic and Health Surveys (DHS). The DHS are nationally representative surveys regularly conducted in the Global South collecting information on a broad range of indicators such as sociodemographic indicators, maternal and child health, malaria and HIV/AIDS. They conduct a two-stage sampling design with Primary Sampling Units (PSU, also known as cluster) and households as sampling units for the first and second stages, respectively. Women aged 15-49 years and men aged 15-59 (15-54 and 15-49 in some surveys) in participating households are eligible. Depending on the survey, data for men for the HIV indicators, HIV biomarkers or both may have been collected only from a sub-sample of the selected households. Some DHS include HIV serological surveys in which participants are asked for consent to be tested for HIV, which is done anonymously in most of the surveys. Individuals who consented are interviewed face-to-face by trained interviewers who use a standard questionnaire.

DHS GPS coordinates were obtained from the DHS database. These coordinates were intentionally and randomly displaced to ensure confidentiality of the respondents. Urban clusters were displaced between 0 and 2 kilometers, while rural clusters were displaced between 0 and 5 kilometers. The displacement is maintained within the country boundary and since 2009 it is maintained within the second administrative

level (i.e., PSU) where possible. The province-level boundaries were also obtained from the DHS spatial database repository (https://spatialdata.dhsprogram.com/home/). The DHS data were linked to the spatial data (GPS coordinates and administrative boundaries).

For our analysis, we selected sub-Saharan African countries with available DHS surveys between 2011 and 2019 that contained the variables of interest and GPS coordinates. We selected the most recent survey in countries with more than one eligible survey.

Data/ Variables

SEP was defined as the relative rank of the participants in the cumulative distribution of the DHS wealth index. The wealth index is a composite measure of living standards based on household assets (e.g., refrigerator and television) and living characteristics (e.g., type of water access and type of flooring). The wealth index was divided homogenously into quintiles from poorest to richest.

The outcome of interest was the self-report of recent HIV testing uptake in the previous 12 months. Participants were asked if they recently had an HIV test and the time since last test. Being HIV positive was defined as testing positive in the serological survey.

Statistical analysis

First, for each country and gender, we calculated the HIV prevalence and the proportion of self-reported HIV testing uptake in the previous 12 months while accounting for survey design and sampling weights at different geographical scales: i) national, ii) first administrative subnational level (i.e., province), and iii) PSU level (or also called as fine scale).

Second, we measured national-, province- and PSU-level socioeconomic inequalities both in the absolute and relative scales. We estimated the slope index of inequality (SII) and the relative index of inequality (RII) to assess the absolute and relative inequalities, respectively .

At the national and province levels, both indicators were obtained by fitting a modified Poisson regression (with robust variance) with a log link function [18] to estimate the

association between self-reported uptake of HIV testing in the past 12 months at each wealth level and the hierarchical ranking of wealth level. Generalized estimating equation was used to account for the clustering of observations [19]. The SII represents the absolute difference in the predicted proportions between the richest and the poorest people, whereas the RII expresses the ratio of the predicted outcomes between these two extremes. Due to the smaller sample sizes at the PSU-level (at least 10 individuals), we fitted a linear regression to estimate fine-scale inequality indicators. Here, the SII is the linear regression coefficient [20] estimating the association between the proportion of recent HIV testing at each wealth level and the hierarchical ranking of wealth (i.e., absolute difference between the richest and poorest populations). RII is the ratio of the predicted outcomes between *wealth rank* = 1 (highest wealth-level) and *wealth rank* = 0 (lowest wealth-level) [20] which may produce negative estimates. To address this, we truncated negative predicted values to zero to calculate the fine-scale RII since the outcome of interest is a proportion.

Third, spatial autocorrelation of the fine-scale SII and RII across SSA were assessed (by gender) using the local *Getis-Ord Gi** statistic for PSUs with a sample size of at least 10. The *Getis-Ord Gi** statistic identifies local patterns and clusters of high- or low-inequality across SSA countries that may not be evident when using global statistics [21] by comparing the local sum and its neighbors to the overall sum. More specifically, a distance-based neighborhood structure was used for *Getis-Ord Gi** computation. Neighboring PSUs were defined based on the distance *d* that assigns at least *k* (number) nearest neighbors to each PSU. We selected the number of nearest neighbors that gave high spatial autocorrelation based on a global Moran's I statistic for each gender and inequality indicator. We categorized the *Gi** statistic based on the sign (cold- or hotspot for negative and positive signs, respectively) and percentile (90%, 95%, 99%) to avoid bias due to multiple and dependent tests [22].

The efficiency of HIV testing programs was assessed by evaluating whether the proportion of recent uptake of HIV testing matched the level of HIV prevalence across various geographical scales. Indeed, HIV prevalence drives, at least partly, the local risk of incident HIV infection as it reflects the probability for one's sexual partner to be infected by HIV. To do so, we assessed the correlation between both indicators through Pearson correlation.

Sensitivity analysis

SII and RII were also calculated for PSUs with a sample size of at least 20 and 30 individuals and their local spatial autocorrelations were assessed as sensitivity analysis. We also assessed local spatial autocorrelation on separate analyses for countries with surveys between 2011 and 2014 and for countries with surveys between 2015 and 2019 to assess possible temporal trends in the spatial distribution of inequalities.

Results

Study population characteristics

Twenty-five countries were eligible between 2011 and 2019 – Angola, Burundi, Cameroon, Chad, Côte d'Ivoire, Democratic Republic of Congo (Congo DR), Ethiopia, Gabon, Ghana, Guinea, Lesotho, Liberia, Malawi, Mali, Mozambique, Namibia, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, South Africa, Zambia and Zimbabwe. Table 1 shows the summary statistics by country and gender. There was a total of 472,763 participants (311,652 women and 161,111 men) with 351,921 individuals (252,508 women and 99,413 men) from PSUs with a sample size of at least 10 and complete data (Table S1). The sample size in the provinces ranged between 275 and 11,342 among women and between 135 and 3,236 among men. At a finer scale, sample size in PSUs ranged between 10 and 96 women and between 10 and 54 men. The distributions of PSU sample size and proportion of recent HIV testing uptake are shown in Figures S1 and S2.

National-level estimates

Table 1 also shows the national estimates of HIV prevalence, HIV testing, and absolute and relative inequalities in recent HIV testing uptake. Overall, at the national level, HIV prevalence ranged from 0.5% (Senegal) to 30% (Lesotho) among women and from 0.4% (Senegal) to 19% (Lesotho) among men. Self-reported uptake of recent HIV testing ranged from 4% (Côte d'Ivoire) to 66% (Zambia) among women and from 4% (Côte d'Ivoire) to 53% (Zambia) among men (Table 1). Women also tended to have higher HIV prevalence and proportion of recent uptake of HIV testing (with an average of 8% and 29%, respectively) than men (with an average of 5% and 22%, respectively).

At the absolute scale, we observed pro-rich absolute inequalities in recent testing uptake in 19 of 25 countries for women and 23 of 25 countries for men (SII > 0) (Table 1). Absolute inequalities ranged between -8 (95% CI -12; -4) percentage points in South Africa and 44 (95% CI 39; 48) percentage points in Ethiopia in female participants. This means that the absolute difference between the richest and poorest quintiles was -8 (95% CI -12; -4) percentage points (i.e., pro-poor) in female participants in South Africa and 44 (95% CI 39; 48) percentage points in Ethiopia. Meanwhile, in male participants, absolute inequality ranged between -3 (95% CI -7; 1) percentage points in Rwanda and 42 (0.36; 0.47) percentage points in Cameroon.

On the other hand, we noted pro-rich relative inequalities in 18 of 25 countries for women and 23 of 25 countries for men (RII > 1) (Table 1). Relative inequalities ranged between 0.85 (95% CI 0.78; 0.91) in Lesotho and 22.66 (95% CI 16.15; 31.78) in Mali in women. This translates to the richest female participants being 0.85 (95% CI 0.78; 0.91) times as likely to report HIV testing in the previous 12 months than the poorest participants in Lesotho, while 22.66 times (95% CI 16.15; 31.78) more likely in Mali. In male participants, it ranged between 0.92 (95% CI 0.82; 1.04) in Rwanda and 14.74 (95% CI 8.89; 24.44) in Mali.

Table 1. Summary estimates of national level HIV prevalence, HIV testing, absolute and relative inequalities in HIV testing uptake in the previous 12 months in 25 sub-Saharan African countries between 2011 and 2019 by country and gender.

		Female					Male				
Country	**Year**	**N**	**HIV prevalence**	**HIV testing ^**	**SII (95% CI)**	**RII (95% CI)**	**N**	**HIV prevalence**	**HIV testing^**	**SII (95% CI)**	**RII (95% CI)**
AO Angola	**2015-16**	**14379**	3%	29%	0.40 (0.37; 0.44)	4.07 (3.54; 4.69)	5684	1%	20%	0.26 (0.21; 0.31)	3.23 (2.63; 3.97)
BI Burundi	**2016-17**	**17269**	1%	30%	0.07 (0.04; 0.10)	1.26 (1.15; 1.39)	7552	0.7%	20%	0.07 (0.04; 0.11)	1.42 (1.19; 1.69)
CD Congo DR	**2013-14**	**18827**	2%	9%	0.19 (0.16; 0.22)	18.29 (12.83; 26.08)	8656	0.5%	7%	0.16 (0.13; 0.19)	12.83 (8.47; 19.43)
CI Côte d'Ivoire	**2011-12**	**5183**	6%	4%	0.06 (0.03; 0.09)	6.04 (3.10; 11.75)	4503	3%	4%	0.04 (0.02; 0.06)	4.34 (2.11; 8.95)
CM Cameroon	**2018**	**14677**	4%	41%	0.40 (0.36; 0.44)	2.68 (2.43; 2.96)	6978	2%	35%	0.42 (0.36; 0.47)	3.05 (2.65; 3.52)
ET Ethiopia	**2019**	**15683**	1%	21%	0.44 (0.39; 0.48)	4.73 (4.13; 5.42)	12688	0.5%	19%	0.35 (0.31; 0.39)	4.11 (3.52; 4.79)
GA Gabon	**2012**	**8422**	6%	33%	0.16 (0.12; 0.20)	1.68 (1.45; 1.94)	5654	3%	24%	0.23 (0.20; 0.27)	3.52 (2.80; 4.42)
GH Ghana	**2014**	**9396**	3%	14%	0.11 (0.08; 0.13)	2.11 (1.74; 2.56)	4388	1%	6%	0.11 (0.08; 0.15)	5.75 (3.25; 10.15)
GN Guinea	**2018**	**10874**	2%	8%	0.23 (0.19; 0.26)	11.09 (8.20; 14.98)	4117	1%	6%	0.15 (0.11; 0.20)	12.25 (7.17; 20.95)
LB Liberia	**2019**	**9239**	2%	20%	0.05 (0.01; 0.08)	1.26 (1.06; 1.49)	4118	2%	13%	0.14 (0.10; 0.17)	3.28 (2.30; 4.67)
LS Lesotho	**2014**	**6621**	30%	59%	-0.10 (-0.14; -0.06)	0.85 (0.78; 0.91)	2931	19%	38%	0.23 (0.17; 0.30)	1.86 (1.57; 2.20)
ML Mali	**2018**	**10424**	1%	6%	0.26 (0.21; 0.30)	22.66 (16.15; 31.78)	4399	0.9%	6%	0.20 (0.15; 0.25)	14.74 (8.89; 24; 44)
MW Malawi	**2015-16**	**24562**	11%	44%	0.01 (-0.02; 0.03)	1.02 (0.96; 1.08)	7478	7%	43%	-0.002 (-0.04; 0.04)	0.996 (0.91; 1.09)

MZ Mozambique	**2015**	**7749**	15%	30%	0.27 (0.22; 0.32)	2.08 (1.82; 2.38)	5283	10%	19%	0.32 (0.26; 0.37)	3.35 (2.77; 4.04)
NM Namibia	**2013**	**10018**	17%	51%	-0.04 (-0.08; -0.01)	0.91 (0.85; 0.99)	4481	11%	38%	0.17 (0.12; 0.22)	1.57 (1.36; 1.81)
RW Rwanda	**2014-15**	**13497**	4%	39%	0.03 (-0.002; 0.07)	1.08 (0.99; 1.18)	6217	2%	37%	-0.03 (-0.07; 0.01)	0.92 (0.82; 1.04)
SL Sierra Leone	**2019**	**15574**	2%	24%	0.12 (0.09; 0.16)	1.74 (1.50; 2.02)	7197	1%	13%	0.20 (0.16; 0.24)	4.93 (3.71; 6.56)
SN Senegal	**2017**	**16787**	0.5%	14%	0.05 (0.03; 0.07)	1.47 (1.25; 1.74)	6977	0.4%	6%	0.08 (0.06; 0.11)	4.48 (3.02; 6.65)
TD Chad	**2014-15**	**17719**	2%	9%	0.05 (0.03; 0.06)	6.82 (4.34; 10.72)	5248	1%	7%	0.16 (0.11; 0.20)	9.09 (5.58; 14.80)
TG Togo	**2013-14**	**9480**	3%	17%	0.19 (0.15; 0.22)	3.15 (2.58; 3.85)	4476	2%	12%	0.21 (0.17; 0.25)	6.90 (4.84; 9.84)
TZ Tanzania	**2011-12**	**10967**	6%	33%	0.12 (0.08; 0.15)	1.44 (1.29; 1.61)	8352	4%	28%	0.13 (0.09; 0.17)	1.61 (1.41; 1.85)
UG Uganda	**2011**	**12153**	8%	12%	0.05 (0.02; 0.07)	1.48 (1.18; 1.85)	9588	6%	12%	0.05 (0.02; 0.07)	1.46 (1.17; 1.82)
ZA South Africa	**2016**	**8514**	28%	61%	-0.08 (-0.12; -0.04)	0.87 (0.82; 0.93)	3618	14%	46%	0.09 (0.03; 0.14)	1.21 (1.06; 1.38)
ZM Zambia	**2018**	**13683**	14%	66%	0.09 (0.05; 0.13)	1.15 (1.07; 1.22)	12132	8%	53%	0.14 (0.10; 0.18)	1.31 (1.22; 1.41)
ZW Zimbabwe	**2015**	**9955**	17%	51%	-0.04 (-0.07; -0.01)	0.92 (0.86; 0.99)	8396	11%	37%	0.07 (0.03; 0.11)	1.19 (1.08; 1.32)
Average			8%	29%				5%	22%		

N: Total number of participants; SII: Slope index of inequality; RII: Relative index of inequality; 95% CI: 95% Confidence Interval.

^Self-reported uptake of HIV testing in the previous 12 months.

First administrative subnational-level estimates

The distribution of province-level HIV prevalence and proportion of recent HIV testing are mapped in Figure 1. We observed within- and between-country variations in their respective spatial distributions. Maps presented in Figure 1 reveal that higher levels of HIV prevalence and proportions of recent HIV testing were observed in regions of southern Africa.

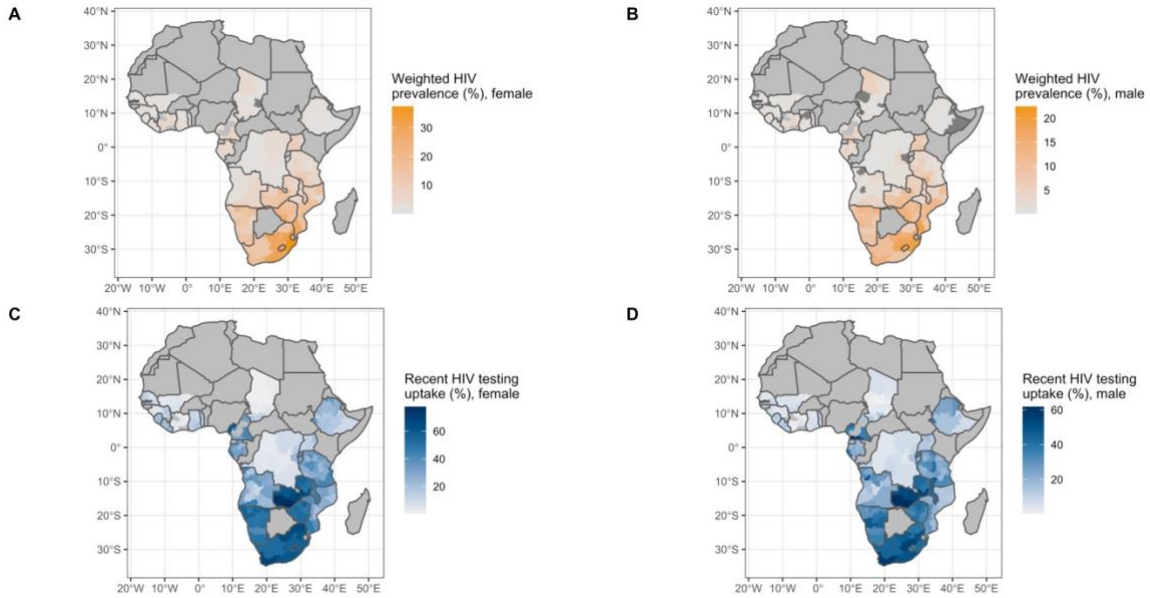

Figure 1. Province-level distribution of HIV prevalence among A) female and B) male participants and self-reported recent (<12 months) uptake of HIV testing among C) female and D) male participants. Dark grey colors indicate unavailability of the HIV biomarker. Missing polygons within the country indicate no data in this region from the Demographic and Health Surveys.

Figure 2 maps the regional absolute and relative inequalities in recent HIV testing. We also observed spatial heterogeneities in these inequalities between the two inequality scales used and between genders. At the absolute scale, we observed pro-rich spatial distribution of SIIs in the majority of the regions in SSA except for few regions in Eastern and Southern Africa (ESA) such as South Africa, Namibia and Malawi. At the relative scale, higher pro-rich relative inequalities were observed more frequently in Western and Central Africa (WCA), while lower inequalities tended to be observed in ESA.

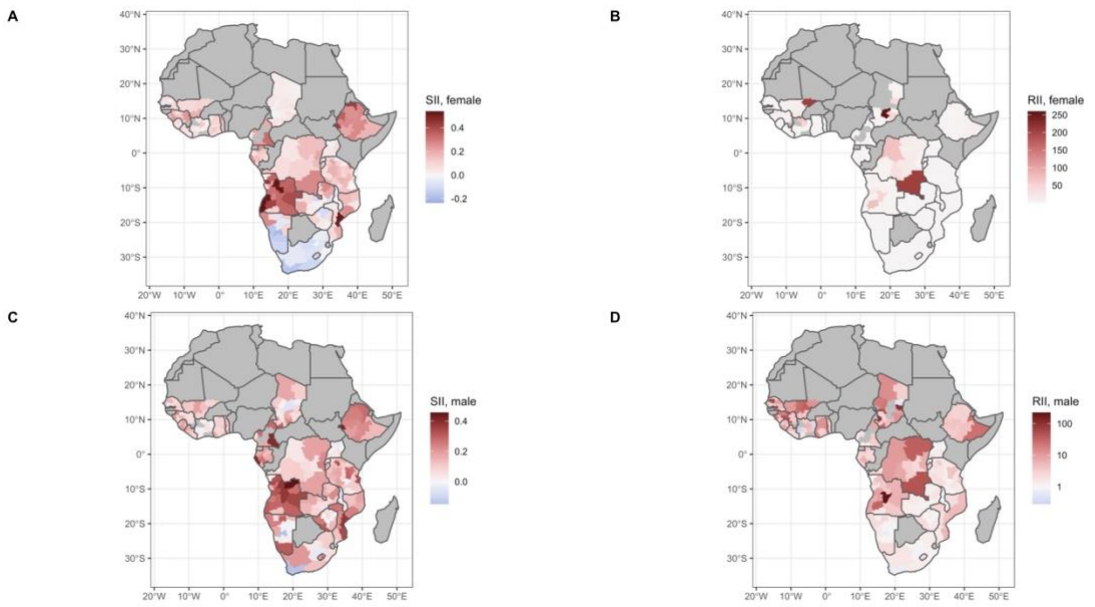

Figure 2. Province-level distribution of wealth-related inequalities in self-reported recent (<12 months) uptake of HIV testing at the A) and C) absolute scale and B) and D) relative scale among female and male participants, respectively, across 25 sub-Saharan African countries. Capped RII values between 0.1 and 300.

Spatial clustering analysis at fine scale

Global Moran's I showed that using one or two nearest neighbors gave the highest spatial autocorrelation for both genders and inequality indicators (Figure S5). For uniformity, we used *k=2* to calculate the *Getis-Ord Gi** statistics. Hotspots and coldspots of inequalities across SSA depended on the inequality scales used and gender (Figure 3). Overall, hotspots in both scales were more marked in WCA and few ESA countries such as Ethiopia (for women and men), Mozambique and Tanzania (only at relative scales for both genders), with area coverage changing depending on the scale and gender.

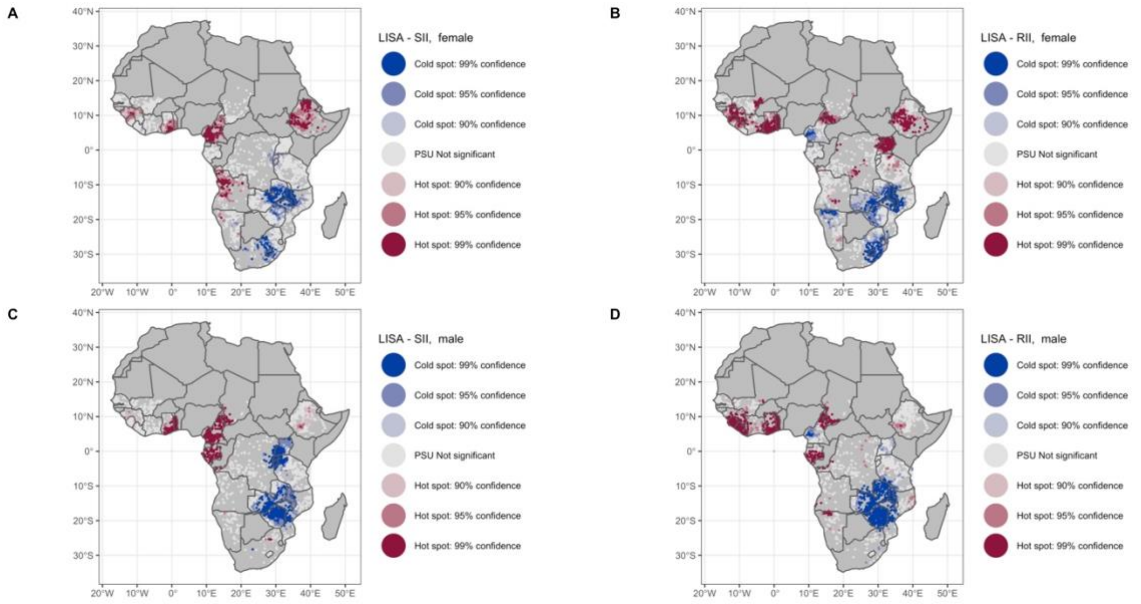

Figure 3. Local spatial autocorrelation of socioeconomic inequalities in self-reported recent (<12 months) uptake of HIV testing as Local Getis-Ord Gi* at Primary Sampling Unit (PSU) level (two nearest neighbors) across 25 sub-Saharan African countries between 2011 and 2019. Spatial clustering at the A) and C) absolute scales and B) and D) relative scales among female and male participants, respectively. Only PSUs with a sample size of at least 10 and more than one wealth quintile were included.

At the absolute scale, we observed pockets of high SII values in western Africa with a few areas in eastern Africa. Hotspots of absolute inequalities in self-reported recent HIV testing uptake were observed in Cameroon, Ghana, Togo and Ethiopia for both genders. In Angola and Namibia, there were also hotspots in few areas for women. Coldspots or pockets of low SII values were mostly observed in ESA such as Zambia, Zimbabwe, Burundi, Rwanda and small areas in Mozambique for both genders as well as in South Africa for women.

At the relative scale, we observed pockets of high RII values mostly in WCA with few areas in eastern Africa in Ethiopia for both genders and Uganda for women. Gabon and some parts in Tanzania had hotspot areas among men. Pockets of low RII values were noted in ESA. We observed coldspot regions for both genders in Burundi, Rwanda and for women in South Africa.

In addition, we also observed diverging patterns of hotspots and coldspots for each gender in the same country. There were pockets of high RIIs in Uganda among women, while pockets

of low RIIs in few areas were noted among men. Areas in Namibia, on the other hand, displayed coldspots of inequalities among women, while hotspots were noted among men.

Efficiency of HIV testing services

We assessed the efficiency of HIV testing services across geographical scales – whether testing services are reaching those with high HIV risk in the population. At the national level, HIV prevalence and proportion of recent HIV testing were found to be positively correlated in female and male participants (Figure S3).

However, this was not the case at subnational levels. Within-country correlation of province-level HIV prevalence and proportion of testing showed that in the majority of the countries these two variables were uncorrelated (i.e., the level of HIV testing did not always match the magnitude of HIV prevalence). Out of 25 countries, only in a few countries we observed 11 settings that had statistically significant positive correlations or "efficient HIV testing services" out of 50 settings for both genders (Figure S4) - Côte d'Ivoire (for both genders), Ethiopia (for both genders), Liberia (for males), Lesotho (for males), Sierra Leone (for males), Rwanda, (for females) Tanzania (for both genders) and Zambia (for females).

Similarly with province-level results, Figure 4 shows that at the PSU level, HIV prevalence did not correlate with the level of recent HIV testing in many of the countries for both genders which contrasted with what we observed at the national level (Figure S3). Only in Burundi (female), Mozambique (female), Namibia (male), Tanzania (both genders) and Zambia (both genders) did we observe a significant positive correlation (i.e., PSUs with higher HIV prevalence tended to have higher uptake of recent HIV testing). Meanwhile, in Lesotho, HIV prevalence and recent testing had a significant negative correlation (i.e., PSUs with higher HIV prevalence had lesser uptake of recent HIV testing).

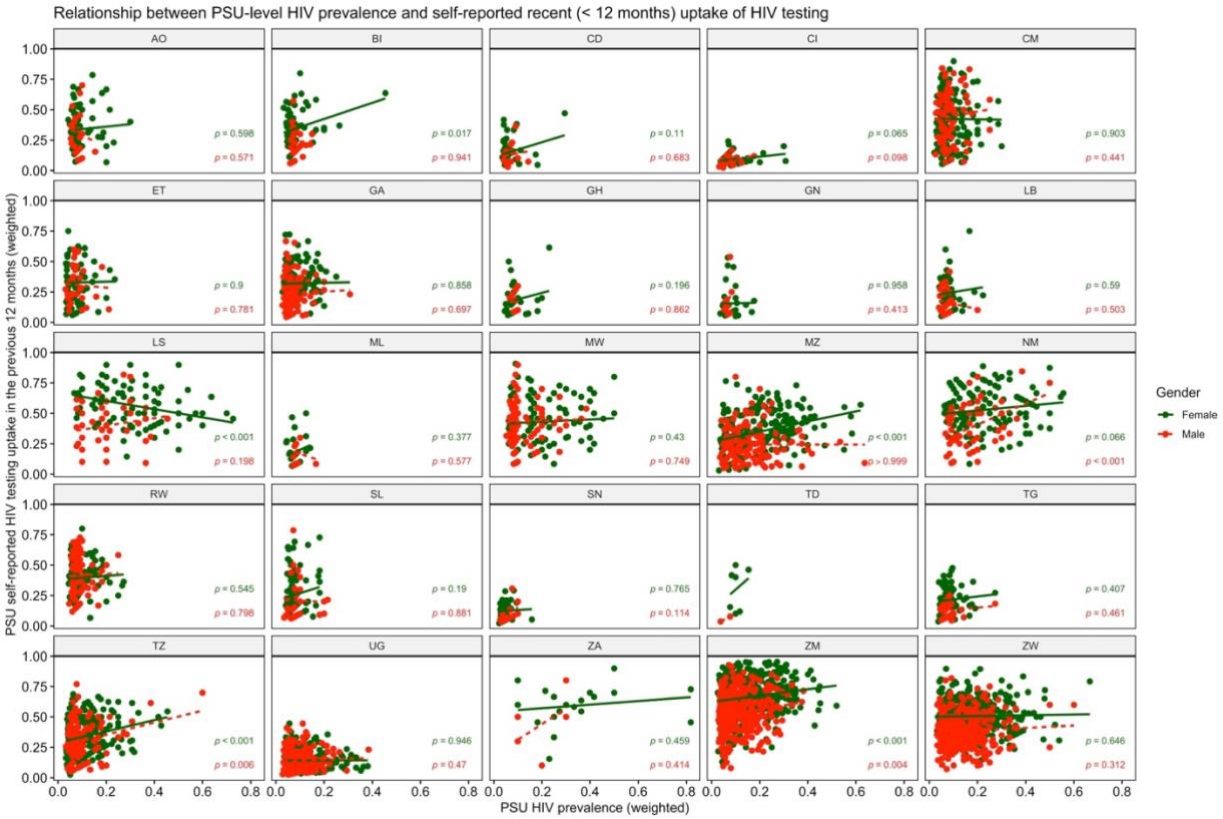

Figure 4. Correlation (Pearson's rho) between weighted HIV prevalence and weighted self-reported recent (< 12 months) uptake of HIV testing at the Primary Sampling Unit (PSU) level in 25 sub-Saharan African countries by gender. Only included PSUs with a sample size equal or higher than 10 with both the HIV biomarker and HIV testing variables. There were not sufficient clusters to calculate correlation p-values in Chad (TD). Each point represents a PSU.

Sensitivity analysis

Results of the local spatial clustering analysis were consistent when sub-setting by cluster size of at least 20 and 30 individuals (Figures S6 and S7). Patterns and areas with pockets of high and low inequalities were also consistent when conducting spatial clustering analysis across countries with surveys between 2011 and 2014 and between 2015 and 2019 separately, (Figure S8 and S9).

Discussion

In this study, we quantified and mapped absolute and relative socioeconomic inequalities of self-reported recent uptake of HIV testing in the previous 12 months at different geographical

scales. We also conducted spatial clustering analysis of such inequalities and explored the efficiency of HIV testing services at various geographical scales across SSA. Our results show existing inequalities at the national, province and PSU levels. Heterogeneities in the spatial distribution of these inequalities at subnational levels and variations in the hotspot areas of such inequalities varied depending on the inequality scale used and gender groups. We also revealed that at the national level, HIV testing programs seemed efficient in reaching those with high risk of acquiring HIV, but at the subnational levels, they seemed to be less efficient in the majority of the countries. The provinces and PSUs with higher recent testing uptake did not match the level of HIV prevalence in the majority of the countries for both genders which contrasts with the correlation of these factors at the national level.

We tended to observe higher HIV prevalence and proportion of recent HIV testing uptake in female participants and countries located in ESA. Higher inequalities were noted among men and in countries located in WCA where the epidemic is typically more concentrated among key populations. These findings were consistent with previous studies [3,5]. Higher HIV burden among women may be explained by higher vulnerability than men in SSA due to several factors such as domestic and gender violence and biological factors [23].
We also highlight that recent HIV testing is not shared equally across wealth levels in SSA (within and between countries) and that such inequalities are not randomly distributed across space. Indeed, our results also showed varying spatial patterns of recent HIV testing inequalities between absolute and relative scales and between female and male participants. This highlights the necessity for HIV testing programs to be tailored depending on the inequality to be addressed and the needs of each gender. We also observed that in few countries like Namibia, national-level inequality estimates showed low relative inequality for women and pro-poor inequality in the absolute scale for both genders. However, hotspots of inequalities were noted in few areas in the country. This suggests that national-level inequality estimates may hide inequalities found at a finer scale.

One could argue that pro-rich inequalities are not unfair especially if those with higher SEP also tend to be the ones who are more at-risk of acquiring HIV. We argue that this may have been true in the earlier stages of the epidemic, but current epidemiological evidence suggest that this may not be the case anymore. We did not assess this with our own data using HIV

prevalence due to the possibility of spurious results when using HIV prevalence rather than HIV incidence data. Prevalence represents a cumulative risk across time, changes slowly and may be affected by differential migration or mortality across SEP groups. However, a study by Santelli et al. showed that after 1997, individuals with lower SEP tended to have high HIV incidence [24]. In addition, a study by Hargreaves et al., although using HIV prevalence, found that HIV prevalence declined among those with higher SEP between 2003 and 2007 [25].

It is important to measure and monitor inequalities at different geographical scales. National estimates are often use for funding allocations by donors, prioritization of programs and comparison especially for inequality metrics. Province-level estimates are important because health programs and interventions are usually implemented at this level, and important for the within-country allocation of funds. Fine-scale analyses are important because they allow for visualization of small-scale variations to precisely target communities in need. The seemingly sub-optimal efficiency of HIV testing programs at subnational levels (i.e., levels of HIV testing which do not match HIV prevalence) may suggest the failure of HIV programs in some settings to reach those who are at-risk of HIV. HIV prevalence was used as a measure of risk for HIV-negative individuals since HIV prevalence reflects the probability of having a HIV-positive partner. However, risk may be affected when the PLHIV undergo ART ensuring viral suppression and thus preventing transmission. Another potential reason is the likelihood that many international and, in some cases, local governments rely on national estimates when implementing HIV programs across different geographical levels due to lack of monitoring of inequalities at smaller scales. If individuals who are more at-risk of HIV are also those with lower SEP, the findings at the subnational levels also imply that pro-rich inequalities in HIV testing services in some settings may lead to inefficient programs, or vice versa, due to lack of an equitable distribution of services tailored to population needs.

This study carries several limitations. First, the self-reported nature of HIV testing uptake may have resulted in under-reporting due to social desirability bias and reporting bias of sensitive information. Second, differential accuracy in self-reporting across socioeconomic groups might have biased our results. Evidence in cancer screening suggest that over-reporting of self-reported screening is common among disadvantaged groups such as racial minorities [26]. If this also applies to self-reporting of HIV testing, this may have led

to an under-estimation of the pro-rich inequalities and over-estimation of the pro-poor inequalities in few countries such as Lesotho and Zimbabwe, that we observed. While self-reported HIV testing history over a lifetime was found to be highly sensitive (96-99%) [27], self-reported recent testing may also be prone to telescoping bias. This refers to the time-based displacement of an event where people perceive recent events as remote and vice versa which may have led to over-reporting of testing [28]. Third, the wealth index can only measure relative wealth within a country. However, it can measure long-term SEP and has also been found to be more stable than consumption expenditure especially in the Global South where informal economy is common. Lastly, some available DHS surveys were conducted before 2014 and may not have captured more recent patterns of inequalities.

In conclusion, to our knowledge, this is the first study to provide a broad context of the socioeconomic inequalities in HIV testing in SSA by quantifying and mapping them at different geographical levels in both absolute and relative scales and by assessing the efficiency of HIV testing services at different levels. By providing estimates of such inequalities at national, province, and PSU levels, and by localizing their hotspots, these findings may help policymakers, local and international organizations to prioritize areas and groups that need HIV testing efforts, while increasing efficiency and saving money. Our results also show the need to monitor inequalities and assess the efficiency of HIV testing services in reaching those who are at-risk of HIV at smaller geographical scales as a complement to national estimates that have the tendency to mask disparities.

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Supplementary material

Table S1. Total number of participants in Primary Sampling Units that have at least 10 individuals. n: Total number of participants.

ISO	Country	Year	Female (n)	Male (n)
AO	**Angola** (WCA)	**2015-16**	11736	2489
BI	**Burundi** (ESA)	**2016-17**	16046	5439
CD	**Congo DR** (WCA)	**2013-14**	9110	3372
CI	**Côte d'Ivoire** (WCA)	**2011-12**	1781	1402
CM	**Cameroon** (WCA)	**2018**	14393	6080
ET	**Ethiopia** (ESA)	**2019**	9711	7895
GA	**Gabon** (WCA)	**2012**	7422	4668
GH	**Ghana** (WCA)	**2014**	8223	1404
GN	**Guinea** (WCA)	**2018**	7383	1164
LB	**Liberia** (WCA)	**2019**	8897	2669
LS	**Lesotho** (ESA)	**2014**	6370	907
ML	**Mali** (WCA)	**2018**	5541	1106
MW	**Malawi** (ESA)	**2015-16**	24204	3549
MZ	**Mozambique** (ESA)	**2015**	7113	4163
NM	**Namibia** (ESA)	**2013**	9160	1760
RW	**Rwanda** (ESA)	**2014-15**	12440	4808
SL	**Sierra Leone** (WCA)	**2019**	14654	4239
SN	**Senegal** (WCA)	**2017**	15952	3796
TD	**Chad** (WCA)	**2014-15**	4389	607
TG	**Togo** (WCA)	**2013-14**	8926	2802
TZ	**Tanzania** (ESA)	**2011-12**	10037	6754
UG	**Uganda** (ESA)	**2011**	9287	7707
ZA	**South Africa** (ESA)	**2016**	6581	634
ZM	**Zambia** (ESA)	**2018**	13276	11740
ZW	**Zimbabwe** (ESA)	**2015**	9876	8259

Figure S1. PSU distribution among women A) sample size and B) proportion of self-reported uptake of recent (< 12 months) HIV testing.

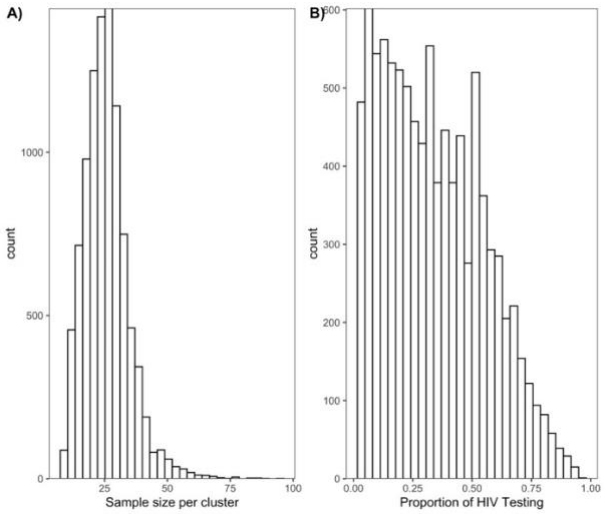


Figure S2. PSU distribution among men A) sample size and B) proportion of self-reported uptake of recent (< 12 months) HIV testing.

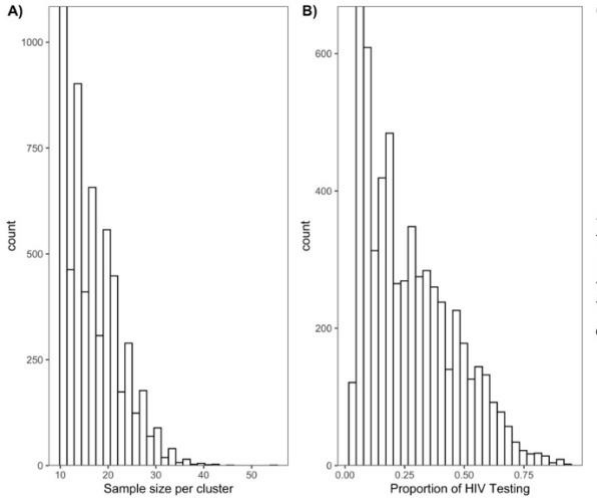


Figure S3. Correlation (Pearson correlation) between weighted HIV prevalence and weighted self-reported recent (< 12 months) uptake of HIV testing at the national level in 25 sub-Saharan African countries by gender.

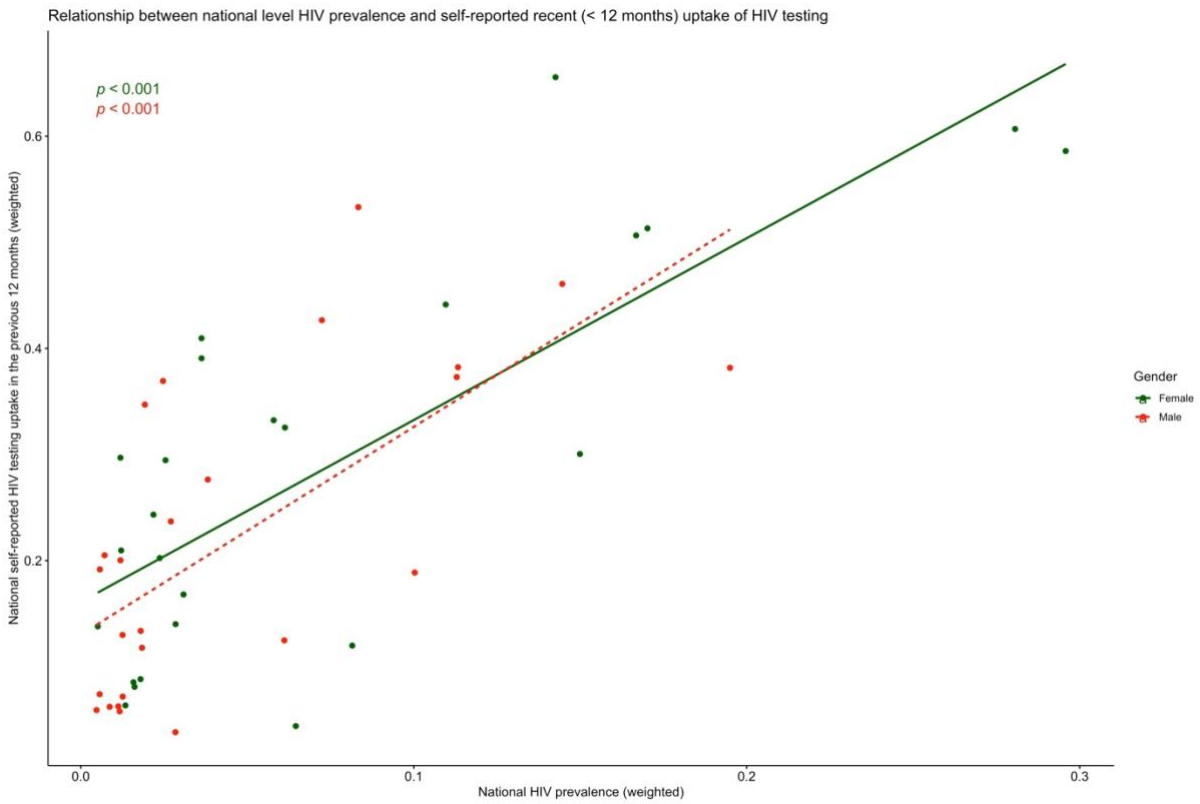


Figure S4. Correlation (Pearson correlation) between weighted HIV prevalence and weighted self-reported recent (< 12 months) uptake of HIV testing at the regional level in 25 sub-Saharan African countries by gender. Only included regions with both the HIV biomarker and HIV testing variables.

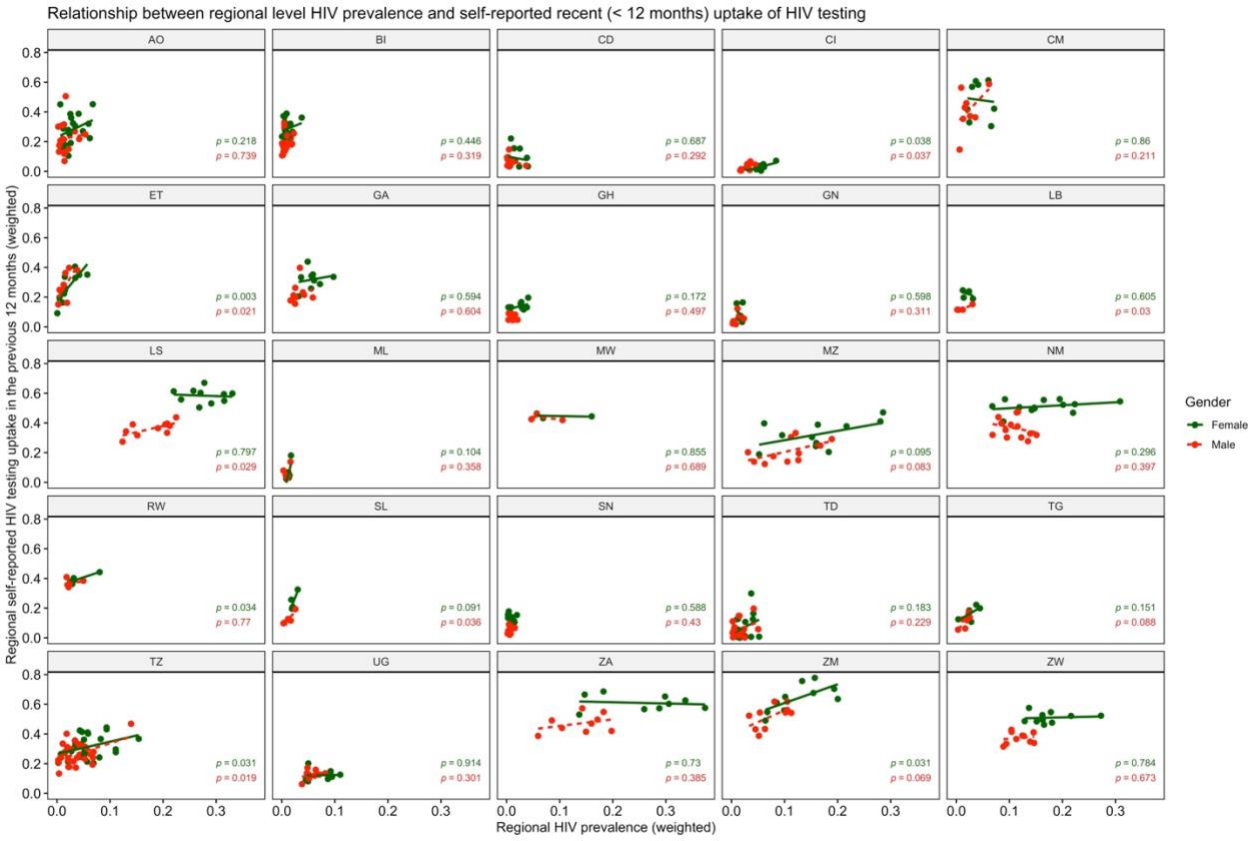


Figure S5. Global Moran's I statistic test by number of nearest neighbor (1-10) by gender and inequality scales. SII: Slope Index of Inequality, RII: Relative Index of Inequality.

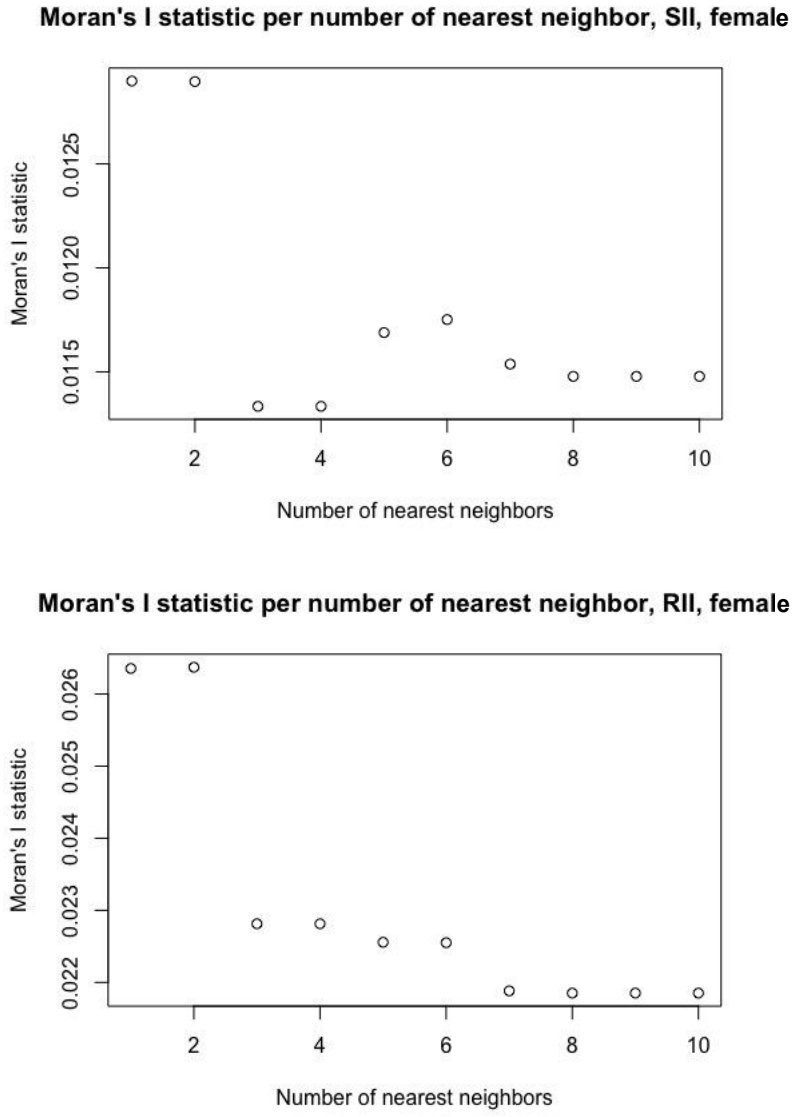
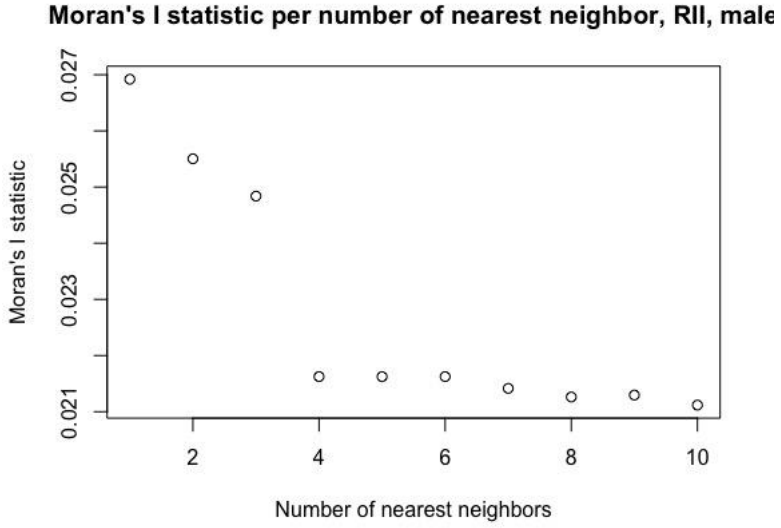


Figure S5 (continued). Global Moran's I statistic test by number of nearest neighbor (1-10) by gender and inequality scales. SII: Slope Index of Inequality, RII: Relative Index of Inequality.



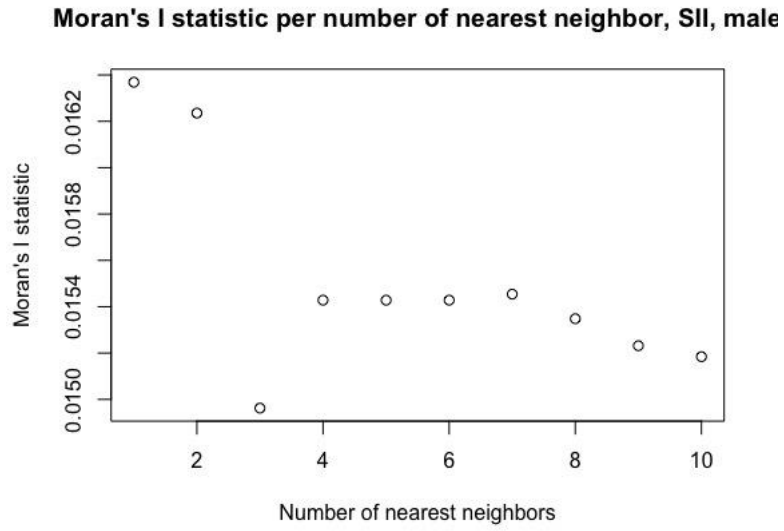


Figure S6. Sensitivity analysis of local spatial autocorrelation of socioeconomic inequalities in self-reported (<12 months) uptake of HIV testing as Local Getis-Ord Gi* at Primary Sampling Unit (PSU) level (2 nearest neighbors) across sub-Saharan African countries. Spatial clustering at the A) and C) absolute scales and B) and D) relative scales among women and men, respectively. Only PSUs with a sample size of at least 20 and more than one wealth quintile were included.

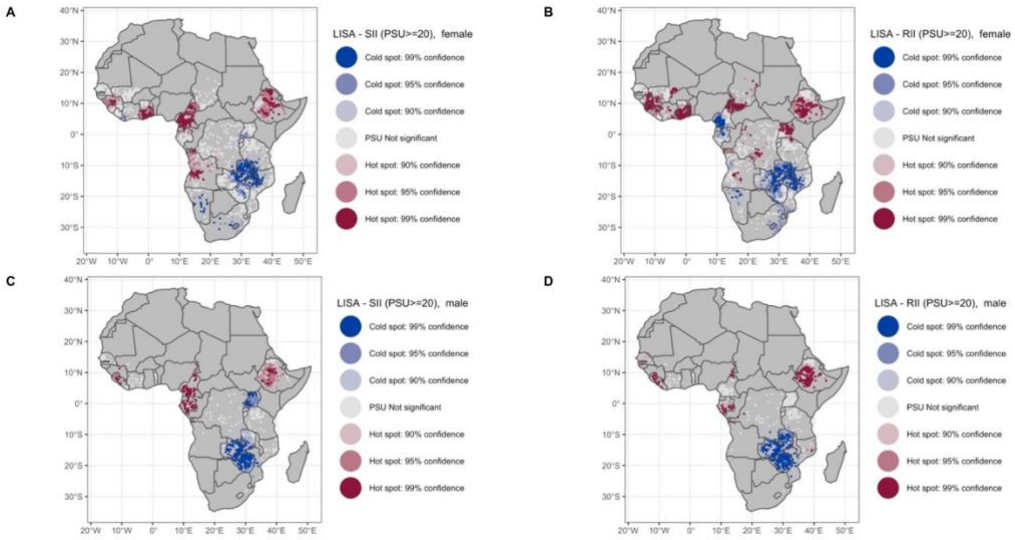


Figure S7. Sensitivity analysis of local spatial autocorrelation of socioeconomic inequalities in self-reported (<12 months) uptake of HIV testing as Local Getis-Ord Gi* at Primary Sampling Unit (PSU) level (2 nearest neighbors) across sub-Saharan African countries. Spatial clustering at the A) and C) absolute scales and B) and D) relative scales among women and men, respectively. Only PSUs with a sample size of at least 30 and more than one wealth quintile were included.

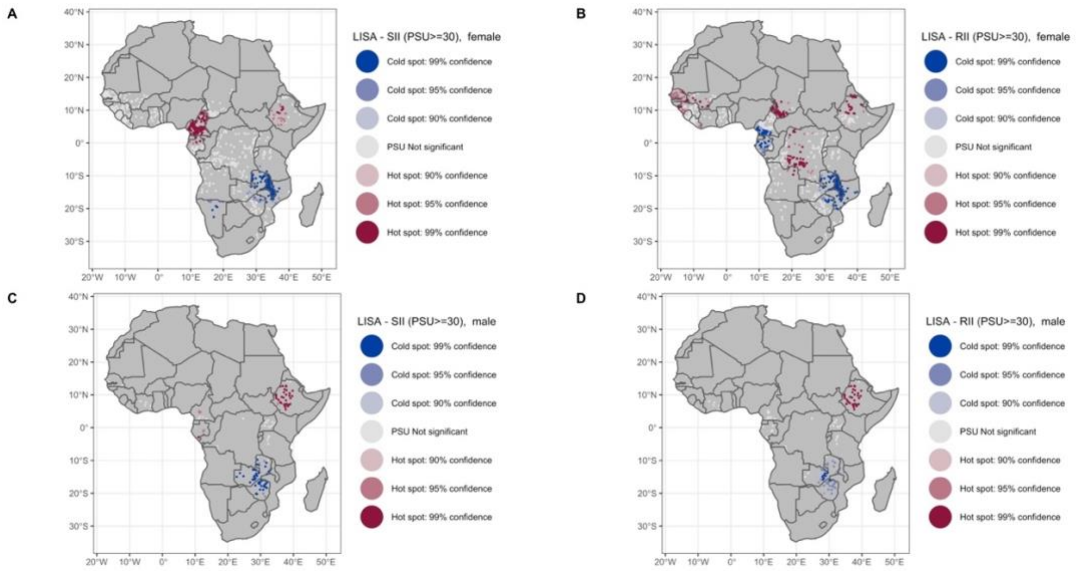


Figure S8. Sensitivity analysis of local spatial autocorrelation of HIV testing socioeconomic inequalities as Local Getis-Ord Gi* at PSU level (two nearest neighbors) across sub-Saharan African countries with surveys between 2011 and 2014. Spatial clustering at the A) and C) absolute scales and B) and D) relative scales among women and men, respectively. Only PSUs with a sample size of at least 10 and more than one wealth quintile were included.

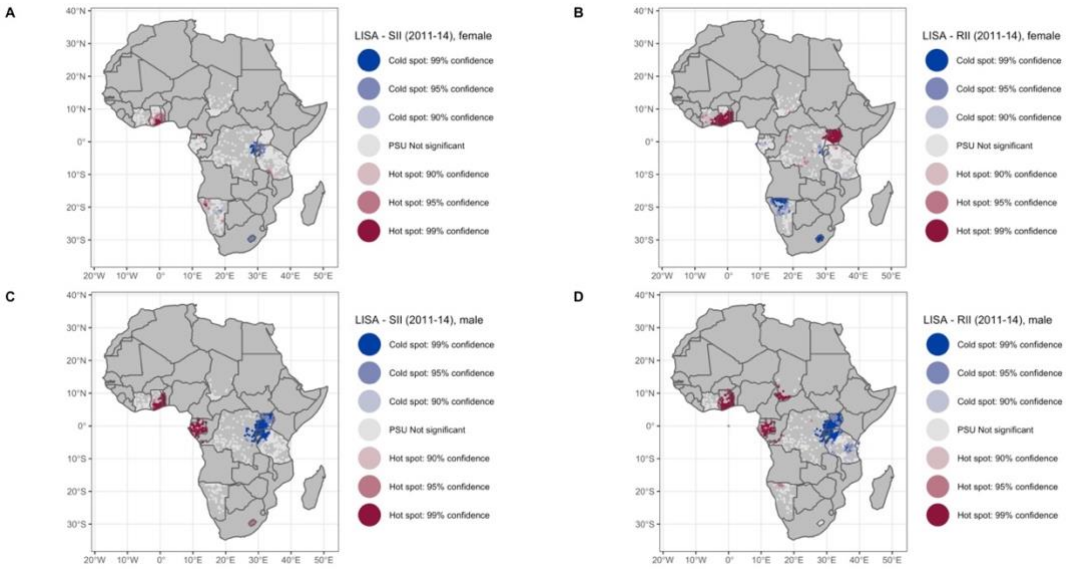
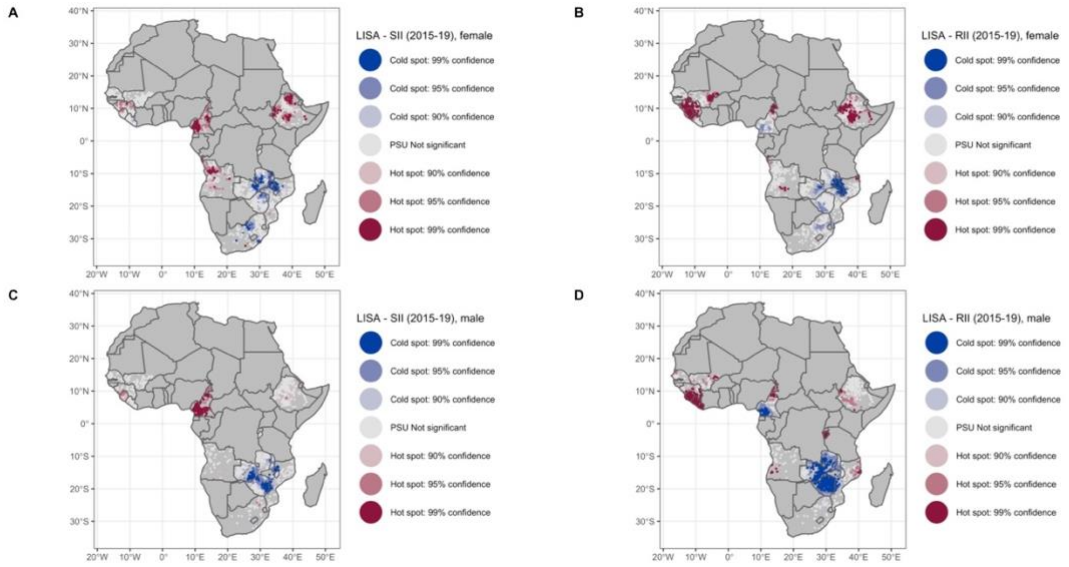


Figure S9. Sensitivity analysis of local spatial autocorrelation of HIV testing socioeconomic inequalities as Local Getis-Ord Gi* at PSU level (two nearest neighbors) across sub-Saharan African countries with surveys between 2015 and 2019. Spatial clustering at the A) and C) absolute scales and B) and D) relative scales among women and men, respectively. Only PSUs with a sample size of at least 10 and more than one wealth quintile were included.



10. Short Article 3 – Contextual factors associated with socioeconomic inequalities in HIV testing

10.1. Summary

After assessing inequalities in recent HIV testing in Chapters 8 and 9, in national and subnational levels, the next step would be to assess their contextual determinants. This chapter corresponds to a short communication which was developed based on a poster presentation submitted to the AIDS 2020 conference. To reach the first 95% of the 2030 UNAIDS 95-95-95 targets, it is crucial to better understand the contextual factors driving inequalities in HIV testing uptake – whether they are mostly influenced by national HIV prevalence or by macro-economic factors. To shed light on this issue, we measured socioeconomic inequalities in recent HIV testing across SSA by calculating the country-specific Erreygers Concentration Index (ECI) and decomposed them using a novel method, the Recentered Influence Function (RIF) decomposition method. We assessed the influence of national HIV prevalence or per capita GDP on the socioeconomic inequalities in recent HIV testing. GDP per capita was used as the macro-economic factor in this specific work due to its availability for all 16 SSA countries from the World Bank database and it is a widely used indicator of economic growth of a country relative to its population (United Nations, 2007).

The ECI was chosen as the measure of inequality in this specific work for the following reasons: 1) it is a corrected version of the CI adapted to a binary outcome (Erreygers, 2009), 2) the RIF decomposition regression method is more adapted to such index compared to the SII and RII, and 3) it provided an opportunity to assess the consistency of inequality estimates using other measure of inequality other than the SII and RII.

In the RIF regression decomposition, we assumed a linear regression between the dependent and independent variables which indicates that the RIF is the dependent variable in an ordinary least square regression whose coefficients are the marginal effects of the covariates on the ECI (Cai et al., 2017; Heckley et al., 2016). The advantages of using this method are: i) it explains the causes of socioeconomic inequality by directly decomposing the weighted covariance of

health and socioeconomic rank; ii) it is capable of decomposing many forms of inequality measures such as the ECI and CI (Heckley et al., 2016); iii) it requires fewer and less restrictive assumptions (Heckley et al., 2016); and iv) simple to estimate and easy to interpret (Cai et al., 2017; Firpo et al., 2009; Heckley et al., 2016).

We found that recent HIV testing uptake was more concentrated among the rich in 12 of 16 SSA countries. Preliminary findings show that national HIV prevalence seemed to be associated with wealth-related inequalities in recent testing, rather than the per capita GDP. This short paper has been posted on medRXiv.

Epidemiological rather than macro-economic factors correlate with socioeconomic inequalities in HIV testing in 16 sub-Saharan African countries

***Running head*: Epidemiological rather than macro-economic factors correlate with socioeconomic inequalities in HIV testing**

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Keywords: HIV; HIV testing; socioeconomic inequalities; contextual factors; sub-Saharan Africa; decomposing inequalities

Main text

As the entry point to many HIV prevention and care services, HIV testing constitutes the first 95 (95% of people living with HIV will know their status) in the UNAIDS ambitious 95-95-95 targets by 2030 in ending the AIDS epidemic [1]. However, socioeconomic inequalities have been well documented in HIV testing, especially in sub-Saharan Africa (SSA), hindering the design of effective and efficient testing strategies. In order to increase testing uptake, better understanding the contextual drivers of these inequalities is necessary. For instance, it is unclear whether they are mostly influenced by epidemiological or by macro-economic factors. Here, to shed light on this issue, we measured and decomposed socioeconomic inequalities in HIV testing in SSA in relation to contextual factors.

We used data from the most recent Demographic and Health Surveys (DHS) conducted between 2011 and 2016 in a set of 16 SSA countries based on a previous study [2]. DHS are standardized nationally representative population-based surveys regularly conducted in low- and middle-income countries to collect data over a wide range of sociodemographic and health indicators including HIV and AIDS indicators such as HIV biomarkers [3]. They have a multistage sampling design with household as sampling units. Individuals aged 15-59 years (majority 15-49 years) in selected households are generally eligible to be included in the survey. The DHS wealth index was used to define participants SEP, particularly the relative rank of individuals in the cumulative distribution of the wealth index. The outcome of interest was the self-reported uptake of HIV testing in the last 12 months. Being HIV positive was defined as having a positive test in the DHS serological survey. Country-specific per-capita Gross Domestic Products (GDP) of the corresponding survey years were obtained from the World Bank official website (https://www.worldbank.org/).

First, we calculated the country-specific Erreygers Concentration Index (ECI, values range from -1 to 1 with 0 indicating equality) while accounting for clustering to estimate wealth-related inequalities in recent HIV testing uptake [4]. Positivity (ECI > 0) indicates that HIV testing was more concentrated among the rich while negativity (ECI < 0) indicates testing was more concentrated among the poor. Second, country-level inequality estimates were decomposed using the Recentered Influence Function (RIF) regression decomposition method to assess the marginal effect of each country-level factor (i.e., national HIV prevalence and per capita GDP) on the ECI [5]. Each contextual factor was assessed separately. To do this, we considered the RIF value of the ECI as our dependent variable in the RIF regression [5]. The RIF is based on the influence function which is used to assess the influence of a perturbation in a distribution on the value of the statistical estimate without recalculating such statistic [6].

We analyzed 16 surveys conducted among 315,847 participants (≥ 15 years old) in Cameroon, Côte d'Ivoire, Democratic Republic of Congo (Congo DR), Ethiopia, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Niger, Rwanda, Sierra Leone, Tanzania, Zambia and Zimbabwe. Significantly positive ECI values ranging from 0.03 [95% Confidence Interval 0.01; 0.05] to 0.21 [95% CI 0.19; 0.23], indicating concentration of HIV testing uptake among the rich, were observed in 12 out of 16 countries. No inequalities were observed in Zimbabwe, Rwanda, Lesotho and Zambia. Figure 1 presents the relationship between country-level ECIs and i) national HIV prevalence; or ii) per-capita GDP. Coefficients from the RIF regression could be interpreted similarly to a standard linear regression. RIF decomposition analysis showed that an increase in national HIV prevalence decreased inequality in recent HIV testing (coefficient -5.5×10^{-3} 95% CI [-9.6×10^{-3}; -1.3×10^{-3}]); while GDP per capita had no significant association with inequality (Coefficient 3.2×10^{-5} [-1.1×10^{-4}; 4.7×10^{-5}]).

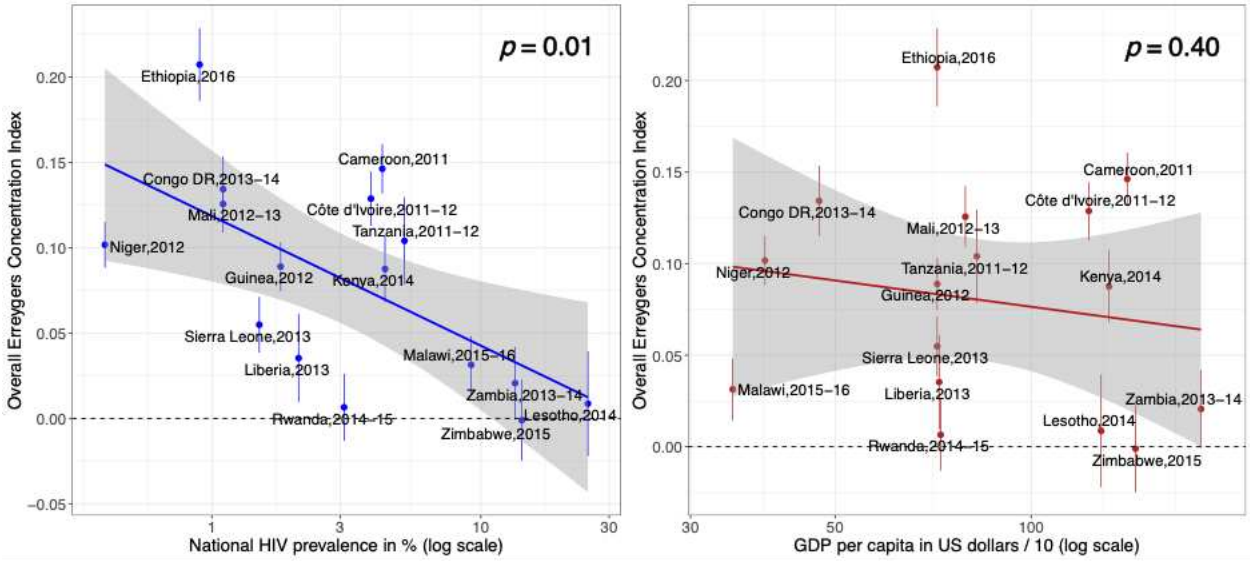

Figure 1. Relationship between country-level Erreygers Concentration Index and national HIV prevalence or GDP per capita in US dollars.

Despite the overall increase in HIV testing in recent years, important pro-rich socioeconomic inequalities in recent testing remained in the majority of SSA countries. Our results suggest that the level of national HIV prevalence seemed to correlate with wealth-related inequalities in recent HIV testing uptake and not with per capita GDP. These findings are consistent with the patterns we observed in a previous study where countries with low HIV prevalence tended to be the countries with low HIV testing uptake as well as high pro-rich inequalities [2]. In countries with high HIV prevalence (e.g., Zimbabwe and Zambia), the difference in recent HIV testing between the richest and poorest individuals seemed to be less considerable compared to countries with low prevalence (e.g., Ethiopia and Niger). These results suggest that HIV testing efforts tend to be large in countries with high HIV prevalence. Indeed, a study found that HIV spending was associated with HIV prevalence [7]. Thus, this shows that inequalities in HIV testing tend to be low in countries with large efforts of HIV testing services.

Results do not suggest a clear pattern of the relationship between per capita GDP and country-level wealth-related inequalities in recent HIV testing. The literature also shows mixed evidence on the relationship of economic growth and inequalities with no clear resolution [8,9]. However, our results somewhat propose that having a higher GDP per capita does not necessarily translate into having lesser levels of inequalities in a country, and vice versa. This may mean that uptake of or access to HIV testing services in richer SSA countries is not necessarily more equitable than in poorer societies.

This study has several limitations. We only had 16 country-level estimates in the RIF regression which limited us to only conduct bivariate analysis. Countries also have different survey years, making between-country comparisons not possible. Since our samples were countries, this may not represent patterns at smaller geographical scales. Despite these limitations, our study is among the first to quantify and compare the impact of contextual drivers on inequalities in HIV testing using an innovative methodology and robust data. This novel method had been also utilized in other fields such as in mental health investigating how population changes influenced income-related inequalities in psychiatric diagnoses over time in Sweden [10] and in ageing and health decomposing the effect of factors on health inequality among the elderly in China [11].

In conclusion, our results, which underline the significantly increased socioeconomic inequalities in HIV testing in low prevalence countries, suggest that national HIV prevalence may explain country-level wealth-related inequalities in HIV testing uptake instead of the economic growth of a country. However, more research is needed, integrating a wider range of epidemiological and socioeconomic variables stratified by gender to fully understand the role of epidemiology and economy on inequalities in HIV testing.

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All authors discussed and planned the study. PAAT extracted and collated the data. PAAT conducted the analysis with inputs from LT and KJ. All authors discussed and interpreted the results. PAAT wrote the initial draft of the report. All authors contributed to subsequent revisions. All authors read and approved the final version of the manuscript.

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11. Article 4 - Mediating factors in the pathway between SEP and HIV testing at the individual level

11.1. Summary

As discussed previously, SEP can affect health outcomes in different pathways and mechanisms including individual characteristics. In Chapter 10, we had a glimpse of contextual factors that may be associated with inequalities in recent testing. In this chapter, individual-level determinants of socioeconomic inequalities in recent HIV testing were investigated. We assessed potential mediating pathways linking SEP and recent HIV testing at the individual level in 18 SSA countries between 2010 and 2018. Pre-identified mediators were categorized into two groups – *demand-related* mediators (characterizes individual's ability to perceive need for and inclination to seek care) and *supply-side* mediators (individual's ability to reach, pay for and engage in health care). The total effect of wealth on recent HIV testing adjusted for confounders (age, type of residence and family situation) was used to quantify inequalities. Pro-rich inequalities in recent testing with variations in magnitudes were observed in majority of the countries. We conducted mediation analysis in countries with substantial inequalities. The richest were more likely to have a favorable condition regarding these mediators such as having comprehensive knowledge about HIV, lesser stigma towards PLHIV and lesser problems to seek care, and these mediators were also positively associated with recent HIV testing. We found no single, strong mediator in the pathway between wealth and recent testing that was consistently strong across all countries and genders, but our findings show that inequalities were mediated more by demand- more than supply-side individual characteristics. The importance of each mediator varied greatly by country and gender. This indicates that addressing inequalities in testing may be addressed not only by tackling a single factor but would require upstream and well-tailored interventions.

This paper has been submitted to the AIDS journal and is currently under review.

Understanding the pathways leading to socioeconomic inequalities in HIV testing uptake in 18 sub-Saharan African countries: a mediation analysis

***Running head*: Pathways leading to socioeconomic inequalities in HIV testing**

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Abstract

Objective:

To better understand the different pathways linking socioeconomic position and HIV testing uptake in 18 sub-Saharan African (SSA) countries.

Design:

We used cross-sectional population-based surveys between 2010 and 2018.

Methods:

Using a potential outcomes framework and the product method, we decomposed the total effect linking wealth and recent (<12 months) HIV testing into i) direct effects, and ii) indirect effects, via *demand-related* (related to individual's ability to perceive need for and to seek care) or *supply-related* (ability to reach, pay for and engage in healthcare) mediators to calculate the proportion mediated (PM) by each mediator.

Results:

High levels of inequalities were observed in nine and 15 countries among women and men, respectively. The mediator indirect effect varied greatly across countries. The PM tended to be higher for *demand-related* than for *supply-related* mediators. For instance, among women, HIV-related knowledge was estimated to mediate up to 12.1% of inequalities in Côte d'Ivoire; and up to 31.5% for positive attitudes toward people living with HIV (PLHIV) in Senegal. For the four *supply-related* mediators, the PM was systematically below 7%. Similar findings were found when repeating analyses on men for the *demand-related* mediators, with higher PM by attitudes toward PLHIV (up to 39.9%) in Senegal.

Conclusions:

Our findings suggest that wealth-related inequalities in HIV testing may be mediated by the *demand-side* more than *supply-side* characteristics, with important variability across countries. Overall, the important heterogeneities in pathways of wealth-related inequalities in HIV testing illustrates that addressing inequalities requires tailored efforts and upstream interventions

Keywords: HIV; HIV testing; socioeconomic inequalities; health inequalities; sub-Saharan Africa; mediation analysis

Introduction

HIV continues to affect many lives globally especially in sub-Saharan Africa (SSA) which accounts for 67% of people living with HIV (PLHIV) in 2020 [1] making HIV prevention and treatment essential, particularly in this region. HIV testing has played a crucial role in the prevention and management of HIV/AIDS as the entry point that links individuals to prevention and treatment services.

The routine offer of HIV testing in health settings, such as antenatal clinics was recommended by the World Health Organization in 2007 [2], which changed the profiles of testing users and increased uptake in HIV testing [3]. However, in spite of the significant progress in reducing HIV incidence over the past decade in SSA, HIV incidence has not declined sufficiently to reach the UNAIDS 90-90-90 fast-track goals by 2020 and the Sustainable Development Goal to end the AIDS epidemic by 2030 [4]. A modelling study that investigated the progress towards the first 90 (90% of PLHIV will know their status) found that 84% of PLHIV in SSA knew their status by 2020, with proportions consistently lower in Western and Central Africa (WCA, 67% and 70%, respectively) than in Eastern and Southern Africa (ESA, 86% and 90%, respectively) [5]. There is still a gap of around 3.8 million PLHIV left undiagnosed in SSA [5].

Health inequalities that favor the wealthiest subgroups have also persisted in most SSA countries, especially in WCA [6]. Studies found that people with higher socioeconomic

position (SEP) was associated with better knowledge of HIV status and increased likelihood to seek testing [7–13]. Potential drivers of these inequalities include knowledge about HIV, stigma, distance to care and cost of services, among many others. A study found that cost of services and physical distance between health facilities were the most significant supply-side barriers in accessing obstetric care in SSA [14]. We hypothesize these drivers to also be important barriers in the uptake of HIV testing. Documenting such mechanisms can be useful in understanding the role of each factor in driving such inequalities.

Despite the literature in socioeconomic inequalities in HIV testing, few studies have explored their possible underlying mechanisms. Such studies are timely to help better orientate testing strategies in order to reach the first 95 of the 2030 UNAIDS 95-95-95 targets and to ensure "no one is left behind". In this study, we analyzed population-based surveys to understand mediating factors linking SEP and HIV testing uptake at the individual level.

Methods

Data and Study Design

We analyzed data from the Demographic and Health Surveys (DHS) conducted between 2010 and 2018 to understand the role of different mediating factors in the pathway between SEP and recent (< 12 months) HIV testing uptake.

The DHS are publicly available nationally representative population-based surveys, conducted regularly in low- and middle-income countries (LMIC) which collect data on a

wide range of objective and self-reported health indicators including data on HIV/AIDS, using a two-stage sampling design [15]. All women aged 15-49 years are eligible in all households and, in some surveys, men aged 15-54/59 from a sub-sample are also eligible to participate (https://dhsprogram.com/). Those who consented are interviewed face-to-face by trained interviewers using a standardized questionnaire that includes items on different sociodemographic characteristics, maternal and reproductive health, and HIV-related questions [15].

Country sample was based on convenience sampling (with data available as of February 2021) that was slightly extended from a previous study [6]. In total, we analyzed 10 WCA countries (Burkina Faso, Cameroon, Côte d'Ivoire, Congo DR, Guinea, Liberia, Mali, Niger, Senegal and Sierra Leone) and eight ESA countries (Ethiopia, Kenya, Lesotho, Malawi, Rwanda, Tanzania, Zimbabwe and Zambia).

The national implementing agencies and research institutes that conducted the surveys were responsible for ethical clearance which ensured informed consent from the participants prior to their involvement and guaranteed confidentiality of information [16].

Variables

Socioeconomic Position

We defined participant SEP based on the DHS wealth index, a composite measure of household wealth based on living standards such as household assets and characteristics [17].

More specifically, we used the wealth rank of the participants in the country-specific cumulative distribution of the wealth index, a continuous variable ranging from 0 to 1.

Outcome variable

The outcome of interest was the self-report of recent (< 12 months) HIV testing.

Mediators

We selected six potential individual-level mediators available in the DHS that we hypothesized to be in the pathway between wealth and recent HIV testing based on the literature. We categorized these mediators into two categories based on a principal component analysis for women (Appendix Figure S1).

The first category of mediators referred to the individual's ability to perceive the need for and to seek care [18] (i.e., HIV-related knowledge and positive attitudes toward PLHIV). The second category included factors that characterize the ability to reach, pay for, and engage in health care [18] (i.e., reporting no distance-related problem to seek care, reporting no money-related problem to seek care, no permission needed from spouse/partner to seek a doctor and no/single difficulty in seeking care). For simplicity, we labelled the first category *demand-related* and the second category *supply-related* mediators. *Supply-related* variables were only available for women in the DHS except in Tanzania.

All mediators were coded as binary variables with favorable responses coded as 1. Complete descriptions of these variables and how they were constructed can be found in Appendix Table S1.

Confounders

The confounders that we identified a priori were age (15-24, 25-34, 35 and above), type of residence (urban and rural) and family situation (in a union, single and widowed/separated).

Statistical analysis

Firstly, we estimated country- and gender-specific percentages of reporting favorable levels of the mediators and recent HIV testing while accounting for survey design and sampling weights. We also calculated the proportions of the mediators at favorable levels between the richest and poorest quintiles.

Secondly, we fitted multivariable modified Poisson regressions adjusting for confounders and accounting for survey design to compute the inequalities and mediated effects [19]. We estimated the wealth-related inequalities in recent HIV testing by estimating the total effect (TE) of wealth on recent testing using Equation 1.

$$\mathrm{P}(recent\ HIV\ testing) = f(wealth,\ confounders) \text{ [Equation 1]}$$

Outcome model:

$\mathrm{P}(recent\ HIV\ testing) = f(wealth, mediator, EM\ interaction,\ confounders)$ [Equation 2],

where EM = exposure-mediator.

Mediator model:

$$\mathrm{P}(mediator) = f(wealth,\ confounders) \text{ [Equation 3]}$$

Thirdly, we applied different outcome and mediator models (Equations 2 and 3) using the product method based on the potential outcomes framework [20,21] to explore different pathways linking wealth and recent HIV testing through the demand-related and supply-related mediators. We explored each mediator separately and assumed that they do not influence one another in the analysis. We considered four assumptions in this analysis: (1) no unmeasured exposure – outcome confounding, (2) no unmeasured mediator – outcome confounding, (3) no unmeasured exposure – mediator confounding, and (4) none of the mediator – outcome confounder is itself affected by the exposure [22]. Figure 1 shows the Directed Acyclic Graph (DAG) of the pathways that we explored.

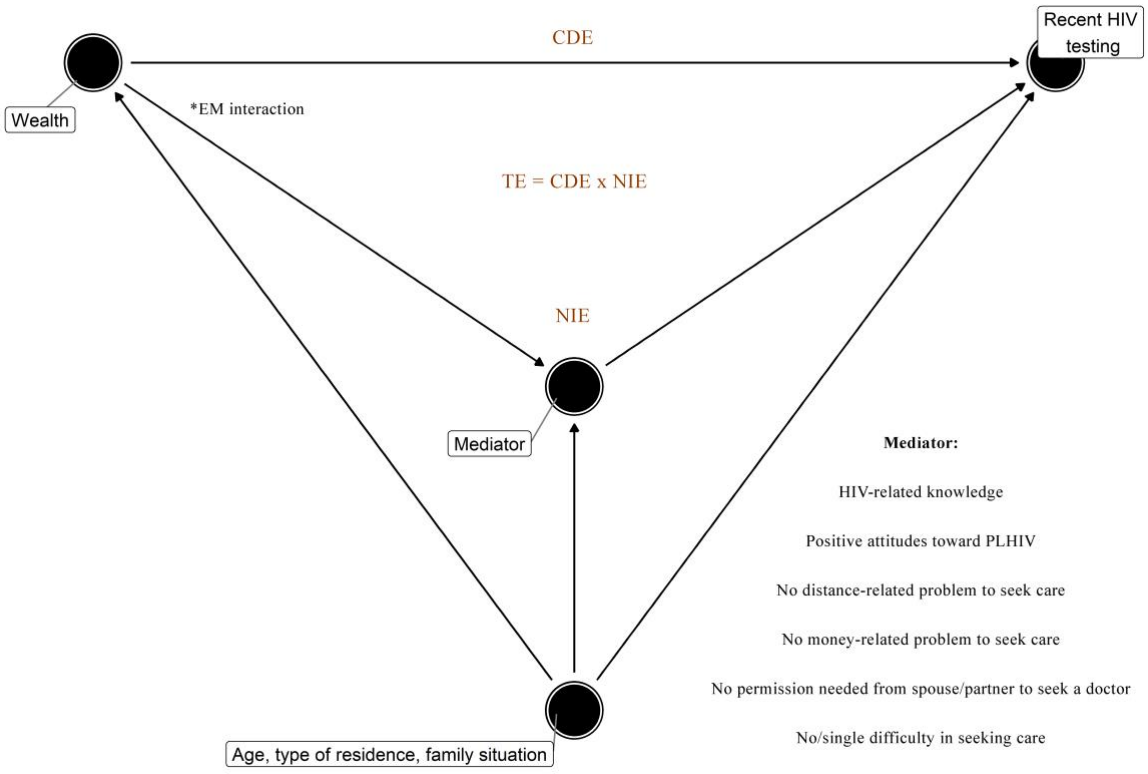

Figure 1. **DAG illustrating the pathway between wealth and recent (< 12 months) HIV testing through each mediator while adjusting for confounders (i.e., age, type of residence and family situation) and exposure-mediator interaction when present (*).** The TE of wealth on recent HIV testing could be disentangled into the CDE and the NIE.

TE: Total Effect. CDE: Controlled Direct Effect. NIE: Natural Indirect Effect. EM: Exposure-mediator.

Lastly, we estimated the proportion mediated (PM, in %) by each mediator. The PM is the proportion of the TE of the exposure on the outcome that is mediated. The PM captures how important the pathway is through the mediator in explaining the observed effect of the exposure on the outcome (i.e., TE) [24]. To calculate the PM, we decomposed the TE of wealth on recent HIV testing into the controlled direct effect (CDE) and the natural indirect effect (NIE) (Figure 1) using coefficients from the outcome and mediator models (Appendix

Text S1). The CDE is the effect of the exposure on the outcome, while the mediator is set to a pre-specified level uniformly over the entire population [21]. Here, we pre-specified the level of the mediator to a favorable level. The NIE represents the change in the outcome when SEP is held constant and the mediator changes to what it would have been for a change in the other SEP category [21,23]. We also accounted for the EM interaction when present to calculate for these effect estimates [21] (Appendix Text S1). We bootstrapped the 95% confidence interval (CI) with 1000 replications.

To focus on settings in which wealth-related inequalities were substantial before decomposing the TE into CDE and NIE to calculate the PM, we established a cut-off based on the TE, with a Prevalence Ratio (PR) ≥ 1.5. All analyses were conducted using R version 4.0.3.

Results

Characteristics of the Study Population

Data were collected from 392,044 participants, 261,935 female and 130,109 male participants. Table 1 and Appendix Table S2 illustrate the survey and participant characteristics. Overall, 93-100% of eligible women were successfully interviewed, and 86-100% of men (Appendix Table S2).

In many of the countries, female and male participants lived in rural areas (except in Côte d'Ivoire, Cameroon and Liberia among both genders, and in Senegal among males). They

were either married or cohabitating, except in Cameroon, Senegal and Lesotho where most males were single (Appendix Table S2).

Table 1. **Survey and population characteristics, by country and gender.**

Western-Central Africa	**BFA (Burkina Faso)**		**CIV (Côte d'Ivoire)**		**CMR (Cameroon)**		**COD (Congo DR)**		**GNA (Guinea)**		**LIB (Liberia)**		**MLI (Mali)**		**NIG (Niger)**		**SEN (Senegal)**		**SLE (Sierra Leone)**	
Survey Year	**2010**		**2011-12**		**2018**		**2013-14**		**2018**		**2013**		**2018**		**2012**		**2017**		**2013**	
Gender	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
N	17,087	7,307	10,060	5,135	14,677	6,978	18,827	8,656	10,874	4,117	9,239	4,118	10,519	4,618	11,160	3,928	16,787	6,977	16,658	7,262
Demand-related mediators																				
HIV-related knowledge (%)	23.3	21.5	14.5	13.2	32.4	25.8	11.8	13.8	14.6	18.9	1.3	17.1	15.8	16.3	10.0	13.9	16.2	21.2	21.9	14.0
Positive attitudes toward PLHIV (%)	32.8	38.7	47.3	46.3	57.0	51.2	33.6	40.2	15.4	17.5	33.6	37.5	29.5	34.0	18.3	24.9	34.2	30.0	34.7	33.0
Supply-related mediators																				
No distance-related problem to seek care (%)	56.4	-	60.3	-	60.3	-	61.1	-	53.9	-	59.9	-	71.5	-	57.1	-	77.9	-	61.4	-
No money-related problem to seek care (%)	28.2	-	33.0	-	32.7	-	31.4	-	39.9	-	53.1	-	59.5	-	40.1	-	55.3	-	32.9	-
No permission needed to seek a doctor (%)	78.9	-	75.6	-	65.4	-	67.3	-	70.5	-	92.2	-	72.9	-	78.9	-	93.4	-	82.5	-
§ No/ single difficulty in seeking care (%)	56.6	-	56.7	-	53.5	-	54.1	-	54.2	-	70.6	-	68.1	-	59.2	-	80.4	-	59.7	-
Recent (< 12 months) HIV testing (%)	11.8	8.6	15.4	9.9	40.0	35.0	9.1	7.6	9.4	5.9	21.6	13.7	9.2	4.9	8.4	2.7	13.0	6.3	17.6	8.2

Eastern-Southern Africa	**ETH (Ethiopia)**		**KEN (Kenya)**		**LES (Lesotho)**		**MWI (Malawi)**		**RWA (Rwanda)**		**TNZ (Tanzania)**		**ZBW (Zimbabwe)**		**ZMB (Zambia)**	
Survey Year	**2016**		**2014**		**2014**		**2015-16**		**2014-15**		**2011-12**		**2015**		**2018**	
Gender	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**

N	15,683	12,688	31,079	12,819	6,621	2,931	24,562	7,478	13,497	6,217	10,967	8,352	9,955	8,396	13,683	12,132
Demand-related mediators																
HIV-related knowledge (%)	18.3	27.0	28.6	23.7	27.0	16.5	35.6	31.5	44.8	40.3	30.5	25.5	44.6	34.9	33.7	24.9
Positive attitudes toward PLHIV (%)	35.5	44.5	73.0	77.7	84.4	71.6	80.5	85.0	83.4	86.4	59.1	64.8	77.2	78.8	70.7	75.1
Supply-related mediators																
No distance-related problem to seek care (%)	49.7	-	77.3	-	74.5	-	44.4	-	78.4	-	-	-	66.7	-	28.8	-
No money-related problem to seek care (%)	45.2	-	63.3	-	72.7	-	47.2	-	50.7	-	-	-	57.0	-	20.5	-
No permission needed to seek a doctor (%)	67.9	-	94.0	-	96.4	-	83.6	-	97.3	-	-	-	94.7	-	3.8	-
§ No/ single difficulty in seeking care (%)	55.1	-	82.0	-	84.9	-	56.2	-	82.8	-	-	-	76.4	-	85.2	-
Recent (< 12 months) HIV testing (%)	21.2	19.7	67.9	57.5	59.1	37.9	44.4	42.3	39.7	36.9	32.5	27.7	49.3	36.8	65.4	53.4

F, female; M, male; N, total number. PLHIV, people living with HIV. § A ioint mediator of no distance-related to seek care, no money-related to seek care and no permission needed to seek a doctor.

Table 1 shows that around 18%-45% of the female participants and 17%-40% of the male participants had comprehensive HIV-related knowledge in ESA countries compared to 1%-32% and 13%-26% among female and male participants, respectively, in WCA countries. Moreover, the proportion of participants with positive attitudes toward PLHIV were lower in WCA countries (around 15%-57% among females and 18%-51% males) compared to ESA countries (about 36%-84% among females and 45%-86% among males). In terms of the supply-related variables, most women reported no supply-related problems except in Burkina Faso, Côte d'Ivoire, Cameroon, Congo DR, Guinea, Niger and Sierra Leone in WCA (majority of women reported money-related problems in seeking care), and in Ethiopia, Malawi and Zambia in ESA (majority of women reported distance-related and money-related problems). Most female participants did not need spousal/partner permission to seek a doctor in all countries except in Zambia.

Self-reported recent HIV testing uptake among female and male participants in WCA was lowest in Niger (8.4% and 2.7%, respectively) and highest in Cameroon (40% and 35%, respectively). Meanwhile in ESA, uptake among women and men was lowest in Ethiopia (21.2% and 19.7%, respectively) and highest in Kenya (67.9% and 57.5%, respectively).

Socioeconomic Inequalities in HIV Testing

Figure 2 illustrates that the richest were more likely to have comprehensive HIV-related knowledge, have positive attitudes toward PLHIV and were less likely to report supply-related problems. We also observed different magnitudes across countries and mediators.

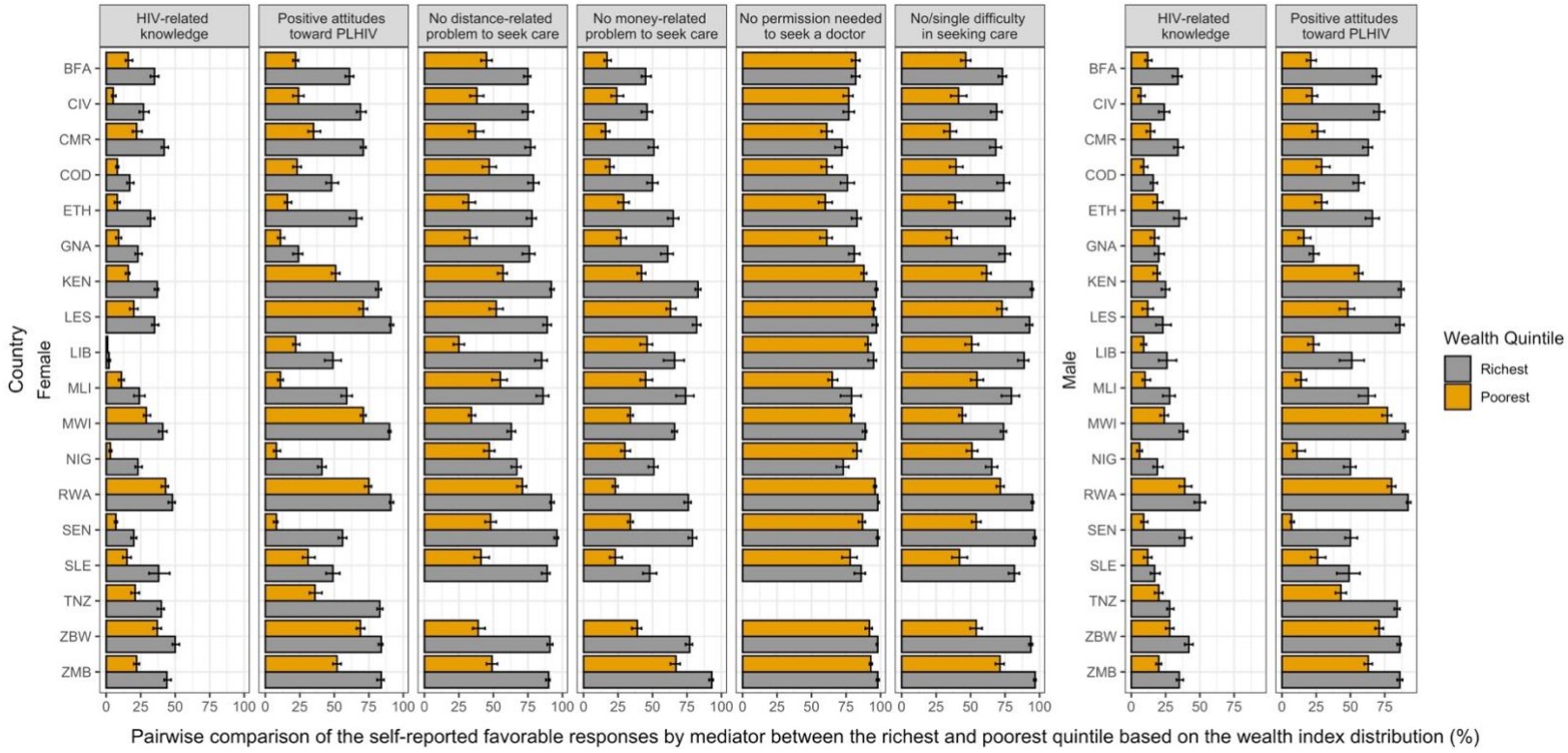

Figure 2. **Path from wealth to mediator - proportion of the individuals in the richest and poorest quintiles who self-reported favorable levels of the mediator in 18 sub-Saharan African countries, stratified by gender.** Supply-related mediators were not available among women in Tanzania in the DHS. Refer to Table 1 for full country names.

Table 2 shows the TE of wealth on recent HIV testing which was the effect estimate we used to measure wealth-related inequalities. We estimated the adjusted PRs of recent testing between the richest and the poorest participants while accounting for confounders. Applying the cut-off of PR ≥ 1.5 led us to keep nine countries for women and 15 countries for men in our final mediation analyses. Levels of wealth-related inequalities vary greatly by country and gender with pro-rich inequalities in HIV testing in most countries. Inequalities tended to be higher among men than women.

Wealth-related inequalities were markedly observed in WCA countries. Among women, the highest inequalities were in Congo DR where the prevalence of recent testing among the richest women was 12.14 (95% CI 7.34 – 20.08) times greater than among the poorest women. Meanwhile in men, the highest inequality was in Niger where the prevalence of testing among the richest men was 46.04 (10.47 – 202.43) times greater than among the poorest men.

Table 2. **Total effect of wealth on recent HIV testing - adjusted prevalence ratios of recent HIV testing between the richest and poorest participants (stratified by gender), while accounting for confounders.**

	Adjusted PR (95% Confidence Interval) $P\,(recent\ HIV\ testing) = f(wealth, confounders)$	
Country	**Female**	**Male**
BFA	**2.74 (2.09 – 3.58)**	**14.97 (9.12 – 24.57)**
CIV	**3.39 (2.53 – 4.52)**	**8.93 (5.27 – 15.15)**
CMR	**2.68 (2.33 – 3.07)**	**3.95 (3.23 – 4.83)**
COD	**12.14 (7.34 – 20.08)**	**15.30 (8.67 – 26.98)**
ETH	**3.97 (3.14 – 5.01)**	**3.89 (3.00 – 5.05)**
GNA	**10.63 (6.57 – 17.19)**	**11.27 (4.93 – 25.74)**
KEN	**1.30 (1.23 – 1.37)**	**1.59 (1.47 – 1.71)**
LES	**0.90 (0.82 – 0.99)**	**1.61 (1.30 – 2.00)**
LIB	1.21 (0.99 – 1.47)	**2.92 (1.94 – 4.38)**
MLI	**11.17 (7.08 – 17.63)**	**6.16 (2.14 – 17.72)**
MWI	**1.10 (1.04 – 1.17)**	**1.13 (1.01 – 1.26)**
NIG	**4.82 (3.23 – 7.17)**	**46.04 (10.47 – 202.43)**
RWA	1.08 (0.99 – 1.19)	0.93 (0.80 – 1.07)
SEN	**1.62 (1.30 – 2.01)**	**3.08 (1.75 – 5.44)**
SLE	**1.35 (1.07 – 1.70)**	**2.58 (1.45 – 4.61)**
TNZ	**1.44 (1.27 – 1.65)**	**1.68 (1.42 – 1.99)**
ZBW	1.13 (1.00 – 1.28)	**1.37 (1.16 – 1.63)**
ZMB	**1.13 (1.04 – 1.23)**	**1.51 (1.37 – 1.66)**

Prevalence Ratio; P, probability; f, function of. Bold fonts indicate that the model is statistically significant and eligible (PR ≥ 1.5), grey colors indicate that the model is statistically significant but

ineligible, and normal fonts indicate that the model is not statistically significant. Refer to Table 1 for full country names.

Mediated Effects

Pathways from wealth to each mediator based on Figure 1 were explored (Appendix Table S3). Among the eligible models in Table 2 (i.e., with substantial levels of inequalities), we observed that wealth was associated with majority of the mediators except for HIV-related knowledge among men in Sierra Leone, positive attitudes toward PLHIV among men in Guinea and no spousal/partner permission needed to seek a doctor in Burkina Faso, Côte d'Ivoire, Liberia and Niger among women (Appendix Table S3). The paths from each mediator to HIV testing uptake were also explored (Appendix Figure S2 and Table S4). In all eligible countries except Lesotho, all mediators were positively associated with recent testing (Appendix Table S4).

There was heterogeneity in the importance and role of each mediator in the pathway between wealth and recent testing across countries and gender groups (Figure 3). Demand-related mediators tended to have higher PM compared to supply-related mediators in women, with magnitudes varying across countries. For example, among women, the TE of wealth on recent testing uptake was mediated by positive attitudes toward PLHIV by 31.46% (20.14%-53.37%) in Senegal, but only by 4.34% (-0.12%-8.78%) in Niger. In other words, we could also say that wealth-related inequality in testing among women in Senegal could be explained by positive attitudes toward PLHIV by 31.46% (20.14%-53.37%). Meanwhile, in Côte d'Ivoire, wealth-related inequalities in testing could be explained by HIV-related knowledge

by 12.14% (7.28%-17.82%), while in Congo DR by only 0.34% (-1.48%-2.05%). Supply-related mediators tended to have lower PM in the majority of the countries except in Burkina Faso, Congo DR, Guinea, and Senegal in which reporting no money-related problem mediated slightly more than or almost similarly to HIV-related knowledge.

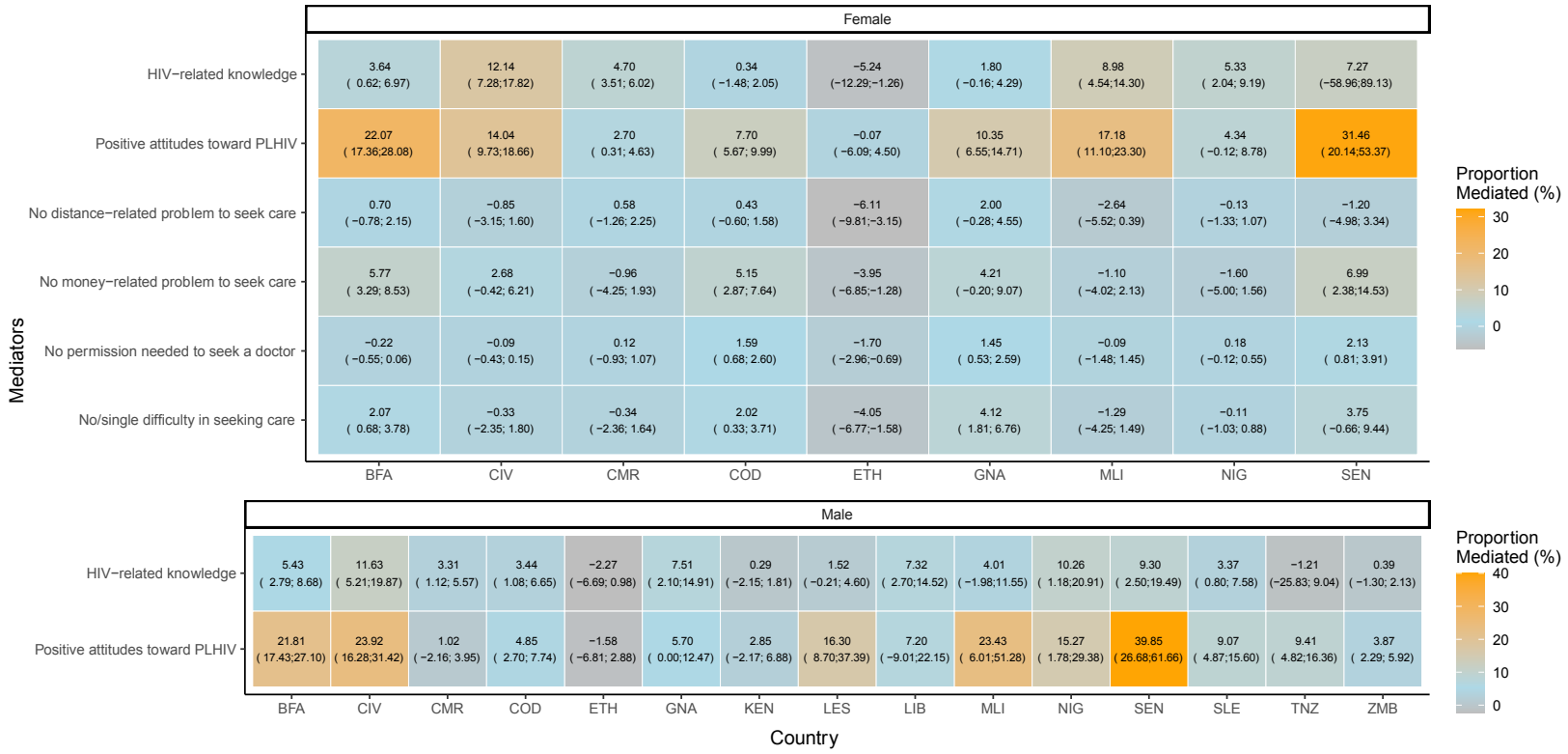

Figure 3. **Heatmap of the proportion mediated by each mediator in the total effect of wealth on HIV testing, stratified by gender (eligible models).** Refer to Table 1 for full country names

Among men, having positive attitudes toward PLHIV tended to mediate the TE of wealth on testing more with a range between -1.58% (-6.81%-2.88%) in Ethiopia and 39.85% (26.68%-61.66%) in Senegal, when compared to HIV-related knowledge that ranged between -2.27% (-6.69%-0.98%) in Ethiopia and 11.63% (5.21%-19.87%) in Côte d'Ivoire. A negative PM indicate that the CDE and NIE were in opposite direction. Appendix Figure S3 shows a small reduction in inequality in a few countries after setting each mediator to a favorable level over the entire participants (i.e., CDE).

Discussion

We analyzed cross-sectional population-based surveys to assess individual-level drivers of wealth-related inequalities in recent HIV testing through mediation analysis in several SSA countries. Richest individuals were more likely to have been recently tested than the poorest with magnitudes varying across countries. We pre-identified several participant's characteristics that could play a mediating role between wealth and recent testing. The richest were more likely to have a favorable situation regarding these mediators (e.g., better knowledge about HIV, lesser stigma towards PLHIV and lesser problems to seek care) and these mediators were also positively associated with HIV testing. For instance, people who have no problems seeking care were also more likely to have been recently tested for HIV. We found no single, strong mediator in the pathway between wealth and recent testing that was consistently strong across all countries and genders, but our results show that inequalities were mediated more by demand- (characterizes individual's ability to perceive need for and

inclination to seek health care) more than supply-side (ability to reach, pay for and engage in health care) characteristics. The importance of each mediator varied greatly by country and gender which may depend on several factors such as social and economic elements, disease epidemiology, funding from donors and the political structures of the country. This illustrates the importance of tailoring HIV testing programs to the local context of the country and the needs of each gender.

Mediation analysis was conducted in countries where substantial levels of pro-rich inequalities were observed, the majority of which were WCA countries which is consistent with studies using different inequality estimates [6,25]. This is quite expected since most WCA countries' health care delivery is through the private sectors which often has inadequate decentralization of HIV services [26]. In ESA, on the other hand, health care delivery is mostly based on public and community health efforts incorporated with international donor funding [27]. Participants were also more likely to report having comprehensive HIV-related knowledge and positive attitudes toward PLHIV in ESA. This could be due to the longer history of HIV programs in this region in response to the higher burden of the epidemic. Inequalities were also found to be higher among men which could be explained by increased access to HIV testing for women through the routine offer in antenatal clinics as part of the prevention of mother-to-child transmission programs [28].

Countries with a low uptake of recent testing tended to have high levels of inequalities with mediators, except for positive attitudes toward PLHIV. This may mean that attitudes toward PLHIV still plays a major role in explaining part of the HIV testing inequalities in a country

regardless of the epidemic. It is well documented that low HIV stigma is associated with higher SEP [29] and higher uptake of HIV testing uptake in the lifetime [30]. Stigma as an important mediator has implications for HIV testing. Due to the negative attitude towards PLHIV and the fear of being treated similarly, people may refuse to participate in any HIV prevention services or activities despite their knowledge [31]. It is also important to note that HIV-related knowledge and positive attitudes toward PLHIV do not influence testing independently from each another based on an additional analysis using a joint mediators approach to check for the identification assumption related to mediators influencing each other. (Appendix Table S5) [32]. Indeed, some studies have shown that high levels of HIV-related knowledge may reduce stigma [33,34]. In a statistical view, when exploring the combined effects of these mediators, the mean of the PMs should thus be considered instead of their sum for it will overestimate their combined effects. This also applies to the supply-related mediators.

A study found that long travel times needed to reach healthcare in rural areas were found to be an important barrier in reaching 90% treatment coverage [35] and distance to care was found to affect uptake of facility delivery [36]. However, our findings showed that reporting no distance-related problem in seeking care mediated a lower proportion of the relationship between wealth and recent testing uptake among women. We did not use physical distance itself but the perception that distance would be a problem in seeking care. In some countries like Senegal, HIV services reach the populations through both fixed and mobile strategies reinforced by mobile screening units [37]. Although magnitude is small, reporting no money-related problem tended to have higher PM in WCA countries which have a widespread policy

of user fees for health services [26]. In most countries, married women do not usually need spousal consent to legally to access sexual and reproductive health facilities [38] which may explain why no spousal/partner permission to seek a doctor did not mediate a large proportion of the relationship.

The absence of a strong mediator that we could potentially control to reduce inequalities in testing across all countries and genders may be due to the fact these inequalities stem from country-level, rather than individual-level factors. Indeed, a study found that upstream structural interventions tended to reduce inequalities [39]. Meanwhile, downstream interventions that focus only on individual factors like education were ineffective in reducing inequalities and were more likely to increase them [39].

This study has several limitations. First, the lack of a variable capturing risk perception of acquiring HIV in the DHS. A study found that risk perception is indeed an important mediator between peer education and HIV testing in key populations [40]. Second, the issue of temporality due to the cross-sectional nature of the data, especially for the demand-related mediators. Since counselling is part of HIV testing, we cannot exclude reverse causality between these demand-related mediators and HIV testing uptake. Another limitation is the self-report of HIV testing and mediators. A study, however, showed that the sensitivity of self-reported HIV testing ranged between 96% and 99% [41]. Despite this, reporting bias may still be present resulting in under-reporting of sensitive information such as attitudes toward PLHIV. Another potential limitation is that inequalities have been measured only through the wealth index which carries its own limits. Although asset-based

wealth index is said to be stable and represents long-term SEP especially in LMIC, it can only assess relative wealth within a population [42]. For this reason, we did not pool the estimates across countries. Survey years were also different which may have contributed to the heterogeneity in inequality estimates and mediated effects.

Despite the limitations, this study has several strengths. We used large, standardized and nationally representative data. Moreover, to our knowledge, this is the first study to present a comprehensive analysis of mediators in several sub-Saharan African countries. Importantly, compared to a classic mediation analysis, we used the potential outcomes framework allowing us to account for exposure-mediator interaction.

In conclusion, this study provides a comprehensive analysis of mediating factors that could potentially explain wealth-related inequalities in HIV testing in several SSA countries. Our results suggest that inequalities in HIV testing may be explained more by individual demand-side characteristics such as HIV-related knowledge and attitudes toward PLHIV than supply-side characteristics. The inter-country and gender heterogeneities in the role of the mediators suggest that addressing inequalities would necessitate tailored efforts. The lack of an identified strong, single mediator across countries illustrates that inequalities may not be addressed by solely acting upon a single factor, but must be tackled upstream with social and structural interventions that address the principal causes of the inequalities. In this paper, we were also able to underline the use of mediation analysis based on the potential outcomes framework in assessing such inequalities. More research is needed to explore other potential mediators and contextual factors. Beyond measuring inequalities in HIV testing, there is a

need to understand their drivers to help tailor interventions that could reduce them and “leave no one behind”.

Acknowledgements

PAAT, LT and KJ conceived and discussed the study with input from TB. PAAT and MH collated and processed the DHS. PAAT conducted the analysis with inputs from TB, LT and KJ. PAAT produced output figures and tables with inputs from LT and KJ. All authors contributed to the interpretation of the results. PAAT wrote the initial draft with inputs from LT and KJ. All authors contributed to subsequent revisions. All authors read and approved the final version of the manuscript.

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Supplementary material

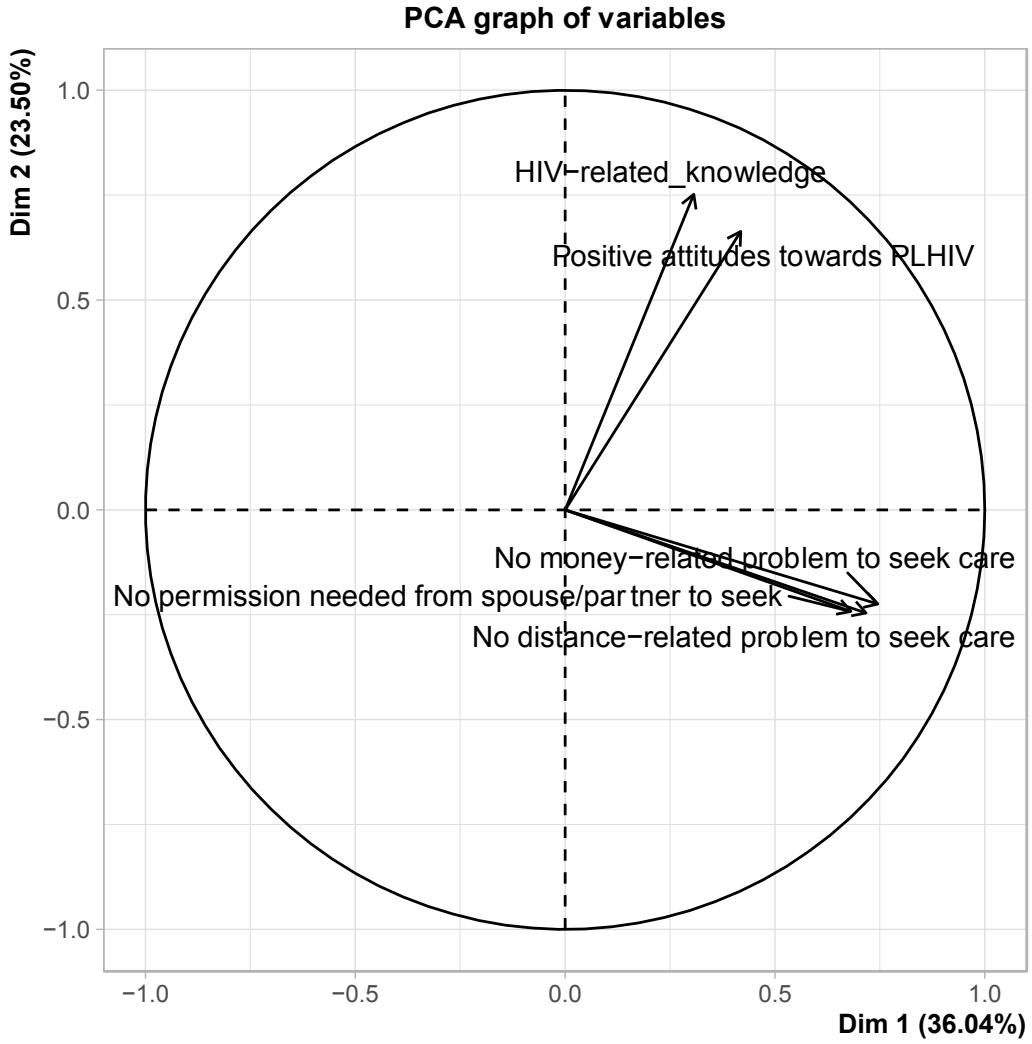


Figure S1. Categorization of the mediators. Principal Component Analysis of the mediators among female participants in 18 sub-Saharan African countries.

Among women, the PCA show the *demand-related* mediators were highly correlated. We found the same result across the *supply-related* mediators. Hence, we categorized these mediators under these two groups. Among men, *demand-related* mediators were also highly correlated (Pearson chi-square p-value: < 2.2e-16).

Table S1. Construction and coding of the mediators.

Variables	Description	Coding	DHS Questions
Mediators			
Demand-related mediators			
HIV-related knowledge	Based on a set of 7 questions related to HIV transmission and prevention defined as a binary variable reflecting comprehensive knowledge about HIV	1 = answering correctly to 7 questions 0 = answering at least one incorrectly	1. Can people reduce their chance of getting HIV by having just one uninfected sex partner who has no other sex partners? 2. Can people get HIV from mosquito bites? 3. Can people reduce their chance of getting HIV by using a condom every time they have sex? 4. Can people get HIV by sharing food with a person who has HIV? 5. Can HIV be transmitted from a mother to her baby: a. During delivery? b. During pregnancy? c. By breastfeeding?
Positive attitudes towards PLHIV	Based on a set of 2 questions about attitudes towards PLHIV defined as a binary variable showing positive attitudes towards PLHIV. The set of two questions differ by country depending on the availability of the variables.	1 = answering favorably to 2 questions 0 = answering at least one unfavorably	1. Female teacher who has the AIDS virus but is not sick should be allowed to continue teaching 2. Would buy vegetables from HIV-positive-vendor 3. Children with HIV+ should not be allowed to go to the same school
Supply-related mediators (among females only)			Many different factors can prevent women from getting medical advice or treatment for themselves. When you are sick and want to get medical advice or treatment, is each of the following a big problem or not a big problem:
Reporting no distance-related problem to seek care	Self-report of distance to facility as not a problem/ not a big problem.	1 = yes 0 = no	1. The distance to the health facility?
Reporting no money-related problem to seek care	Self-report of getting money for medical advice or treatment as not a problem/ not a big problem.	1 = yes 0 = no	2. Getting money needed for advice or treatment?
No permission needed from spouse/partner to seek a doctor	Self-report of getting permission to see a doctor as not a problem/ not a big problem.	1 = yes 0 = no	3. Getting permission to go to the doctor?
No/ single difficulty in seeking care	Only one or no difficulty in access. Combined variable of the 3 proxy variables related to supply above.	1 = yes 0 = no	

Text S1. Formulas based on Valeri and Vanderweele to estimate the Control Direct Effect (CDE), Natural Indirect Effect (NIE), Total Effect (TE) and Proportion mediated (PM).

$$\mathrm{E}\{(Y = 1|a, m, c)\} = \theta o + \theta 1a + \theta 2m + \theta 3am + \theta' 4c \quad \text{(Outcome model)}$$
$$\mathrm{E}\{(M = 1|a, c)\} = \beta o + \beta 1a + \beta' 2c \quad \text{(Mediator model)}$$

where, Y = outcome, a = exposure, m = mediator, c = confounder.

$$PR^{CDE} = \exp\{(\theta 1 + \theta 3m)(a - a*)\}, \text{ m=1}$$

$$PR^{NIE} = \frac{\{1 + \exp(\beta 0 + \beta 1a* + \beta' 2c)\}\{1 + \exp(\theta 2 + \theta 3a + \beta 0 + \beta 1a + \beta' 2c)\}}{\{1 + \exp(\beta 0 + \beta 1a + \beta' 2c)\}\{1 + \exp(\theta 2 + \theta 3a + \beta 0 + \beta 1a* + \beta' 2c)\}}$$

where a = 1, a* = 0, m = 1.

TE = NIE x CDE (when Y is binary)

$$PM = CDE\ x\ (NIE - 1)/(CDE\ x\ NIE - 1)$$

Valeri L, VanderWeele TJ. "Mediation analysis allowing for exposure–mediator interactions and causal interpretation: Theoretical assumptions and implementation with SAS and SPSS macros": Correction to Valeri and VanderWeele (2013). Psychol Methods. 2013 Dec;18(4):474–474.

Table S2. Survey and population characteristics, by country and gender.

Western-Central Africa	BFA (Burkina Faso)		CIV (Côte d'Ivoire)		CMR (Cameroon)		COD (Congo DR)		GNA (Guinea)		LIB (Liberia)		MLI (Mali)		NIG (Niger)		SEN (Senegal)		SLE (Sierra Leone)	
	2010		2011-12		2018		2013-14		2018		2013		2018		2012		2017		2013	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
N	17,087	7,307	10,060	5,135	14,677	6,978	18,827	8,656	10,874	4,117	9,239	4,118	10,519	4,618	11,160	3,928	16,787	6,977	16,658	7,262
Response Rate (%) *	98	97	93	91	98	98	99	97	99	97	98	95	98	96	95	88	96	91	97	96
Wealth index (%)																				
Poorest	17.50	17.30	17.60	19.10	16.60	15.40	18.60	16.90	18.90	17.30	17.10	18.20	17.50	18.60	18.10	14.80	16.50	16.70	18.50	18.50
Poorer	18.70	19.10	17.30	16.50	18.70	18.40	19.10	18.90	19.70	18.00	17.60	18.30	18.80	19.90	18.80	17.40	17.80	17.50	18.30	18.30
Middle	19.00	18.30	18.20	17.90	20.10	20.80	18.60	20.70	18.90	18.00	19.30	17.70	19.10	18.60	19.70	19.30	19.70	19.80	18.80	18.50
Richer	19.90	18.90	20.80	22.10	21.30	21.00	19.40	20.50	19.80	20.30	22.20	21.00	21.10	20.10	20.60	20.40	21.30	22.80	20.30	18.10
Richest	24.90	26.40	26.20	24.40	23.20	24.30	24.30	23.00	22.70	26.40	23.90	24.90	23.40	22.80	22.80	28.10	24.70	23.20	24.00	26.50
Age in years (%)																				
15-24	38.80	33.80	39.50	33.90	39.00	38.20	41.20	36.40	40.10	35.90	40.30	38.50	38.00	31.20	34.20	28.00	40.60	39.90	39.40	34.20
25-34	32.50	25.90	34.10	29.40	30.00	25.40	32.70	26.40	30.80	23.00	30.40	30.30	34.40	24.60	37.00	24.80	32.20	25.50	30.80	25.10
35 and above	28.80	40.30	26.40	36.80	31.00	36.50	26.10	37.20	29.10	41.10	29.30	31.20	27.60	44.20	28.80	47.20	27.30	34.60	29.80	40.80
Type of residence (%)																				
Urban	27.10	28.90	51.40	50.30	54.60	55.20	38.40	37.00	37.60	41.90	61.00	58.60	26.30	25.60	18.80	24.60	49.70	53.10	35.60	37.20
Family situation (%)																				
In union	79.40	63.70	62.70	52.70	56.60	47.10	64.20	58.20	71.10	55.10	58.30	53.90	81.40	66.10	88.50	69.80	64.90	43.10	65.50	57.10
Single	17.50	34.20	30.20	42.40	32.30	48.20	26.00	37.50	25.20	43.60	31.00	42.50	16.00	33.10	7.90	28.60	30.30	55.50	28.40	39.30
Widowed/ separated	3.10	2.20	7.10	4.90	11.10	4.80	9.70	4.20	3.70	1.30	10.70	3.70	2.60	0.80	3.60	1.50	4.80	1.40	6.20	3.50

*Based on each country's DHS Final Report

Table S2 (continued). Survey and population characteristics, by country and gender.

Eastern-Southern Africa	ETH (Ethiopia)		KEN (Kenya)		LES (Lesotho)		MWI (Malawi)		RWA (Rwanda)		TNZ (Tanzania)		ZBW (Zimbabwe)		ZMB (Zambia)	
	2016		2014		2014		2015-16		2014-15		2011-12		2015		2018	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
N	15 683	12 688	31 079	12 819	6 621	2 931	24 562	7 478	13 497	6 217	10 967	8 352	9 955	8 396	13 683	12 132
Response Rate (%)*	95	86	97	90	97	94	98	95	99.5	99.5	96	89	96	92	96	92
Wealth index (%) Poorest	16.80	15.80	15.60	14.10	14.50	14.30	19.30	16.00	19.00	14.60	17.00	16.30	17.10	15.00	17.80	16.50
Poorer	17.90	18.30	17.60	17.70	15.60	18.20	19.10	18.40	19.50	17.80	18.00	18.30	17.00	18.00	17.40	17.90
Middle	19.00	19.30	19.40	19.80	18.80	20.40	18.90	19.80	19.20	20.20	18.00	19.00	17.60	19.30	18.10	20.00
Richer	19.80	21.50	21.10	24.60	24.20	22.50	19.10	20.70	19.50	22.70	20.60	20.90	23.20	22.90	22.00	22.40
Richest	26.50	25.10	26.40	23.90	26.90	24.60	23.70	25.20	22.80	24.70	26.40	25.40	25.10	24.70	24.60	23.30
Age in years (%) 15-24	39.20	35.10	37.20	36.40	41.80	42.70	42.40	43.10	38.70	36.60	39.20	42.30	39.10	41.20	41.90	39.70
25-34	33.80	28.50	34.10	30.30	31.00	25.40	31.00	26.00	33.00	30.20	31.00	26.10	32.90	27.00	30.00	25.60
35 and above	27.00	36.40	28.70	33.30	27.30	31.90	26.50	30.80	28.30	33.20	29.80	31.50	28.00	31.80	28.10	34.70
Type of residence (%) Urban	22.20	19.70	40.80	43.40	36.50	33.80	18.30	18.50	19.50	20.00	27.00	25.60	38.50	36.00	46.60	44.10
Family situation (%) In union	65.20	58.90	59.70	52.70	54.60	40.00	65.70	58.10	51.70	54.20	63.00	53.00	61.80	51.50	55.90	53.00
Single	25.70	38.60	28.90	41.80	33.10	51.50	21.00	38.30	37.80	43.50	25.50	42.30	25.20	43.20	31.20	42.60
Widowed/ separated	9.10	2.50	11.40	5.40	12.40	8.50	13.30	3.50	10.50	2.30	11.50	4.70	13.00	5.30	12.90	4.40

*Based on each country's DHS Final Report

Table S3. Path from exposure to mediator. Adjusted prevalence ratios of favorable levels of the mediator between the richest and poorest participants while accounting for confounders.

	Adjusted PR (95% Confidence Intervals) $P\ (mediator) = f(wealth, confounders)$							
Country	**Mediator**							
	HIV-related knowledge		**Positive attitudes toward PLHIV**		**No distance-related problem to seek care**	**No money-related problem to seek care**	**No permission needed to seek a doctor**	**No/single difficulty in seeking care**
	Female	**Male**	**Female**	**Male**	**Female**	**Female**	**Female**	**Female**
BFA	**2.04 [1.68;2.46]**	**2.46 [1.87;3.24]**	**2.43 [2.05;2.89]**	**2.98 [2.40;3.71]**	**1.56 [1.38;1.77]**	**3.68 [2.95;4.58]**	0.93 [0.85;1.01]	**1.52 [1.35;1.72]**
CIV	**5.20 [3.75;7.21]**	**5.99 [3.92;9.16]**	**3.18 [2.68;3.76]**	**4.87 [4.05;5.85]**	**2.01 [1.72;2.34]**	**3.99 [3.20;4.98]**	1.06 [0.95;1.19]	**2.06 [1.75;2.42]**
CMR	**1.95 [1.66;2.30]**	**2.36 [1.81;3.09]**	**1.96 [1.76;2.19]**	**2.18 [1.85;2.57]**	**1.89 [1.69;2.11]**	**4.71 [3.91;5.68]**	**1.38 [1.24;1.55]**	**2.06 [1.80;2.37]**
COD	**2.05 [1.55;2.70]**	**2.29 [1.56;3.37]**	**1.93 [1.57;2.37]**	**1.73 [1.42;2.12]**	**1.46 [1.27;1.69]**	**3.20 [2.53;4.03]**	**1.35 [1.22;1.49]**	**1.82 [1.56;2.13]**
ETH	**6.33 [4.83;8.30]**	**3.36 [2.63;4.30]**	**4.00 [3.27;4.90]**	**2.99 [2.45;3.64]**	**2.46 [2.06;2.94]**	**3.00 [2.55;3.54]**	**1.32 [1.20;1.46]**	**2.07 [1.79;2.39]**
GNA	**1.82 [1.25;2.65]**	**1.75 [1.07;2.84]**	**2.69 [1.71;4.23]**	1.49 [0.82;2.72]	**2.16 [1.76;2.64]**	**3.14 [2.50;3.96]**	**1.25 [1.10;1.42]**	**2.10 [1.75;2.53]**
KEN	**2.69 [2.37;3.05]**	**1.61 [1.39;1.87]**	**2.04 [1.91;2.18]**	**1.77 [1.68;1.88]**	**1.73 [1.63;1.84]**	**2.33 [2.16;2.50]**	**1.13 [1.10;1.16]**	**1.68 [1.59;1.76]**
LES	**2.14 [1.76;2.60]**	**2.12 [1.42;3.17]**	**1.34 [1.27;1.42]**	**1.96 [1.74;2.20]**	**1.75 [1.58;1.93]**	**1.45 [1.34;1.56]**	**1.03 [1.01;1.05]**	**1.32 [1.25;1.40]**
LIB	**3.93 [1.42;10.89]**	**2.58 [1.68;3.95]**	**2.76 [2.20;3.45]**	**2.69 [2.06;3.51]**	**2.94 [2.31;3.73]**	**1.39 [1.20;1.61]**	1.02 [0.98;1.07]	**1.61 [1.41;1.84]**

Abbreviations: PR, prevalence ratio; P, probability, f, function of; NA, Not available.

Bold fonts indicate the PR is statistically significant and grey colours indicate it is not statistically significant
Refer to Table S2 for full country names

Table S3 (continued). Path from exposure to mediator. Adjusted prevalence rations of favorable levels of the mediator between the richest and poorest participants while accounting for confounders.

	Adjusted PR (95% Confidence Intervals) $P\ (mediator) = f(wealth, confounders)$							
Country	**Mediator**							
	HIV-related knowledge		**Positive attitudes toward PLHIV**		**No distance-related problem to seek care**	**No money-related problem to seek care**	**No permission needed to seek a doctor**	**No/single difficulty in seeking care**
	Female	**Male**	**Female**	**Male**	**Female**	**Female**	**Female**	**Female**
MLI	**5.06 [3.34;7.66]**	**3.67 [2.31;5.84]**	**10.15 [7.34;14.04]**	**8.63 [6.30;11.83]**	**2.16 [1.88;2.48]**	**2.68 [2.28;3.14]**	**1.45 [1.30;1.61]**	**2.17 [1.91;2.47]**
MWI	**1.56 [1.43;1.70]**	**1.60 [1.36;1.89]**	**1.31 [1.27;1.35]**	**1.21 [1.16;1.26]**	**1.92 [1.74;2.12]**	**2.37 [2.20;2.55]**	**1.15 [1.12;1.19]**	**1.87 [1.76;2.00]**
NIG	**6.42 [4.11;10.03]**	**3.69 [2.01;6.77]**	**5.50 [3.61;8.36]**	**6.49 [4.09;10.29]**	**1.45 [1.25;1.69]**	**2.16 [1.77;2.64]**	0.92 [0.83;1.03]	**1.35 [1.16;1.57]**
RWA	1.08 [0.98;1.18]	1.10 [0.92;1.32]	**1.23 [1.19;1.28]**	**1.19 [1.14;1.26]**	**1.26 [1.19;1.33]**	**4.70 [4.21;5.25]**	**1.03 [1.02;1.05]**	**1.38 [1.31;1.44]**
SEN	**3.58 [2.89;4.44]**	**3.88 [2.79;5.39]**	**6.90 [5.90;8.06]**	**6.42 [5.14;8.01]**	**2.01 [1.84;2.20]**	**3.25 [2.97;3.56]**	**1.11 [1.08;1.14]**	**1.88 [1.75;2.02]**
SLE	**2.11 [1.52;2.94]**	1.72 [0.95;3.10]	**1.48 [1.19;1.83]**	**1.76 [1.23;2.52]**	**1.89 [1.61;2.23]**	**2.74 [1.94;3.85]**	**1.16 [1.05;1.27]**	**1.94 [1.61;2.32]**
TNZ	**1.68 [1.45;1.94]**	**1.34 [1.13;1.60]**	**2.25 [2.05;2.47]**	**2.11 [1.93;2.31]**	NA	NA	NA	NA
ZBW	**1.61 [1.40;1.85]**	**1.70 [1.42;2.05]**	**1.32 [1.23;1.42]**	**1.34 [1.24;1.44]**	**1.99 [1.76;2.25]**	**3.02 [2.67;3.41]**	**1.09 [1.06;1.13]**	**1.79 [1.64;1.95]**
ZMB	**2.33 [2.01;2.69]**	**2.22 [1.86;2.66]**	**1.91 [1.78;2.06]**	**1.59 [1.49;1.70]**	**1.69 [1.51;1.90]**	**1.43 [1.33;1.53]**	**1.06 [1.03;1.08]**	**1.35 [1.26;1.43]**

Abbreviations: PR, prevalence ratio; P, probability, f, function of; NA, Not available.

Bold fonts indicate the PR is statistically significant and grey colours indicate it is not statistically significant
Refer to Table S2 for full country names

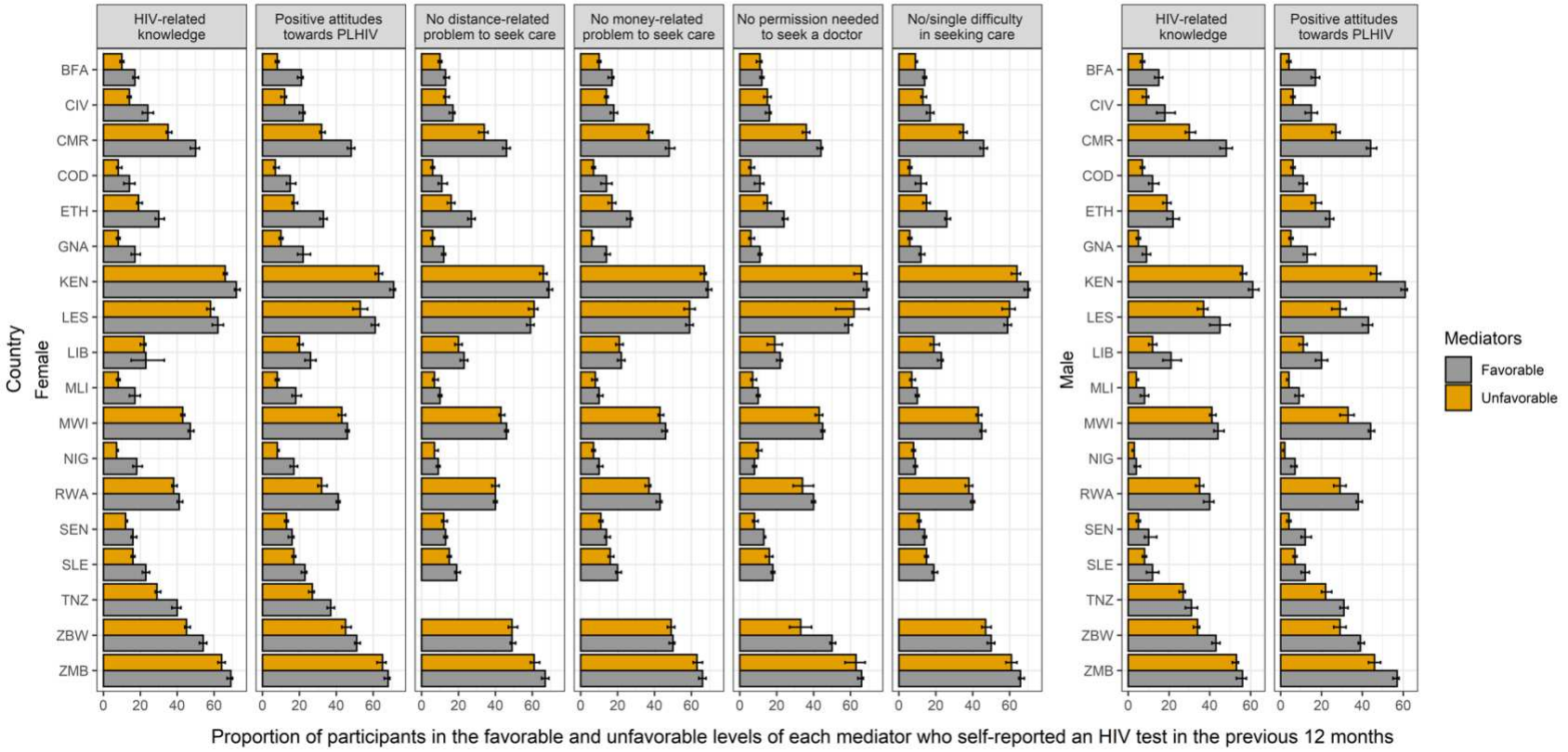


Figure S2. Path from mediator to outcome. Bivariate analysis of HIV testing uptake and mediators. Proportion of HIV testing uptake among the favorable and unfavorable levels of the mediator in 18 sub-Saharan African countries, stratified by gender. Refer to Table S2 for full country names.

Table S4. Path from mediator to outcome. Adjusted prevalence ratios of recent HIV testing between favorable and unfavorable levels of the mediators, while accounting for confounders.

		Adjusted PR (95% Confidence Intervals) $P\,(recent\ HIV\ testing) = f(mediator, confounders)$					
Country	**Mediators**	**HIV-related knowledge**	**Positive attitudes toward PLHIV**	**No distance-related problem to seek care**	**No money-related problem to seek care**	**No permission needed to seek a doctor**	**No/ single difficulty in seeking care**
BFA	**Female**	**1.42 [1.29;1.57]**	**2.09 [1.88;2.32]**	**1.10 [0.98;1.23]**	**1.36 [1.23;1.51]**	**1.07 [0.94;1.22]**	**1.20 [1.08;1.35]**
	Male	**1.56 [1.35;1.82]**	**2.90 [2.41;3.49]**	NA	NA	NA	NA
CIV	**Female**	**1.51 [1.35;1.69]**	**1.58 [1.40;1.77]**	**1.03 [0.91;1.16]**	**1.18 [1.06;1.32]**	**0.97 [0.84;1.11]**	**1.05 [0.94;1.18]**
	Male	**1.82 [1.50;2.21]**	**2.27 [1.86;2.76]**	NA	NA	NA	NA
CMR	**Female**	**1.29 [1.24;1.35]**	**1.33 [1.26;1.41]**	**1.20 [1.13;1.27]**	**1.19 [1.13;1.25]**	**1.18 [1.11;1.25]**	**1.17 [1.11;1.24]**
	Male	**1.46 [1.36;1.57]**	**1.55 [1.41;1.70]**	NA	NA	NA	NA
COD	**Female**	**1.38 [1.21;1.57]**	**1.79 [1.58;2.02]**	**1.17 [1.01;1.35]**	**1.54 [1.35;1.75]**	**1.34 [1.15;1.56]**	**1.32 [1.14;1.54]**
	Male	**1.52 [1.25;1.86]**	**1.67 [1.37;2.05]**	NA	NA	NA	NA
ETH	**Female**	**1.21 [1.13;1.29]**	**1.54 [1.42;1.65]**	**1.16 [1.07;1.26]**	**1.20 [1.12;1.28]**	**1.14 [1.05;1.23]**	**1.19 [1.10;1.28]**
	Male	**1.13 [1.05;1.22]**	**1.37 [1.25;1.50]**	NA	NA	NA	NA
GNA	**Female**	**1.56 [1.35;1.80]**	**2.07 [1.73;2.46]**	**1.25 [1.05;1.49]**	**1.76 [1.52;2.04]**	**1.35 [1.10;1.65]**	**1.41 [1.18;1.69]**
	Male	**1.36 [1.00;1.84]**	**2.33 [1.75;3.09]**	NA	NA	NA	NA
KEN	**Female**	**1.10 [1.08;1.13]**	**1.19 [1.15;1.22]**	**1.09 [1.06;1.13]**	**1.04 [1.02;1.07]**	**1.06 [1.01;1.12]**	**1.13 [1.09;1.17]**
	Male	**1.12 [1.08;1.16]**	**1.35 [1.29;1.42]**	NA	NA	NA	NA
LES	**Female**	**1.04 [1.00;1.09]**	**1.11 [1.05;1.18]**	**1.02 [0.98;1.07]**	**1.01 [0.97;1.06]**	**0.95 [0.86;1.05]**	**1.01 [0.96;1.06]**
	Male	**1.13 [1.02;1.26]**	**1.45 [1.29;1.62]**	NA	NA	NA	NA
LIB	**Female**	**1.18 [0.90;1.55]**	**1.29 [1.18;1.42]**	**1.12 [1.01;1.23]**	**1.10 [1.00;1.21]**	**1.27 [1.09;1.48]**	**1.14 [1.03;1.26]**
	Male	**1.51 [1.25;1.82]**	**1.61 [1.36;1.91]**	NA	NA	NA	NA

Abbreviations: PR, prevalence ratio; P, probability, f, function of; NA, Not available.

Bold fonts indicate the PR is statistically significant and grey colours indicate it is not statistically significant
Refer to Table S2 for full country names

Table S4 (continued). Path from mediator to outcome. Adjusted prevalence ratios of recent HIV testing between favorable and unfavorable levels of the mediators, while accounting for confounders.

		Adjusted PR (95% Confidence Intervals) $P\,(recent\ HIV\ testing) = f(mediator, confounders)$					
Country	**Mediators**	**HIV-related knowledge**	**Positive attitudes toward PLHIV**	**No distance-related problem to seek care**	**No money-related problem to seek care**	**No permission needed to seek a doctor**	**No/ single difficulty to in seeking care**
MLI	**Female**	**1.63 [1.34;1.98]**	**1.91 [1.60;2.28]**	**1.14 [0.93;1.41]**	**1.21 [1.01;1.45]**	**1.14 [0.89;1.47]**	**1.19 [0.97;1.46]**
	Male	**1.33 [1.01;1.75]**	**1.58 [1.12;2.22]**	NA	NA	NA	NA
MWI	**Female**	**1.05 [1.01;1.08]**	**1.05 [1.01;1.09]**	**1.02 [0.99;1.05]**	**1.04 [1.01;1.07]**	**1.04 [0.99;1.08]**	**1.02 [0.99;1.05]**
	Male	**1.04 [0.98;1.10]**	**1.17 [1.08;1.27]**	NA	NA	NA	NA
NIG	**Female**	**1.36 [1.17;1.58]**	**1.24 [1.10;1.40]**	**1.02 [0.89;1.17]**	**1.18 [1.04;1.33]**	**0.91 [0.80;1.05]**	**1.02 [0.89;1.15]**
	Male	**1.61 [1.10;2.37]**	**1.86 [1.29;2.68]**	NA	NA	NA	NA
RWA	**Female**	**1.06 [1.02;1.11]**	**1.22 [1.14;1.30]**	**0.99 [0.93;1.04]**	**1.13 [1.08;1.17]**	**1.15 [0.99;1.35]**	**1.04 [0.98;1.11]**
	Male	**1.10 [1.03;1.18]**	**1.28 [1.15;1.43]**	NA	NA	NA	NA
SEN	**Female**	**1.26 [1.14;1.40]**	**1.42 [1.30;1.55]**	**1.05 [0.94;1.17]**	**1.20 [1.10;1.31]**	**1.40 [1.16;1.69]**	**1.17 [1.04;1.31]**
	Male	**1.48 [1.15;1.89]**	**2.23 [1.81;2.75]**	NA	NA	NA	NA
SLE	**Female**	**1.30 [1.18;1.42]**	**1.38 [1.27;1.51]**	**1.12 [1.02;1.24]**	**1.20 [1.10;1.31]**	**1.09 [0.97;1.21]**	**1.12 [1.02;1.22]**
	Male	**1.39 [1.12;1.72]**	**1.67 [1.35;2.07]**	NA	NA	NA	NA
TNZ	**Female**	**1.34 [1.26;1.42]**	**1.31 [1.23;1.39]**	NA	NA	NA	NA
	Male	**1.14 [1.05;1.24]**	**1.28 [1.17;1.39]**	NA	NA	NA	NA
ZBW	**Female**	**1.09 [1.05;1.14]**	**1.10 [1.05;1.16]**	**1.04 [0.99;1.09]**	**1.07 [1.02;1.11]**	**1.43 [1.25;1.63]**	**1.09 [1.04;1.15]**
	Male	**1.15 [1.09;1.22]**	**1.18 [1.09;1.27]**	NA	NA	NA	NA
ZMB	**Female**	**1.04 [1.01;1.07]**	**1.06 [1.03;1.09]**	**1.07 [1.03;1.11]**	**1.02 [0.98;1.06]**	**1.00 [0.93;1.08]**	**1.05 [1.00;1.09]**
	Male	**1.03 [0.99;1.07]**	**1.15 [1.10;1.20]**	NA	NA	NA	NA

Abbreviations: PR, prevalence ratio; P, probability, f, function of; NA, Not available.

Bold fonts indicate the PR is statistically significant and grey colours indicate it is not statistically significant
Refer to Table S2 for full country names

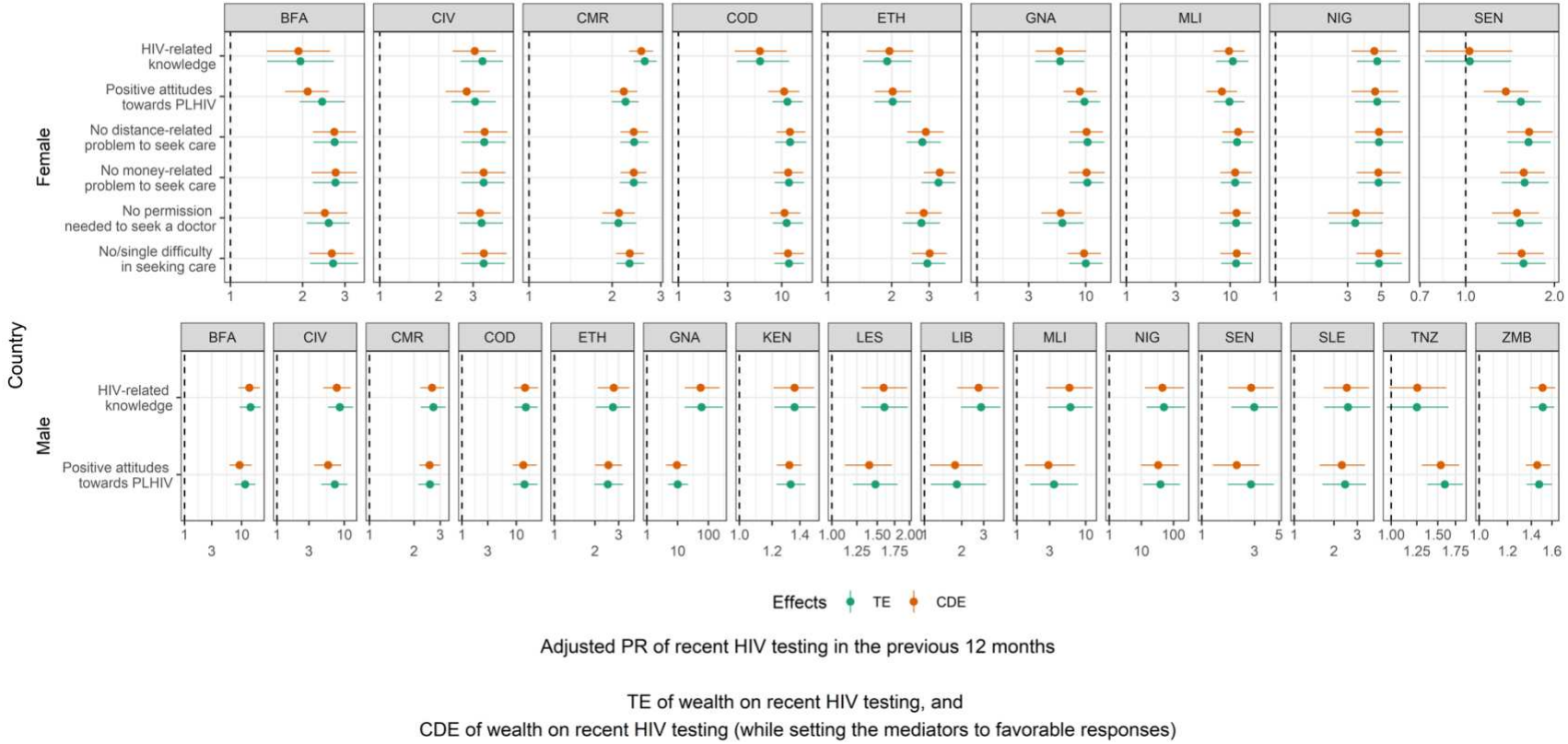


Figure S3. Forest plot of the Total Effect and Controlled Direct Effect by mediator and gender. Refer to Table S2 for full country names. PR: Prevalence Ratio, TE: Total Effect, CDE: Controlled Direct Effect.

Table S5. Proportion mediated (%) by individual and joint mediators, stratified by gender, in 18 sub-Saharan African countries.

Country	Gender	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM
Mediator		HIV-related knowledge	Positive attitudes toward PLHIV	Sum	Mean	Joint demand-related mediator	No distance-related problem to seek care	No money-related problem to seek care	No permission needed to seek a doctor	Sum	Mean	Joint supply-related mediator
BFA	**Female**	4.0%	22.0%	26.0%	13.0%	13.0%	1.0%	6.0%	0.0%	6.0%	2.0%	1.0%
	Male	5.0%	22.0%	27.0%	14.0%	12.0%	-	-	-	-	-	-
CIV	**Female**	12.0%	14.0%	26.0%	13.0%	10.0%	-1.0%	3.0%	-0.0%	2.0%	1.0%	0.0%
	Male	12.0%	24.0%	36.0%	18.0%	20.%	-	-	-	-	-	-
CMR	**Female**	5.0%	3.0%	7.0%	4.0%	3.0%	1.0%	-1.0%	0.0%	0.0%	0.0%	0.0%
	Male	3.0%	1.0%	4.0%	2.0%	2.0%	-	-	-	-	-	-
COD	**Female**	0.0%	8.0%	8.0%	4.0%	4.0%	0.0%	5.0%	2.0%	7.0%	2.0%	1.0%
	Male	3.0%	5.0%	8.0%	4.0%	5.0%	-	-	-	-	-	-
ETH	**Female**	-5.0%	0.0%	-5.0%	-3.0%	-3.0%	-6.0%	-4.0%	-2.0%	-12.0%	-4.0%	-2.0%
	Male	-2.0%	-2.0%	-4.0%	-2.0%	-2.0%	-	-	-	-	-	-
GNA	**Female**	2.0%	10.0%	12.0%	6.0%	6.0%	2.0%	4.0%	1.0%	8.0%	3.0%	2.0%
	Male	8.0%	6.0%	13.0%	7.0%	6.0%	-	-	-	-	-	-
KEN	**Female**	6.0%	3.0%	9.0%	4.0%	4.0%	-8.0%	-6.0%	-1.0%	-16.0%	-5.0%	-1.0%
	Male	0.0%	3.0%	3.0%	2.0%	1.0%	-	-	-	-	-	-
LES	**Female**	-5.0%	-6.0%	-12.0%	-6.0	-5.0%	6.0%	-1.0%	0.0%	5.0%	2.0%	-1.0%
	Male	2.0%	16.0%	18.0%	9.0%	1.0%	-	-	-	-	-	-
LIB	**Female**	2.0%	32.0%	34.0%	17.0%	32.0%	14.0%	4.0%	1.0%	19.0%	6.0%	5.0%
	Male	7.0%	7.0%	15.0%	7.0%	7.0%	-	-	-	-	-	-

Abbreviation: PM, Proportion Mediated
Refer to Table S2 for full country names.

Table S5 (continued). Proportion mediated (%) by individual and joint mediators, stratified by gender, in 18 sub-Saharan African countries.

Country	Gender	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM
Mediator		**HIV-related knowledge**	**Positive attitudes toward PLHIV**	**Sum**	**Mean**	**Joint demand-related mediator**	**No distance-related problem to seek care**	**No money-related problem to seek care**	**No permission needed to seek a doctor**	**Sum**	**Mean**	**Joint supply-related mediator**
MLI	**Female**	9.0%	17.0%	26.0%	13.0%	14.0%	-3.0%	-1.0%	0.0%	-4.0%	-1.0%	-1.0%
	Male	4.0%	25.0%	29.0%	15.0%	17.0%	-	-	-	-	-	-
MWI	**Female**	3.0%	2.0%	5.0%	2.0%	2.0%	1.0%	3.0%	1.0%	5.0%	2.0%	1.0%
	Male	3.0%	7.0%	10.0%	5.0%	4.0%	-	-	-	-	-	-
NIG	**Female**	5.0%	4.0%	10.0%	5.0%	7.0%	0.0%	-2.0%	0.0%	-2.0%	-1.0%	0.0%
	Male	10.0%	15.0%	26.0%	13.0%	16.0%	-	-	-	-	-	-
RWA	**Female**	1.0%	19.0%	20.0%	10.0%	6.0%	-1.0%	48.0%	2.0%	48.0%	16.0%	14.0%
	Male	-2.0%	-11.0%	-13.0	-7.0%	-5.0%	-	-	-	-	-	-
SEN	**Female**	7.0%	31.0%	39.0%	19.0%	26.0%	-1.0%	7.0%	2.0%	8.0%	3.0%	3.0%
	Male	9.0%	40.0%	49.0%	25.0%	28.0%	-	-	-	-	-	-
SLE	**Female**	13.0%	10.0%	23.0%	12.0%	13.0%	6.0%	14.0%	1.0%	21.0%	7.0%	4.0%
	Male	3.0%	9.0%	12.0%	6.0%	7.0%	-	-	-	-	-	-
TNZ	**Female**	9.0%	17.0%	26.0%	13.0%	17.0%	-	-	-	-	-	-
	Male	-1.0%	9.00%	8.00%	4.0%	1.0%	-	-	--	-	-	-
ZBW	**Female**	9.0%	6.0%	15.0%	7.0%	7.0%	5.0%	0.2%	0.1%	0.3%	0.1%	0.1%
	Male	6.0%	4.0%	10.0%	5.0%	5.0%	-	-	-	-	-	-
ZMB	**Female**	5.0%	-10.0%	-6.0%	-3.0%	-3.0%	-178.0%	1.0%	0.0%	-177.0%	-59.0%	-1.0%
	Male	0.0%	4.0%	4.0%	2.0%	2.0%	-	-	-	-	-	-

Abbreviation: PM, Proportion Mediated
Refer to Table S2 for full country names.

Part Four:
General Discussion

12. Discussion

12.1. Synthesis of findings

This thesis aimed to fill gaps in the literature in order to better understand socioeconomic inequalities in HIV testing uptake in SSA through multi-country analysis using rich and robust population-based surveys. These findings may provide a broader context of such inequalities in SSA to help design programs that could potentially reduce inequalities and aid in epidemic control to improve overall health. Although I am using the term "health inequality" in an objective manner to describe the differential differences in the distribution of recent HIV testing between social groups and gender, it is important to note that these differences essentially constitute inequities because they are unjust and avoidable.

The first contribution of this thesis entailed quantifying country-level absolute and relative inequalities in recent HIV testing uptake and assessing their temporal trends before and after 2008 – a year after the expanded provider-initiated HIV testing was recommended by WHO using data within the DHS in 16 SSA countries. We measured absolute and relative inequalities by estimating the SII and RII, respectively, pre- and post-2008. Temporal trends were assessed by calculating the SII difference and RII ratio of post-2008 and pre-2008 estimates. Estimates across countries were pooled using random-effect meta-analysis. Through this work, we found that there was a dramatic increase in the self-reported uptake of recent HIV testing over time. This increase may have been due to several factors, such as the expanded provider-initiated testing and counselling, and the increasing availability of ART. However, this increase was not the same for everyone. Before 2008, there were small to minor differences between men and women in recent HIV testing uptake, but after 2008 there was a higher increase in HIV testing uptake of women in the majority of countries. Over time, absolute inequalities favoring those with higher SEP remained in female participants and even increased in male participants over time. Meanwhile, overall relative inequalities decreased for both genders. Overall, despite progress especially in relative inequalities, pro-rich inequalities remained in most countries after 2008 especially in males. This supports the hypothesis based on the literature that relative

inequalities in health outcomes will reduce but not disappear (Hargreaves et al., 2013b). Important between-country heterogeneities in the magnitude of inequalities were noted. Similar findings were noted when repeating the analysis using highest educational attainment as a measure of SEP and when repeating the analysis with a sub-sample of young participants aged 15-24 years - a vulnerable population which generally lacks access to HIV prevention services.

However, monitoring and addressing inequalities must not stop at the national level and rely on summary estimates such as the national mean. Using such summary statistics often conceals differences in health outcomes between social and gender groups. Little is known about the state of inequalities in HIV testing at smaller scales.

Thus, the second contribution of this thesis aimed to explore the spatial variation of absolute and relative socioeconomic inequalities of recent HIV testing across various geographical scales in 25 countries between 2011 and 2019. We also conducted spatial clustering analysis of such inequalities and assessed the efficiency of HIV testing programs (i.e., whether the recent uptake of HIV testing matched the level of HIV prevalence) at different geographical scales. To do this, SII and RII were estimated and mapped at the national, province and PSU levels. Spatial autocorrelation analysis was conducted to identify local hotspots and coldspots of such inequalities across SSA. Efficiency of HIV testing programs was assessed through Pearson's rho evaluating the correlation between the proportion of recent HIV testing and HIV prevalence. We observed that the choice of the geographical scale had a clear impact on the magnitude of inequalities. Our results revealed existing inequalities not just at the national level but also at subnational levels – province and PSU levels. Heterogeneities in the spatial distribution of these inequalities at subnational levels and variations in the hotspot areas of such inequalities, varied depending on the inequality scale used and gender. Overall, hotspots of inequalities were more frequently observed in countries in WCA and in a few countries in ESA. Surprisingly, in most countries and for both genders, the proportion of recent HIV testing in provinces and PSU did not correlate with the level of HIV prevalence, which was in contrast to the conclusions reached when looking only at the correlation of these factors at the national level. This suggests that significant HIV testing efforts have yet to be applied at subnational levels to match the level of HIV testing uptake to the level of HIV risk. This also implies that it is not plausible to extrapolate national-level estimates to smaller geographical scales.

After quantifying and mapping inequalities, it is also essential to understand factors that could drive or could explain them. To understand the contextual factors that are associated with wealth-related inequalities in HIV testing, we explored contextual factors that may explain such inequalities in the same set of 16 countries as in the first article (Chapter 8) with surveys between 2011 and 2016. Preliminary findings were presented at the AIDS 2020 conference. In this work, the ECI was used to quantify wealth-related inequalities in recent HIV testing uptake. A novel method, the RIF regression decomposition, was used to assess the marginal effect of each contextual factor on inequality. We found that national HIV prevalence was associated with inequality and not the per capita GDP. This work may be more developed in the future, extending the analysis to other countries, stratified by gender, and integrating a broader range of epidemiological and socioeconomic variables.

The last objective of this thesis was to assess individual-level drivers of wealth-related inequalities in recent HIV testing through mediation analysis, based on the potential outcomes framework, in 18 SSA countries between 2010 and 2018. This was to assess individual-level factors that may be modifiable to reduce inequalities. For this study, to quantify inequalities, the total effect of wealth on recent HIV testing was used. The findings of this work confirm previous results that the richest individuals were more likely to have been recently tested than the poorest with magnitudes varying across countries. We pre-identified several participant's characteristics that could play a mediating role between wealth and recent testing. Mediators were categorized into two groups for simplicity – demand-related mediators (factors that characterize an individual's ability to perceive need for and inclination to seek care) and supply-side mediators (factors that characterize an individual's ability to reach, pay for and engage in health care). Demand-related mediators included HIV-related knowledge and positive attitudes toward PLHIV, while supply-related mediators included reporting no distance-related problems in seeking care, no money-related problems in seeking care, no permission needed to seek a doctor and no/ single difficulty in seeking care. The richest were more likely to have favorable conditions regarding these mediators, such as having comprehensive knowledge about HIV, lesser stigma towards PLHIV and lesser problems to seek care, and these mediators were also positively associated with recent HIV testing uptake. We found no single, strong mediator in the pathway between wealth and recent testing that was consistently strong across all countries and genders, but our findings showed that inequalities were mediated more by demand- than

by supply-side characteristics. The role of each mediator also varied greatly by country and gender. These results suggest that inequalities may be addressed not by tackling only a single factor but through upstream and well-tailored interventions.

In summary, the large scale-up of HIV testing uptake masked socioeconomic inequalities in recent HIV testing and other inequalities related to gender and geography. We observed diverging patterns of inequalities depending on the inequality indicator. Overall relative inequalities decreased over time for both women and men, while overall absolute inequalities remained stable in women and increased in men over time across SSA countries. Such inequalities also existed and varied in magnitude across places and levels – national, province and PSU levels. Inequalities were more marked in WCA and among men. At the national level, HIV testing programs seemed to be efficient. Meanwhile, at subnational levels, they tended to be less efficient in majority of the countries. Various contextual- and individual-level factors may explain these wealth-related inequalities in HIV testing by gender which could help tailor HIV prevention programs. National HIV prevalence tended to be associated with country-level inequality estimates but not per capita GDP. No single, strong individual-level mediator between wealth and recent testing was found that was consistently strong across all countries and genders but we found that inequalities may be mediated more by demand- (i.e., comprehensive HIV-related knowledge and positive attitudes towards PLHIV) more than supply-side individual factors.

12.2. Why focus on the general population and not key population?

Key populations are known to play an important role in the HIV epidemic because they are disproportionately affected by HIV and experience specific difficulties in accessing care or testing. However, we chose to focus this thesis on the general population for several reasons.

First, key populations (i.e., men who have sex with men [MSM], sex workers [SW], people who inject drugs [PWID], transgender people and prisoners) may tend to under-report HIV-related outcomes due to stigma, discrimination, and fear. Indeed, it was found that MSM living with HIV were about six times more frequent to under-report known HIV-positive status compared to men in the general population in the US (Soni et al., 2021). We expect this to be higher in SSA since in many SSA countries several key populations (e.g., MSM and SW) continue to be criminalized and receive punitive punishments from

imprisonment to death (Duvall et al., 2015; Jürgens et al., 2010; Laar & DeBruin, 2017).

Second, there is no definite variable in the DHS to identify other key populations aside from having had commercial sex or had contact with SW (i.e., DHS questions asked if participants had received gifts or other goods in exchange for sex, or a sexual relationship with recent sexual encounter and if they paid for sex with gifts or other goods). While commercial sex and sex work both involve prostitution, the former may involve coercion while sex work is usually voluntary. This is difficult to distinguish using the DHS. We may not be able to make any overall insights since each member of this group has different circumstances and a story to tell which deserves separate and tailored analysis.

Third, since this thesis centers on multi-country analysis, having sparse data on key populations due to under-reporting may limit us in conducting the investigation due to low sample size. Last but not the least, as far as we know, there are no data sources comparable to DHS for key populations, so that a multi-country study would not have been possible. However, we acknowledge that having data available for key populations would be a valuable information since reaching these groups is one of the keys to ending the epidemic.

12.3. Why stratify by gender?

We stratified our analyses by gender (except in Chapter 10) because there are gender-differences in opportunities, health-seeking behaviors and attitudes toward HIV testing in addition to the differential burden of the disease. Women in SSA tend to have more opportunities for HIV testing as part of routine testing in antenatal care to prevent mother-to-child transmission. Men were also reported to underestimate their HIV risk compared to women, despite reporting more high-risk behaviors; meanwhile, women tended to report more fears of getting tested (Obermeyer & Osborn, 2007; Sahlu et al., 1999; Stein & Nyamathi, 2000). Based on a previous review, while not all studies confirm gender differences in general attitudes toward testing, differences in motivations were consistent (Obermeyer & Osborn, 2007). For instance, men were more likely to be tested if they presented symptoms, while women were more likely to be tested if their partners had tested positive, based on a study done

in Asia (Paxton et al., 2005). Mechanisms leading to inequalities are expected to vary between genders, thus deserving a stratified analysis.

12.4. Strengths, limitations and perspectives

In this section, I will present the overall strengths, limitations and perspectives of the thesis categorized according to different sections, focusing on those that have not yet been discussed in the individual articles.

12.4.1. Use of the Demographic and Health Surveys

This thesis has several strengths. Primarily, the use of the DHS offers several advantages according to Corsi et al. that are also relevant to this thesis. First, they allow for the investigation of the changes in health and program implementation indicators over time (here, uptake of recent HIV testing) using repeated cross-sectional designs in countries with several surveys (Corsi et al., 2012), as we did in Chapter 8. Second, the core questions in the DHS have been standardized and pre-tested to ensure comparability across populations and over time. Other advantages are the national coverage of the surveys, high participation rates that usually exceed 90%, and standard data collection and interviewer training which guarantees the reliability and accuracy of survey estimates in representing the health status in a wide range of countries in the Global South (Corsi et al., 2012). The wide coverage of data collected within the DHS enabled us to conduct deeper analysis of the data beyond count of prevalence and examine associations or relationships between health and social characteristics.

Despite the strengths of the DHS, they also have some limitations. First, many countries only collect data on children and women of reproductive age with data on men only collected from a subsample of selected households. However, in this thesis, we were able to successfully measure inequalities and trends and perform other analyses in men, so this may not have limited our results. Second, the DHS are conducted independently in each participating country, which means that the indicators are not measured at the same periods, limiting the simultaneous comparisons across countries. Third, while we have updated our datasets to the best of our ability over the course of the thesis, we were only limited to the available data. In particular, DHS for some countries with high HIV prevalence, such as Eswatini, were unavailable; having

data from such countries could have added valuable insight to our findings. Future work may also explore other datasets such as the Population-Based HIV Impact Assessments surveys (PHIA) which includes HIV incidence estimates. Fourth, since the DHS are cross-sectional, we could only establish associations between SEP and recent HIV testing, and not causal relationships. Future research in assessing inequalities using longitudinal data on the field may be helpful in providing more robust data especially on the drivers of such inequalities. The DHS also only collect data from participants aged less than 60 years old. We were not able to analyze data of individuals aged 60 years and older and those aged less than 15 years. Moreover, the majority of health measures in the DHS are self-reported with the few exceptions of blood biomarkers such as HIV. These may have been susceptible to misclassification due to recall and social desirability bias, with individuals under-reporting socially undesirable outcomes and over-reporting more desirable attributes (Latkin et al., 2017)

A phenomenon that is related to recall bias is the telescoping effect, which refers to inaccurate perceptions regarding time. Individuals may tend to report recent events as more remote in time than they actually occurred (backward telescoping) or remote events as more recent than they are (forward telescoping) (Prohaska et al., 1998), which may result in overestimation of the frequency of the events (Rubin & Baddeley, 1989). Our results based on recent HIV testing in the last 12 months may be prone to such effects. The approximate critical time in which events shift from being displaced backward or forward in time seems to be three years (Janssen et al., 2006), so that people who have been tested within three years (e.g., 18 months) may report themselves as being recently tested (i.e., in the past 12 months) which may lead to over-reporting of recent testing. However, this bias may have been limited since the DHS question posed by the interviewer is specific and clear regarding the period and it is probably non-differential so it may not have affected our inequality measurements. A study of those aged 16-80 years also found a very small effect of age in the subjective speed of time, when asked about events that occurred under 10 years ago (Friedman & Janssen, 2010). We could have further limited the risk of this bias by studying lifetime HIV testing. Though, as mentioned in the previous section, we chose recent testing since it is more relevant in SSA which is a high HIV prevalence area.

12.4.2. Measures of socioeconomic position and health inequalities

Another aspect is the measure of SEP used in this thesis research. We used wealth index only as a measure of SEP in all analyses except in the first article (Chapter 8) where we also repeated the analysis using education. As mentioned in Chapter 6, the wealth index provides several advantages, such as being able to capture long-term SEP and being able to withstand economic shocks. While wealth and education were found to be highly correlated (Howe et al., 2012), repeating all our analyses on education could add a valuable insight in future work, as education captures another dimension of SEP, as described in Chapter 6.

We used well-established methods in the field of health inequalities to quantify socioeconomic inequalities in HIV testing uptake (i.e., SII and RII) which have several advantages. First, they include information from all SEP levels. Second, these two measures are sensitive to the changes in the mean level of population health outcome or changes in the frequency of the health problem under study (Schneider et al., 2005). In comparing inequalities between countries, especially in the absolute scale, it is therefore important to consider the overall level of the outcome (i.e., self-reported recent uptake of HIV testing). Indeed, a study done by Houweling et al. found that relative inequalities tend to increase with low overall level, while absolute inequalities tend to increase with intermediate overall level (Houweling et al., 2007) which is consistent to the findings in the first article about the temporal trends (Chapter 8) and in second article about the spatial distribution of these inequalities (Chapter 9).

Despite their advantages, they also have their disadvantages. First, while they account for the changes in the SEP composition of the population, Renard and colleagues argued that the RII and, to a lesser degree, the SII often translate improvements in the distribution of individuals in the higher SEP level (specifically educational level) as worsening and they warn against the use of these indices in changing socioeconomic structures (Renard et al., 2019). This may be relevant to the first objective of this thesis where we used highest educational attainment as a complementary analysis. This may not be the case for the other analyses since we used the individual wealth index score to rank the participants (Chapters 8 and 11), and the wealth index quintile (Chapter 9) which has similar distribution of participants in each quintile. Second, they may yield unreliable results when applied to small samples with aggregate data (Schneider et

al., 2005). We conducted sensitivity analyses using different cluster sample sizes to quantify PSU-level SII and RII in the second article (Chapter 9) to test the robustness of our findings.

In quantifying inequalities, we only conducted a bivariate analysis of recent HIV testing and SEP without accounting for confounders, except in article 4 (Chapter 11) where the total effect of wealth on testing while accounting for confounders was used as a measure of inequality. Future research may explore a multivariable regression accounting for confounders such as age, type of residence and family situation when estimating the SII and RII. The analysis could have also been extended to other countries, especially for the mediation analysis, but due to the limited time, the data have only been updated on the period of analyses and extended to a few countries. Extending to other countries may have allowed for the use of a multivariable RIF regression when decomposing inequalities in recent testing in relation to contextual factors in the short article (Chapter 10) since we used countries as samples in the analysis. In a future study, a multilevel data may be used allowing for a multilevel decomposition analysis to account simultaneously for the individual-level and subnational-level wealth, for instance.

In Chapter 11, we only explored a simple Directed Acylic Graph (DAG) with a single mediator in each model for easier extrapolation across multiple countries. A more complex DAG accounting for multiple mediators could be conducted in future work.

12.4.3. Other perspectives

There are other potential future studies that may be conducted to further extend this research and fully maximize the use of the DHS and other population-based surveys. First, an impact evaluation of existing or hypothetical HIV prevention policies or programs could be conducted using methods in causal inference such as natural experiments or quasi-experimental methods. These methods can be used as alternatives to experimental methods to provide causal estimates from observational studies. This may hopefully help in the development of programs that could reduce or prevent inequalities. An example would be to use datasets from the Policy-Relevant Observational Studies for Population Health Equity and Responsible Development (PROSPERED) project. They collect high quality longitudinal information about the health of the world's population since 1995 for series of social policies in several countries to assess changes in national policies over time and their effects on health outcomes

(https://www.prosperedproject.com/). As an illustrative example, a study using the DHS with the information on policy changes from the PROSPERED project was conducted to evaluate, using a regression discontinuity design, the effectiveness of policy changes aimed at reducing child marriage by increasing the minimum legal age for marriage (Batyra & Pesando, 2021). The PROSPERED project also contains databases on poverty reduction such as unemployment insurance benefits and family cash benefits. By using one of these datasets (e.g., unemployment insurance benefits) and the DHS, difference-in-differences method can be used to predict what would have happened in the intervention area that received insurance benefits without the intervention (Abadie, 2005). This can be done by indicating the time the policy or intervention started and identifying the group exposed to the policy or intervention. Other methods can also be employed such as the synthetic control study that allows for the construction of a counterfactual by selecting a weighted average of the outcome from a group like the treated group, which is a more accurate representation of what would have happened in the treated area without the intervention (Bouttell et al., 2018). Second, regarding the spatial analysis, we only conducted spatial clustering analysis across SSA which may be relevant to international bodies and funders. However, an analysis conducting similar analysis within countries may be more relevant for local governments and organizations to guide their programs.

A possible direction that we could have chosen in terms of HIV prevention, aside from focusing on HIV testing, is the prevention cascade proposed by Hargreaves and colleagues. Although this approach does not focus on HIV testing, it suggests that HIV prevention can be achieved by targeting three components: demand-side interventions that improve risk perception and awareness and acceptability of HIV prevention approaches, supply-side interventions that ensure prevention products and procedures are accessible and available; and adherence interventions that support ongoing adoption of prevention behaviors with or without prevention products (Hargreaves et al., 2016). The underlying mechanisms in this HIV prevention approach are two-fold: reduction in the likelihood of transmission if a contact occurs and reduction of the number of effective contacts (Hargreaves et al., 2016). Reduction of the probability of transmission depends on the efficacy of the prevention approaches such as condoms, VMMC, PrEP and TaSP. Meanwhile, reduction of effective contacts involves reduction of sexual partners or changes in drug use. Compared to the cascade of care and HIV prevention continuum which both build on HIV testing (Chapter 1) and focus on individual-level steps necessary to achieve viral suppression, this prevention approach identifies population-level

constraints to translate the direct mechanisms of HIV prevention into population-level effects (Hargreaves et al., 2016).

The findings in this thesis provide a macro-level perspective on the socioeconomic inequalities in HIV testing in SSA. This may serve as a foundation to a future work exploring a more in-depth micro-level analysis of such inequalities of countries, for instance, with contrasting findings such as those with low and high levels of inequalities. The quantitative analysis conducted in this thesis may be completed by a qualitative study on the field to gain a deeper understanding of socioeconomic inequalities in HIV testing and how different drivers, or programs impact different population groups. This may be an opportunity to draw learnings from countries that successfully reduced inequalities in HIV testing, while at the same time understand the barriers and challenges being experienced in countries with high inequalities. The analyses conducted in this thesis may also be used in other HIV programs, other fields and be extended to key populations, the elderly and the youth using the appropriate data.

This thesis research, specifically the first article (Chapter 8), has been a foundation to the Master internship of Mohamed Hamidouche at the Ecole Pasteur-Cnam Santé Publique in 2020, which I co-supervised with Kévin Jean. This study extended the analysis of quantifying absolute and relative inequalities to a wider range of HIV indicators. The results will be discussed in the next section (Section 12.5).

12.5. Extending analyses to other HIV indicators: results from an additional study

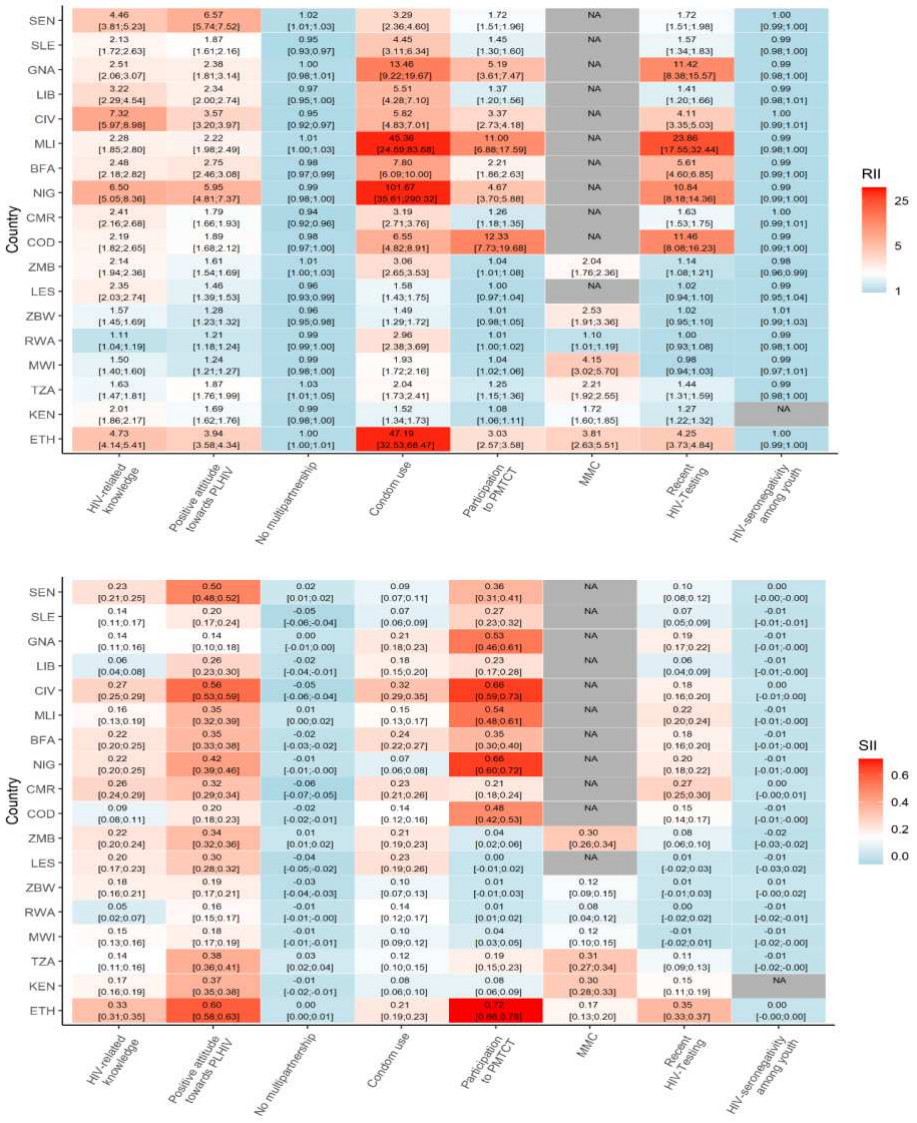
This section is based on a paper which has been published in the AIDS journal (Hamidouche, Ante-Testard et al., 2022).

Socioeconomic inequalities in the access to and uptake of HIV prevention services comprise important barriers to global prevention targets, especially in SSA. In this work, we conducted a comprehensive assessment of socioeconomic inequalities in the access to and uptake of HIV prevention services (HIV-related knowledge, positive attitudes toward PLHIV, no multipartnership, condom use, participation to PMTCT, medical male circumcision [MMC], recent HIV testing and HIV seronegativity among the youth) based on data from the

DHS conducted in 18 SSA countries between 2010 and 2018. Country-specific wealth-related inequalities were measured using the RII and SII and were then pooled using random-effects meta-analyses. We compared inequalities between African regions using the Wilcoxon ranksum test.

We noted important levels of wealth-related inequalities, both on the relative and absolute scales, in HIV-related knowledge, positive attitudes toward PLHIV, condom use, participation to PMTCT, uptake of MMC and recent HIV testing (Figure 9). The magnitude of these inequalities varies across countries and indicators. However, inequalities tend to be more marked in WCA than in ESA countries. On the relative scale, levels of inequalities were significantly higher in WCA as compared to ESA countries for the following indicators: HIV-related knowledge, positive attitude towards PLHIV, condom use, participation to PMTCT and recent HIV testing (all rank-sum test p-values <0.05). Absolute levels of inequalities were also higher in WCA for participation to PMTCT (0.43 versus 0.12, respectively, p=0.009) and for recent HIV testing, although this was marginally significant (0.16 versus 0.09, respectively, p=0.06).

Figure 9. Relative (top) and absolute (bottom) wealth-related inequalities in various HIV-related indicators across 18 sub-Saharan African countries.



Countries are ordered wet to east. RII: relative index of inequality; SII: slope index of inequality; PLHIV: People living with HIV; PMTCT: Prevention of Mother-to-Child Transmission; MMC: Medical Male Circumcision. Source: (Hamidouche, Ante-Testard et al., 2022).

Overall, no large socioeconomic inequalities in reporting multiple sexual partners were observed. Large overall absolute and relative inequalities remained regarding lack of knowledge and stigmatizing attitudes toward PLHIV, and this may undermine HIV prevention, care and treatment (Nyblade et al., 2021). Concerning inequalities were observed in condom use, PMTCT, MMC and HIV testing, especially in WCA countries.

This is concerning because these interventions prevent new infections, directly for condom use and MMC, or when linked to care and treatment for PMTCT and HIV testing. The large inequalities in condom use may reflect problems with access to free condoms. However, PMTCT, MMC and HIV testing are also interventions that are usually provided at no direct cost for the individual, which demonstrates that providing free HIV services is not the sole factor required to ensure equitable access to prevention interventions. Lessons should be drawn from the experiences of PMTCT or HIV testing programs in ESA countries that are currently offered to all at no cost, without generating measurable health inequalities.

No socioeconomic inequalities in disfavor to the poorest were observed regarding HIV prevalence among the youth, an indicator we used as a proxy for HIV incidence. For WCA countries, we did find inequalities that disfavored of the richest (i.e., the wealthiest young people being more likely to be HIV-positive), although the effect size was low. These results may appear inconsistent with the findings that inequalities disfavor the poorest in terms of access to HIV prevention services that we report here. They may however be linked to the complex and changing social epidemiology of HIV.

To our knowledge, this study forms the first effort to quantify both relative and absolute socioeconomic inequalities on a large set of HIV-related indicators collected from large, representative surveys conducted in numerous SSA countries. Such monitoring has provided important insight into the way policies may be tailored to the patterns of inequalities to best address them, which is also relevant to other fields, such as child health. We hope that this study will help in the strategical articulation of HIV prevention approaches that is essential in reducing inequalities adopted by the 2021-2026 Global AIDS Strategy.

13. Public health implications

"It is not enough to speak about inequalities, but it is also necessary to demonstrate objectively their existence".

-Pan American Health Organization

Measuring inequalities between and within countries is the first step to addressing them by taking decisions to implement actions and strategies that reduce and ultimately eliminate these disparities in health outcomes. It is necessary for researchers, practitioners and policy makers to develop the capacity of the personnel who work with decision-making bodies to carry out their own studies to measure and monitor inequalities in HIV prevention programs (Schneider et al., 2005). This thesis may hopefully serve as a tool or guide in measuring and monitoring inequalities.

13.1. Trends in socioeconomic inequalities in HIV testing

In Chapter 8, we reported temporal trends in inequalities that diverged depending on the scale used: decreasing trend in the relative scale and plateauing or increasing in the absolute scale among women and men, respectively. These diverging trends in inequalities depending on the inequality scale used have important implications for policymakers. Different conclusions about the impact of the scale-up in HIV testing on inequalities can be drawn from these diverging patterns. Because of this, it has been highly recommended to report both absolute and relative inequalities (King et al., 2012; World Health Organization, 2017). While we show the importance of reporting both inequality scales, it is also important to understand what it means to choose one scale over the other. Harper et al. argue that choosing relative inequalities indicates a very strict egalitarian position that places more weight on equality regardless of other factors such as who received more testing. Meanwhile, absolute inequalities take into account other considerations such as changes in overall population health and absolute rates of the outcome in each social group (Harper et al., 2010).

The trend observed in relative inequalities may have followed Victora's inverse equity theory especially the decreasing trend that we saw in relative inequalities. This may have occurred after the peak in RII that Victora and colleagues described in Chapter 3. As a reminder, this hypothesis suggests that higher SEP groups will benefit first from new health interventions which can lead to a conclusion that general improvements in health are accompanied by a widening of relative inequalities in health outcomes. The gap widens as the wealthy benefits from new interventions. Over time, the poor will catch up and gain more access as we have observed. This phenomenon also follows the diffusion of innovation theory where new intervention spreads through the population (Rogers, 1983), here specifically from those with higher SEP to those with lower SEP. The absolute inequalities, Victora et al. also hypothesized, based on the inverse equity theory, would increase in the short term, which we observed in the first article, and would only decrease when interventions finally reached the disadvantaged groups by which time the coverage among the affluent was already close to 100% (Victora et al., 2018).

However, practitioners and policymakers should not rely on the theory that eventually the poor will catch up without making any effort towards careful monitoring of inequalities and devising programs to reach everyone equitably. According to Victora et al., when national coverage is low and inequality is driven by the early adoption of those with high SEP, governments should work to increase access in all groups rather than target specific groups (Victora et al., 2018). They argue that the rapid uptake of by those with high SEP or "early adopters" (Rogers, 1983) may motivate others to follow. Policymakers could then use this opportunity to identify specific barriers to the adoption by those with low SEP and speed up the uptake by removing such barriers. A corollary would be that interventions that are delivered similarly to all recipients may result to differential outcomes because, for instance, the less affluent or educated are less able to access, understand and engage with the intervention (White et al., 2009) which are all barriers to the adoption of interventions.

13.2. Equity and efficiency

The findings of the spatial analysis in Chapter 9 may help policymakers, organizations and practitioners to identify hotspots of socioeconomic inequalities in HIV testing to localize efforts

and prioritize areas with the greatest inequality. At the same time, the main result of this specific thesis work is the sub-optimal efficiency (i.e., uptake of HIV testing did not match HIV prevalence) of HIV testing services in smaller geographical scales in the majority of countries. Conversely, national-level estimates showed efficiency of testing services. This suggests that governments, researchers and other relevant stakeholders should monitor inequality and efficiency of HIV testing at each geographical level and should not rely on national-level estimates only when designing and implementing programs at subnational levels. In delivering services in public health, the trade-off between equity and efficiency and between equity and effectiveness should be considered regularly when delivering public health services such as HIV testing. For instance, choosing the most effective intervention but at the same time the most efficient and cost-effective to spend the limited resources. However, an inequitable outcome is sub-optimally effective and less costly, yet an intervention tailored to individual needs may be expensive (White et al., 2009). As mentioned previously in the first article, socioeconomic inequalities in HIV testing could also go beyond the concept of equity if those least likely to be tested are at highest risk of getting infected by HIV. Indeed, we found that at smaller geographical scales, the level of uptake of HIV testing often does not match the level of HIV risk in the majority of countries.

13.3. Equitable population-based interventions

As we have seen in Chapter 1, the cascade of care and HIV prevention continuum that builds on HIV testing as their foundation and usually consist of several steps. Policymakers, practitioners and researchers should be aware that at any stage there is the potential to generate inequalities without careful attention to and monitoring of differential differences between social groups.

Population-based interventions such as HIV prevention programs that focus on guiding, advising and encouragement rely heavily on individuals being able and motivated to engage with these activities which have been described as highly agentic – individuals must use their personal resources or so-called agency to benefit. This has been found to be ineffective and inequitable (Adams et al., 2016). On the other hand, population interventions that require individuals to use little or no agency to benefit may be more effective and equitable. An example given by Adams et al. is that when food manufacturers reduce the salt content of bread,

decreased salt intake occurs without the individuals having to consciously engage with any information or actively change their behavior (Adams et al., 2016). A possible example in HIV prevention is the routine offer of HIV testing in antenatal care for women which may be one of the major reasons why lower inequalities were found among women in SSA. Meanwhile, men must rely on voluntary behavior change and actively seek health care to get tested. An intervention that would require less agency from individuals is the use of HIV self-test kits that can be done at home at their convenience. A randomized trial found increased overall testing in male partners of pregnant women using combined approach including HIV self-test kits and targeted education on how to use the kits (Mutale et al., 2021). However, there was a decrease in the proportion of men who sought follow-up facility-based testing. In the case of the ESA region, most of the countries in this region have the highest HIV burden with a long history and experience in HIV programs. They may have already put interventions in place that require lesser agency from individuals. Countries like Rwanda and Zimbabwe have developed community-based HIV strategies that strengthened their overall response to HIV over time, in addition to the aid they had been receiving from the Global Fund, PEPFAR and other NGO (Binagwaho et al., 2016; National AIDS Council of Zimbabwe & Joint United Nations Programme on HIV/AIDS, 2006). Rwanda had integrated HIV services within the existing healthcare system and assured delivery of services to remote areas allowing PLHIV to be treated near their communities (Binagwaho et al., 2016), which we argue would require lesser agency from PLHIV to access services since they do not need to travel or pay for transportation costs.

One type of low agency intervention is called nudge interventions. According to Thaler and Sunstein, a nudge is "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates..." (Thaler & Sunstein, 2009). Examples in HIV programs are the opt-out provider-initiated testing and monetary incentives. In a randomized clinical trial, small incentives and changes in default schemes (i.e., opt-in or opt-out) increased acceptance of patients to an HIV testing, but when used in combination their effects were less than additive (Montoy et al., 2018). They found that, on average, moving from opt-in to opt-out testing influenced behavior more than the largest incentives in the study (Montoy et al., 2018).

There are many reasons why high-agency interventions generate inequalities according to Adams and colleagues. In high-agency interventions, individuals are required to demonstrate their cognitive, psychological, time and material resources which all tend to be socioeconomically patterned (Adams et al., 2016). Individuals with higher SEP and with better health literacy may find it easier to understand and absorb the information in public health messages. More affluent individuals are more likely to have material resources to afford direct and indirect costs of HIV prevention services. Despite the advantages and value of low agency interventions, they are still underuse in public health due to the perception that such interventions are less acceptable to various people, and they have been considered as synonymous to limiting free choice. However, Adams et al. argued that it is unlikely that individuals genuinely do make "free choices" such as food choices, which are strongly influenced by advertisement and what food is available and affordable as well as cultural norms (Adams et al., 2016; Hepple & Nuffield Council on Bioethics, 2007). This may also be the case for HIV testing. Choosing to get tested may also be influenced by several factors such as the testing modality that is available and the attitudes of people towards testing and PLHIV.

13.4. Improving socioeconomic position to reduce inequalities in HIV testing

As seen in Chapter 3, to some extent, high SEP or wealth directly supports better health outcomes because wealthier people are put in life situations where they can afford the resources that improve and protect health such as better access to information and education, health facilities, living conditions, transportation, and health beliefs. Wealth is a part of a complex web of social and economic conditions that affect health over a lifetime. Since getting tested for HIV involves accessing healthcare facilities, individuals would still need to pay for opportunity costs such as transportation costs and the time being away from work despite HIV test being free in many SSA countries. Indeed, studies have shown that provision of small financial incentives including cash transfers can motivate individuals to attend HIV testing because the incentives offset various costs involved (Chamie et al., 2021). A randomized controlled trial conducted in Zimbabwe investigated the effect of providing economic incentives to caregivers of children aged 8-17 years on uptake of HIV testing and counselling. The authors found that fixed incentives and lottery-based incentives increased the uptake by

older children and adolescents (Kranzer et al., 2018). Another randomized clinical trial in South Africa (part of the HPTN 068 trial) found that a conditional cash transfers targeted towards less affluent girls in high school reduced the risk of physical intimate partner violence in the last 12 months. The authors argue that the reduction in the opportunity for intimate partner violence was also partly due to girls choosing not to engage in sexual partnerships which adds to the growing body of evidence as to how cash transfers may reduce the HIV risk of young women (Kilburn et al., 2018).

Aside from providing incentives or cash transfers, it may also be worthwhile to improve wealth to reduce inequalities, however, due to its complexity with many factors coming into play, this may be challenging and may need a long time to achieve. For this reason, controlling for modifiable individual characteristics may be more manageable. However, in the mediation analysis, we found that the individual-level factors – HIV-related knowledge and positive attitudes toward PLHIV – only partly explained wealth-related inequalities with only minimal reduction in inequalities when controlled for and with varying importance across countries and genders. This suggests that to reduce or eliminate inequalities, a single intervention modality may not be sufficient. It would require a combination of strategies such as upstream and downstream interventions, e.g., an upstream policy measure coupled with downstream interventions such as HIV peer-education programs. Indeed, a one-size-fits-all type of intervention was recognized to be problematic and is likely to be another type of intervention that may widen inequality (White et al., 2009). Only implementing downstream interventions that target individual factors, such as education through media campaigns, was found to increase inequalities (Lorenc et al., 2013). Interventions that are tailored to the needs of individuals or groups may more likely result in equitable outcomes (Marcus et al., 1998; White et al., 2009).

13.5. Improving access to HIV testing to improve socioeconomic position

We discussed how SEP can improve one's health outcomes and access to health interventions, however, it could also be the other way around. Indeed, a study conducted in Kenya and Uganda found that universal HIV testing and treatment may improve employment outcomes and other

socioeconomic wellbeing indicators for HIV-positive individuals and their children (Jakubowski et al., 2022). Well-tailored, inequality non-generating HIV intervention may break the poverty trap experienced by the poorest populations – allowing them to enjoy interventions and not become trapped in a continuous cycle of poverty and disease.

13.6. Improving access to HIV testing through self-testing

As previously discussed, many HIV testing modalities were developed to improve access to HIV testing and counteract the challenges such as the stigma surrounding testing and HIV in general. One of which is HIV self-testing which has been recommended by the WHO as an innovative strategy to reach the UNAIDS targets to end AIDS by 2030 (McGuire et al., 2021). It could be a useful strategy in reaching men (Hamilton et al., 2021), key populations (Witzel et al., 2020) and their partners (Thirumurthy et al., 2016), youth (Ong et al., 2021), elderly and other hard-to-reach groups due to the low agency required from individuals to engage with the intervention. In addition, as discussed in Chapter 2, HIVST is highly accepted due to its convenience, confidentiality, its potential to overcome stigma and reduce opportunity costs when visiting a healthcare facility (Figueroa et al., 2015; Jamil et al., 2021; Njau et al., 2019; Stevens et al., 2018).

However, HIVST also faces many challenges in implementation especially in Western and Central Africa (Ekouevi et al., 2020). One of the challenges in HIVST is the challenge of linking individuals to care (Ekouevi et al., 2020; Mutale et al., 2021). However, a recent systematic review found that HIVST with digital supports including social media, mobile applications, text messaging and digital vending machines were "feasible, acceptable, preferable, and was shown to increase uptake, engage first-time testers and hard-to-reach populations and successfully link individuals to treatment" (McGuire et al., 2021). It is uncertain though whether HIVST is reaching everyone in need, especially the disadvantaged groups. Moreover, in most cases, individuals with higher SEP may likely have more access to such digital supports compared to those with lower SEP. If the inverse equity theory (Victora et al., 2000) also applies to HIVST, as being a relatively new public health intervention, individuals with higher SEP may benefit first from such program. Without careful attention to health inequalities during the planning until the implementation stage, such intervention may also have the potential to generate

inequalities unintentionally (White et al., 2009) as discussed in Chapter 3. It may be beneficial for current and future HIVST interventions and other testing modalities to monitor socioeconomic inequalities and other forms of inequalities, from planning to implementation, to help in better tailoring such interventions, to prevent and reduce inequalities and improve overall health.

Conclusion

The original contribution of this thesis to the existing body of knowledge is to provide a multi-country analysis of socioeconomic inequalities in HIV testing uptake in SSA. This thesis will hopefully serve as a guide on how to use free and publicly available population-based surveys such as the DHS for inequality monitoring especially in the Global South where there is usually limited funding for surveys and data collection. Socioeconomic inequalities have long been a relatively blind spot for HIV in SSA, probably due to the "key population lens" which somewhat overlaps with inequality lens – many key populations are expected to belong to low SEP, but the inverse is also true. This is unfortunate because it shows that lessons from social epidemiology have not been used when tackling HIV in SSA. Although, this may have recently changed with the WHO releasing its first comprehensive report on the state of inequality in HIV and other infectious diseases and using concepts from the field (World Health Organization, 2021a). This thesis is part of the movement to apply lessons from social epidemiology to HIV in SSA.

This thesis provides a broad context of the socioeconomic inequalities in recent HIV testing uptake in several countries in SSA and other types of inequalities defined by gender and geography in both absolute and relative scales. We reveal that inequalities in HIV testing that favor the rich persist in the majority of countries, despite the success in scaling up HIV testing uptake over the years as ART became increasingly available and with the routine offer of HIV testing and counselling in health facilities. We show that depending on the inequality scale, diverging trends in inequalities in recent HIV testing may be observed (i.e., overall relative inequalities decreased in both genders, while overall absolute inequalities plateaued in women and increased in men). The magnitude, heterogeneity and spatial distribution of inequalities depend on the inequality indicator used, which demonstrates the importance of reporting both scales when monitoring inequalities. In addition, this thesis demonstrates that there is a need to assess the spatial distribution of inequalities in recent HIV testing and the efficiency of HIV testing services across various geographical scales as national-level estimates often hide disparities found on smaller scales. This suggests that important efforts are also needed at the subnational levels to ensure that HIV testing efforts match the level of HIV risk. Lastly, we show that there are different contextual and individual factors that may explain these inequalities and their heterogeneities across countries and gender.

Overall, the findings of this thesis have the potential to inform the design of well-tailored HIV testing interventions that would not increase nor generate inequalities but may reduce them in order to reach the UNAIDS first 95 by 2030. These interventions may follow the principle of "proportionate universalism" which suggest that actions or programs should be universal but adapted in proportion to the level of disadvantage or need in order to reduce inequalities (Francis-Oliviero et al., 2020). Through this principle, services would therefore be universally available, not only for the most disadvantaged, and would be able to respond to the level of needs. This was proposed as a means of implementing upstream interventions aimed at addressing the root causes of inequalities. However, upstream and downstream interventions could also be seen as complementary actions acting at different levels in order to both address the root causes or determinants of inequalities, and proximal-level causes involving individual factors (Francis-Oliviero et al., 2020). This thesis highlights the importance of assessing and monitoring inequalities in HIV testing in the fight against HIV/AIDS.

Personal conclusion

This thesis has been an avenue for me to grow as a researcher. From being a nurse to an early-career researcher, I was able to experience the other side of the coin, from practice to research.

I worked as a nurse for almost four years in the Philippines before I decided to pursue higher studies in France. My experiences as a nurse gave me an opportunity to gain clinical knowledge related to HIV and its management. It also gave me first-hand experience on how inequalities in health affect healthcare professionals, patients and their families. On the other hand, this doctoral research has broadened my knowledge in which I gained a deeper understanding of HIV in an international and epidemiological perspective. Moreover, it provided me knowledge of the dynamics of health inequalities and how to better understand them through systematic approaches.

This PhD helped me to develop strong skills in the analysis of large epidemiological databases using advanced statistical methods. It also served as an eye opener for me on how rampant and persistent socioeconomic inequalities are in terms of access to HIV testing and made me aware of its current state outside healthcare facilities. I am very grateful for this journey because it gave me a wider perspective and the opportunity to meet, collaborate with and learn from scientists and experts in their respective fields.

However, despite the valuable skills and learnings gained from conducting quantitative analysis of large population-based surveys, it could only go as far. The practical and human aspect of the research was still lacking. A field experience or visit to see the realities of what is happening on the ground in at least one of the countries in the study may have been a source of valuable insights scientifically and personally. The conferences, such as the AFRAVIH, would have been a great opportunity for such a visit. However, due to the COVID-19 pandemic, that lasted for the whole two years of my PhD, I was not able to attend such conferences in person and to continue with my research visit at the University of California, San Diego in 2020.

Overall, this thesis made me realize that inequalities in HIV testing and other public health challenges we face today are multifactorial and to address them, we would also need transdisciplinary solutions. The siloing that we see today from different disciplines may not be effective in addressing inequalities and challenges in HIV. HIV is a complex disease and a social issue that involves many disciplines from biomedical research to sociology. For this reason, for future research projects, I am interested in exploring transdisciplinary research such as in the fields of global health and planetary health that offer transdisciplinary research and a new paradigm in tackling public health challenges.

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French section

In compliance with the requirements of the doctoral school, a PhD thesis written in English is required to include a substantial part in French. Hence, this French section is comprised of: i) a short summary of the entire thesis, and ii) a complete French version of the first published article of this thesis.

A. French synthesis

Introduction

Le virus de l'immunodéficience humaine/syndrome d'immunodéficience acquise (VIH/sida) reste une menace pour la santé publique dans le monde entier et a un impact considérable sur les sociétés et la santé des populations. C'est l'une des maladies les plus meurtrières au monde, en particulier en Afrique subsaharienne (ASS). La région, qui abriterait 67 % de toutes les personnes vivant avec le VIH (PVVIH) en 2020 (UNAIDS, 2021a), est l'épicentre de la pandémie. Des progrès considérables ont été réalisés au fil des ans pour mettre fin au VIH/SIDA, mais la stigmatisation et les inégalités, entre autres, continuent à alimenter l'épidémie (UNAIDS, 2020a).

Pour optimiser les bénéfices du traitement du VIH, le Programme commun des Nations Unies sur le VIH/SIDA (ONUSIDA) avait fixé des objectifs ambitieux mais réalisables - le cadre stratégique « 90-90-90 » visant à atteindre 90 % des personnes infectées par le VIH diagnostiquées, 90 % des personnes diagnostiquées recevant un traitement, et 90 % des personnes recevant un traitement étant viralement supprimées d'ici 2020 (UNAIDS, 2014). Cet objectif, associé à la disponibilité croissante des thérapies antirétrovirales (TAR), a conduit à une intensification réussie des programmes de dépistage du VIH en ASS. La proportion de PVVIH connaissant leur statut est passée d'environ 10 % en 2005 à 84 % au niveau mondial en 2020 (UNAIDS, 2021c; World Health Organization, 2019a). Toutefois, une telle augmentation globale peut masquer d'importantes disparités entre les groupes socio-économiques.

L'objectif des interventions de santé publique est d'améliorer la santé globale de la population. Néanmoins, elles peuvent également générer ou même accroître les inégalités de santé existantes. Cela peut se produire lorsqu'une attention particulière n'est pas accordée aux groupes défavorisés et marginalisés lors de la mise en œuvre des programmes et des interventions. Ce phénomène a été bien décrit au Nord. Ainsi, contrairement à ce que l'on pourrait supposer, les programmes qui ont augmenté les services de dépistage du cancer n'ont pas nécessairement diminué les inégalités de santé (de Klerk et al., 2017). A l'inverse, on en sait peu au Sud à ce sujet, notamment en raison de systèmes nationaux et décentralisés de surveillance, fournissant peu de données fiables dans le domaine des inégalités de santé. Cependant, plusieurs théories ont formalisé la manière dont les inégalités liées à une intervention peuvent également se produire dans ces contextes. En particulier, « l'hypothèse de l'équité inverse » suggère que les inégalités en matière de santé évoluent de manière dynamique dans le temps en défaveur des pauvres. Cette hypothèse, qui a été développée à l'origine dans le domaine de la santé infantile en 2000 par Victora et al., propose que les groupes socio-économiques plus élevés bénéficient en premier des nouvelles interventions de santé publique et que ce n'est que lorsque les riches auront atteint un niveau de développement qui n'est plus susceptible de progresser que les pauvres commenceront à rattraper leur retard, réduisant ainsi l'écart au fil du temps (Victora et al., 2000). Une autre raison potentielle pour laquelle il y a peu de preuves au Sud, spécifiquement en ASS, concernant ce phénomène est qu'il a longtemps été considéré par beaucoup que l'épidémie de VIH est une urgence de santé publique nécessitant une réponse globale qui prend le pas sur d'autres questions telles que les inégalités de santé. Toutefois, cela a peut-être changé récemment avec la publication du premier rapport complet sur les inégalités de santé en matière de VIH par l'Organisation mondiale de la santé (OMS) (World Health Organization, 2021a).

Plusieurs études épidémiologiques ont déjà mis en évidence des inégalités socio-économiques dans le continuum de soins du VIH, notamment en ce qui concerne le recours et l'accès au dépistage du VIH. Cependant, ces inégalités ont été documentées dans des populations et des contextes variés et à l'aide de différents modèles d'étude. On ne dispose toujours pas d'une vision à grande échelle des inégalités socio-économiques en matière de dépistage du VIH.
Ainsi, cette thèse vise à combler les lacunes de la littérature qui pourraient nous permettre de mieux comprendre les inégalités socio-économiques dans le recours au dépistage du VIH en

ASS, grâce à une analyse multi-pays utilisant des enquêtes de population riches et robustes. L'objectif repose sur l'hypothèse générale qu'il existe des niveaux substantiels d'inégalités dans le dépistage du VIH qui méritent d'être mieux compris, notamment en termes de tendances temporelles, de distribution géographique, de facteurs contextuels et de voies médiatrices, et qu'ils peuvent être quantifiés à partir d'enquêtes en population. Quatre objectifs spécifiques ont été formulés à cette fin :

i) Quantifier les inégalités socio-économiques dans le dépistage du VIH et évaluer leurs tendances dans le temps ;
ii) Explorer la distribution spatiale des inégalités dans le dépistage du VIH à différentes échelles géographiques ;
iii) Identifier les facteurs contextuels associés aux inégalités dans le dépistage du VIH ; et
iv) Comprendre les voies médiatrices reliant la position socioéconomique (PSE) au dépistage du VIH au niveau individuel.

Pour atteindre ces objectifs, nous avons analysé les données des Enquêtes Démographiques et de Santé (EDS), qui représentent des données riches et gratuites disponibles à des fins académiques. Ces résultats peuvent fournir une compréhension plus fine de ces inégalités en ASS pour aider à concevoir des programmes qui pourraient potentiellement réduire les inégalités et aider au contrôle des épidémies pour améliorer la santé globale.

Enquêtes Démographiques et de Santé

Nous avons utilisé les données du programme EDS qui constituent une source de données riche qui n'a pas été systématiquement utilisée pour évaluer les inégalités dans le dépistage du VIH en ASS, ce que cette thèse propose de faire. Le programme EDS mène des enquêtes par sondage auprès de ménages représentatifs au niveau national au Sud. Il collecte des données sur un large éventail d'indicateurs de population, de santé, de VIH et de nutrition afin de suivre les progrès des programmes de santé (Corsi et al., 2012; Rutstein & Rojas, 2006). Il s'agit d'enquêtes basées sur la population qui comprennent un échantillon allant de 5 000 à 30 000 ménages, où les femmes âgées de 15 à 49 ans peuvent participer (The DHS Program, 2021a). Dans certaines EDS, les hommes âgés de 15 à 54 ans (jusqu'à 59 ans dans certaines enquêtes) sont également

éligibles dans la totalité ou un sous-échantillon de ménages sélectionnés selon l'enquête. Elles sont généralement menées tous les cinq ans environ pour permettre des comparaisons dans le temps. Les participants consentants sont interrogés sont interrogées en face à face par des enquêteurs formés qui utilisent un questionnaire standardisé comprenant des questions sur les caractéristiques sociodémographiques, les comportements sexuels et la santé reproductive, ainsi qu'une section spécifique axée sur les questions liées au VIH. Les EDS utilisent une méthode d'échantillonnage stratifiée à deux degrés pour garantir la représentativité aux niveaux national et infranational (Corsi et al., 2012).

Grâce à la collecte de prélèvements sanguins auprès d'échantillons représentatifs de la population adulte, les EDS ont joué un rôle majeur dans le suivi de l'épidémie de VIH/SIDA dans plusieurs pays du Sud global. L'enquête sur les indicateurs du SIDA (EIS), un type d'EDS, a été développée pour fournir aux pays un outil standard pour collecter les indicateurs nécessaires au suivi efficace des programmes de lutte contre le VIH/SIDA, notamment la prévalence du VIH et les connaissances, attitudes et pratiques en matière de VIH/SIDA.

Les EDS recueillent également de manière routinière des informations géographiques dans la plupart des pays ayant fait l'objet d'une enquête récente, où les grappes (c'est-à-dire les groupements de ménages ayant participé à l'enquête) sont géoréférencées. Les coordonnées GPS obtenues à partir de la base de données de l'EDS sont intentionnellement déplacées pour garantir la confidentialité des répondants.

Quantifier les inégalités socio-économiques dans le dépistage du VIH et évaluer leurs tendances dans le temps

La première contribution de cette thèse a consisté à quantifier les inégalités absolues et relatives au niveau des pays dans le recours récent au dépistage du VIH et à évaluer leurs tendances temporelles avant et après 2008 - un an après que l'OMS ait recommandé l'élargissement du dépistage du VIH à l'initiative du soignant - en utilisant les données des EDS dans 16 pays d'ASS. Nous avons mesuré les inégalités absolues et relatives en estimant l'indice de pente des inégalités (IPI) et l'indice relatif des inégalités (IRI), respectivement, avant et après 2008. Les tendances temporelles ont été évaluées en calculant la différence de l'IPI et le rapport de l'IRI entre les estimations post-2008 et pré-2008. Les estimations entre les pays ont été regroupées à

l'aide d'une méta-analyse à effet aléatoire. Grâce à ce travail, nous avons constaté qu'il y a effectivement eu une augmentation spectaculaire de l'auto-déclaration du dépistage récent du VIH au fil du temps. Cette augmentation peut être due à plusieurs facteurs tels que l'élargissement du dépistage et du conseil à l'initiative du soignant et la disponibilité croissante de la TAR. Toutefois, cette augmentation n'a pas été la même pour tous. Avant 2008, les différences entre les hommes et les femmes en matière de recours récent au dépistage du VIH étaient faibles ou mineures, mais après 2008, on a constaté une augmentation plus importante du recours au dépistage du VIH chez les femmes dans la majorité des pays. Au fil du temps, les inégalités absolues favorisant les personnes ayant un PSE plus élevé ont persisté chez les femmes et ont même augmenté chez les hommes au fil du temps. Parallèlement, les inégalités relatives globales ont diminué pour les deux sexes. Dans l'ensemble, malgré les progrès réalisés, notamment en ce qui concerne les inégalités relatives, les inégalités en faveur des riches ont persisté dans la plupart des pays après 2008, surtout chez les hommes. Cela corrobore l'hypothèse selon laquelle les inégalités relatives en matière de santé vont se réduire mais pas disparaître (Hargreaves et al., 2013b). D'importantes hétérogénéités entre les pays quant à l'ampleur des inégalités ont été constatées. Des résultats similaires ont été constatés en répétant l'analyse en utilisant le niveau d'éducation comme mesure du PSE et en répétant l'analyse sur un sous-échantillon de jeunes participants âgés de 15 à 24 ans - une population vulnérable qui n'a généralement pas accès aux services de prévention du VIH.

La tendance observée dans les inégalités relatives peut être cohérente avec la théorie de l'équité inverse de Victora, en particulier la tendance à la baisse que nous avons observée dans les inégalités relatives. Ceci peut avoir eu lieu après le pic de l'IRI. Pour rappel, cette hypothèse suggère que les groupes à PSE élevé seront les premiers à bénéficier des nouvelles interventions en matière de santé, ce qui peut mener à la conclusion que les améliorations générales en matière de santé s'accompagnent d'un élargissement des inégalités relatives dans les résultats de santé. L'écart se creuse à mesure que les riches bénéficient des nouvelles interventions. Avec le temps, les pauvres rattrapent, en partie seulement, leur retard et bénéficient d'un meilleur accès, comme nous l'avons observé. Pour les inégalités absolues, Victora et al. ont également émis l'hypothèse, basée sur la théorie de l'équité inverse, qu'elles augmenteraient à court terme, ce que nous avons observé dans le premier article, et qu'elles ne diminueraient que lorsque les interventions

atteindraient enfin les groupes défavorisés, moment où la couverture parmi les plus favorisés serait déjà proche de 100 % (Victora et al., 2018).

Toutefois, le suivi et la lutte contre les inégalités ne doivent pas s'arrêter au niveau national et s'appuyer sur des estimations sommaires telles que la moyenne nationale. L'utilisation de telles statistiques sommaires dissimule souvent les différences de résultats sanitaires entre les groupes sociaux et les sexes. On sait peu de choses sur l'état des inégalités en matière de dépistage du VIH à des échelles plus petites.

Explorer la distribution géographique des inégalités socio-économiques dans le dépistage du VIH à différentes échelles géographiques

Ainsi, la deuxième contribution de cette thèse visait à explorer la variation spatiale des inégalités socio-économiques absolues et relatives du dépistage récent du VIH à travers les échelles géographiques. Par ailleurs, à effectuer une analyse de regroupement spatial de ces inégalités et à explorer l'efficacité des programmes de dépistage du VIH (i.e., si le recours récent au dépistage du VIH correspondait au niveau de prévalence du VIH) à diverses échelles géographiques dans 25 pays entre 2011 et 2019. Pour ce faire, les IPI et IRI ont été estimés et cartographiés au niveau national, provincial (premier échelon administratif infranational) et au niveau de l'unité (UPE). Une analyse d'autocorrélation spatiale a été réalisée pour identifier les « hotspots » et les « coldspots » de ces inégalités dans toute l'ASS. L'efficacité des programmes de dépistage du VIH a été évaluée par le biais du rho de Pearson évaluant la corrélation entre la proportion de tests récents et la prévalence du VIH. Nous avons observé que le choix de l'échelle géographique avait un impact clair sur l'ampleur des inégalités. Nos résultats ont révélé l'existence d'inégalités non seulement au niveau national mais aussi aux niveaux infranational - au niveau des provinces et des UPEs. Les hétérogénéités dans la distribution spatiale de ces inégalités aux niveaux infranational et les variations dans les hotspots et les coldspots de ces inégalités varient en fonction de l'échelle d'inégalité utilisée et du sexe. Dans l'ensemble, les hotspots des inégalités ont été davantage observés dans les pays d'Afrique occidentale et centrale (AOC) et dans quelques pays d'Afrique orientale et australe (AOA). De manière surprenante, dans la plupart des pays et pour les deux sexes, la proportion de tests VIH récents dans les provinces et les UPE n'était pas corrélée avec le niveau de prévalence du VIH, ce qui contrastait avec les conclusions obtenues en examinant uniquement la corrélation de ces

facteurs au niveau national. Cela suggère que d'importants efforts en matière de dépistage du VIH doivent encore être déployés au niveau infranational pour adapter le niveau de recours au dépistage du VIH au niveau de risque du VIH (telle que mesurée par la prévalence locale du VIH). Cela implique également qu'il serait trompeur d'extrapoler les estimations au niveau national à des échelles géographiques plus petites.

Les résultats de l'analyse spatiale peuvent aider les décideurs politiques, les organisations et les praticiens à identifier les hotspots des inégalités socio-économiques dans le dépistage du VIH afin de localiser les efforts et de donner la priorité aux zones où les inégalités sont les plus grandes. Dans le même temps, le principal résultat et spécifique de ce travail de thèse spécifique est l'efficacité sous-optimale des services de dépistage du VIH (i.e., le recours au dépistage du VIH ne correspond pas à la prévalence du VIH) à des échelles géographiques plus petites, que nous avons soulignée, dans la majorité des pays. A l'inverse, les estimations au niveau national ont montré l'efficience des services de dépistage. Cela suggère que les gouvernements, les chercheurs et les autres parties prenantes concernées devraient surveiller l'inégalité et l'efficacité du dépistage du VIH à chaque niveau géographique et ne pas se baser uniquement sur les estimations au niveau national lors de la conception et de la mise en œuvre des programmes aux niveaux infranationaux. Dans la distribution de services de santé publique tels que le dépistage du VIH, le compromis entre l'équité et l'efficience et entre l'équité et l'efficacité doit être régulièrement examiné. Par exemple, choisir l'intervention la plus efficace tout en dépensant les ressources limitées de la manière la plus efficiente et la plus rentable. Cependant, une intervention inéquitable est moins efficace et moins coûteux, alors qu'une intervention adaptée aux besoins individuels peut être coûteuse (White et al., 2009).

Identifier les facteurs contextuels associés aux inégalités socio-économiques dans le dépistage du VIH

Après avoir quantifié et cartographié les inégalités, il est également essentiel de comprendre les facteurs qui pourraient les conduire ou pourraient les expliquer. Pour comprendre les facteurs contextuels associés aux inégalités liées à la richesse en matière de dépistage du VIH, nous avons exploré les facteurs contextuels susceptibles d'expliquer ces inégalités dans le même ensemble de 16 pays entre 2003 et 2016 que dans le premier travail de cette thèse. Les résultats préliminaires ont été présentés lors de la conférence AIDS 2020. Dans ce travail, l'indice de

concentration d'Erreygers (ICE) a été utilisé pour quantifier les inégalités liées à la richesse dans le recours récent au dépistage du VIH. Une nouvelle méthode, la décomposition par régression RIF, a été utilisée pour évaluer l'effet marginal de chaque facteur contextuel sur l'inégalité. Nous avons constaté que la prévalence du VIH était associée aux inégalités et non au produit intérieur brut (PIB) par habitant. Ce travail pourrait être plus développé à l'avenir, en étendant l'analyse à d'autres pays (stratifiés par sexe) et en intégrant un éventail plus large de variables épidémiologiques et socio-économiques. Dans cette analyse, nous avons utilisé les pays comme échantillons. Dans une étude future, des échantillons au niveau infranational pourront également être utilisés. Pour ce faire, un modèle hiérarchique pourrait être menée.

Comprendre les voies médiatrices reliant le PSE au dépistage du VIH au niveau individuel

Le dernier objectif de cette thèse était d'évaluer ce qui détermine au niveau individuel les inégalités liées à la richesse dans le dépistage récent du VIH par une analyse de médiation, basée dans le cadre du modèle à résultats potentiels (en anglais « potential outcome model »), dans 18 pays d'ASS entre 2010 et 2018. Il s'agissait de tenter d'évaluer les facteurs au niveau individuel qui pourraient être modifiables pour réduire les inégalités. Pour cette étude, afin de quantifier les inégalités, l'effet total de la richesse sur le dépistage récent du VIH a été utilisé. Les résultats de ce travail confirment les résultats précédents selon lesquels les individus les plus riches étaient plus susceptibles d'avoir été récemment testés que les plus pauvres, avec des amplitudes variant selon les pays. Nous avons préalablement identifié plusieurs caractéristiques des participants qui pourraient jouer un rôle médiateur entre la richesse et le dépistage récent. Pour des raisons de simplicité, les médiateurs ont été classés en deux groupes : les médiateurs liés à la demande de soins (facteurs qui caractérisent la capacité d'un individu à percevoir le besoin et l'inclination à rechercher des soins) et les médiateurs liés à l'offre de soins (facteurs qui caractérisent la capacité d'un individu à accéder, payer et s'engager dans des soins de santé). Les médiateurs liés à la demande comprenaient la connaissance du VIH et les attitudes positives envers les PVVIH, tandis que les médiateurs liés à l'offre comprenaient le fait de ne pas déclarer de problème lié à la distance pour avoir recours aux soins, de ne pas avoir de problème lié à l'argent pour avoir recours aux soins, de ne pas avoir besoin de permission pour consulter un médecin et de ne pas avoir de difficulté à avoir recours aux soins. Les personnes plus riches étaient plus susceptibles d'avoir une condition favorable en ce qui concerne ces médiateurs,

comme le fait d'avoir des connaissances complètes sur le VIH, moins de stigmatisation envers les PVVIH et moins de problèmes pour se faire soigner, et ces médiateurs étaient également associés positivement à la réalisation récente d'un test de dépistage du VIH. Nous n'avons pas trouvé de médiateur unique et fort dans le chemin entre la richesse et le dépistage récent qui soit systématiquement fort dans tous les pays et pour tous les sexes, mais nos résultats montrent que les inégalités sont davantage médiées par les caractéristiques individuelles du côté de la demande que de l'offre de soins. En particulier, les attitudes positives envers les PVVIH ont eu tendance à avoir la plus grande proportion de médiation dans le chemin entre la richesse et le dépistage récent dans tous les pays. Cependant, l'importance de chaque médiateur variait considérablement selon le pays et le sexe. Cela illustre l'importance d'adapter les programmes de dépistage du VIH au contexte local du pays et aux besoins de chaque sexe.

Ces résultats suggèrent aussi que pour réduire ou éliminer les inégalités, une modalité unique d'intervention est probablement insuffisante. Il faudrait une combinaison de stratégies telles que des interventions en amont ou structurelles, par exemple une mesure politique couplée à des interventions en aval et comportementales telles que des interventions d'éducation par les pairs sur le VIH. En effet, il a été reconnu qu'un type d'intervention unique était problématique et qu'il s'agissait probablement d'un autre type d'intervention susceptible de creuser les inégalités (White et al., 2009). On a constaté que seule la mise en œuvre d'interventions en aval qui ciblent un facteur individuel, comme l'éducation par le biais de campagnes médiatiques, augmentait les inégalités (Lorenc et al., 2013). Les interventions qui sont adaptées aux besoins des individus ou des groupes sont plus susceptibles d'aboutir à des résultats équitables (Marcus et al., 1998 ; White et al., 2009).

Conclusion

En conclusion, la contribution originale de cette thèse au corpus de connaissances existant est de fournir une analyse multi-pays des inégalités socio-économiques dans le recours au dépistage du VIH en ASS. Les résultats ont le potentiel d'informer sur la meilleure façon de concevoir des interventions de dépistage du VIH bien adaptées qui pourraient réduire les inégalités et ne les aggraveraient pas, ni ne les généreraient, afin d'atteindre les 95 premiers objectifs de l'ONUSIDA d'ici 2030. Ces interventions peuvent suivre le principe de l'universalisme proportionné qui suggère que les actions ou les programmes devraient être universels mais

adaptés en fonction du niveau de désavantage ou de besoin afin de réduire les inégalités (Francis-Oliviero et al., 2020). Grâce à ce principe, les services seraient donc universellement disponibles, pas seulement pour les plus défavorisés, et seraient en mesure de répondre au niveau des besoins. Ce principe a été proposé comme un moyen de mettre en œuvre des interventions en amont visant à s'attaquer aux causes profondes des inégalités. Cependant, les interventions en amont et en aval pourraient également être considérées comme des actions complémentaires agissant à différents niveaux afin de s'attaquer à la fois aux causes profondes ou aux déterminants des inégalités, et aux causes proximales impliquant des facteurs individuels (Francis-Oliviero et al., 2020). Cette thèse souligne l'importance de l'évaluation et du suivi des inégalités en matière de dépistage du VIH dans la lutte contre le VIH/SIDA. Ce travail s'inscrit dans ce mouvement visant à appliquer les leçons de l'épidémiologie sociale au VIH en Afrique subsaharienne.

B. French version of Article 1

Le paragraphe suivant correspond à une traduction française du première article (Chapitre 8) de cette thèse.

Appendix 1: French version of the article.

Tendances temporelles des inégalités socio-économiques dans le recours au dépistage du VIH : résultats à partir d'enquêtes en population générale dans 16 pays d'Afrique sub-saharienne.

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Résumé

Contexte

L’augmentation globale du recours au dépistage du VIH au cours des dernières décennies pourrait masquer des disparités entre groupes socioéconomiques. Ã partir d’enquêtes en population générale conduites en Afrique subsaharienne, nous avons quantifié les inégalités socio-économiques liées au recours récent au dépistage du VIH, ainsi que leurs tendances temporelles au cours des deux dernières décennies.

Méthodes

Nous avons analysé les données des enquêtes démographiques et de santé dans des pays d'Afrique subsaharienne où au moins une enquête avait été réalisée avant et après 2008. Pour chaque pays, les proportions de recours récent (<12 mois) ont été calculées par niveaux de richesse et d'éducation, et les inégalités ont été quantifiées à l’aide des indices relatifs d’inégalité et de pente d’inégalité. Les tendances temporelles dans les inégalités ont été évaluées et les résultats ont été moyennés entre pays à l'aide de méta-analyses à effets aléatoires.

Résultats

Nous avons analysé les données de 32 enquêtes menées entre 2003 et 2016 dans 16 pays auprès de 537 784 participants. Dans les enquêtes antérieures à 2008, les femmes signalaient un taux de participation au test du VIH supérieur à celui des hommes dans 8 pays sur 16 ; et dans 15 pays sur 16 dans les enquêtes postérieures à 2008. Après 2008, les femmes les plus riches étaient en moyenne 2,77 (IC 95%: 1,42-5,40) fois plus susceptibles de rapporter un dépistage récent que les plus pauvres; et 3,55 (1,85-6,81) fois chez les hommes. La différence absolue moyenne dans le dépistage récent entre les plus riches et les plus pauvres était de 11,1 (4,6-17,5) points de pourcentage chez les femmes et de 15,1 (9,6-20,6) chez les hommes. Au cours du temps, les inégalités relatives dans le dépistage récent du VIH ont diminué parmi les deux genres, tandis que les inégalités absolues stagnaient chez les femmes et augmentaient chez les hommes.

Conclusions

L’augmentation globale du recours au dépistage du VIH, qui a été stimulée par la volonté d’étendre le traitement du VIH en Afrique subsaharienne, a entraîné une diminution des inégalités relatives, alors que les inégalités absolues ont persisté. Dans la plupart des pays, de grandes inégalités subsistaient encore, à la fois à sur les

échelles absolue et relative, en particulier en Afrique occidentale et centrale. Une plus grande attention devrait être accordée à l'équité dans le suivi des programmes de dépistage du VIH.

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Introduction

En tant que porte d'entrée vers de nombreux services de prévention et de traitement du VIH, le traitement antirétroviral (ARV), le dépistage du VIH a joué un rôle central dans la réponse au VIH. Les stratégies de dépistage du VIH ont évolué au cours du temps, à mesure que l'accès au traitement ARV a progressé dans la plupart des pays, passant d'une approche précautionneuse axée sur le conseil et la confidentialité vers un objectif d'accès systématique au dépistage en milieu hospitalier et vers des approches communautaires à grande échelle.[1,2] Cela s'est traduit par une augmentation significative dans l'accès et le recours au dépistage du VIH dans de nombreux pays.

En Afrique en particulier, le pourcentage de personnes vivant avec le VIH (PVVIH) connaissant leur statut est passé de 10% en 2005 à 85% en Afrique orientale et australe et à 64% en Afrique occidentale et centrale en 2018. [3] Cependant, il est estimé qu'1.1 million de personnes vivant avec le VIH / sida en Afrique orientale et australe, et 1,3 million en Afrique occidentale et centrale ne sont toujours pas informés de leur statut. Cela signifie que des efforts sont encore nécessaires pour atteindre l'objectif de 90% des PVVIH connaissant leur statut d'ici 2020, c'est à dire le premier 90 de l'objectif mondial 90-90-90 adopté par le Programme commun des Nations Unies sur le VIH / sida (ONUSIDA).[4] Il est également essentiel de veiller à ce que, dans les progrès vers ces objectifs aucun sous-groupe de la population ne soit laissé pour compte.

Plusieurs études transversales menées en Afrique subsaharienne ont révélé un moindre recours au test de dépistage du VIH dans les groupes de population les plus pauvres ou les moins éduqués. [5–9] Savoir si ces inégalités ont reculé ou progressé au cours de l'intensification des activités de dépistage du VIH reste une question ouverte. En effet, le déploiement d'interventions de santé publique ne se traduit pas nécessairement par une réduction des inégalités de santé, et peut même exacerber ces inégalités. Ainsi, il a été récemment démontré que les programmes visant à augmenter le recours au dépistage du cancer n'avaient pas réussi à réduire les inégalités socioéconomiques en matière d'accès. [10,11] Il était donc essentiel de surveiller les tendances chronologiques en matière d'inégalités socioéconomiques en réponse aux progrès du dépistage du VIH, afin de s'assurer de l'équité des programmes de lutte contre le VIH, conformément aux objectifs de développement durable.

Dans cette étude, sur la base d'enquêtes en population menées dans plusieurs pays d'Afrique subsaharienne, nous évaluons les tendances temporelles des inégalités socioéconomiques relatives et absolues dans le recours au test du VIH sur la période correspondant à la progression du dépistage du VIH et l'extension du traitement antirétroviral.

Matériel et méthodes

Nous avons analysé les données collectées à partir des enquêtes démographiques et de santé (EDS). Les EDS sont des enquêtes transversales représentatives au niveau national, qui collectent des données sur un large éventail d'indicateurs de santé, et notamment des données spécifiques sur le VIH / sida. Sur la base d'un plan d'échantillonnage à plusieurs niveaux et avec le ménage comme unité d'échantillonnage, tous les adultes (généralement âgés de 15 à 49 ans) issus des ménages sélectionnés sont éligibles. Selon l'enquête, les données relatives aux hommes et / ou les indicateurs du VIH ne peuvent être collectées que dans un sous-échantillon des ménages sélectionnés. Les adultes consentants sont interrogés en face-à-face par un enquêteur entrainé utilisant un questionnaire standardisé. Les questions du questionnaire couvrent divers aspects tels que les caractéristiques sociodémographiques, les comportements sexuels, la santé reproductive, ainsi qu'une section spécifique consacrée aux problèmes liés au VIH. [12] Les données des enquêtes EDS sont publiquement disponibles à des fins de recherche universitaire (https://dhsprogram.com /).

Nous avons sélectionné les pays d'Afrique subsaharienne pour lesquels au moins une enquête EDS comprenant des indicateurs du VIH a été menée avant et après 2008, c'est-à-dire avant et après la publication des recommandations internationales visant à élargir les tests de dépistage du VIH initiés par les soignants. [13] Suite à ces recommandations, le profil des utilisateurs du test du VIH est susceptible d'être passé d'un petit groupe auto-sélectionné à une frange plus large de la population ayant accès aux services de santé.[5] Pour les pays où plusieurs enquêtes étaient disponibles pour l'une ou l'autre des périodes sélectionnées, l'enquête la plus récente(disponible en mars 2019) a été considérée. Les enquêtes antérieures et postérieures à 2008 ont ensuite été qualifiées d'enquêtes antérieures et ultérieures, respectivement.

Données collectées

Chaque ménage a été classifié comme rural ou urbain selon les définitions utilisées dans chaque pays. Les caractéristiques sociodémographiques individuelles recueillies dans le cadre de l'entretien comprenaient l'âge, le niveau d'éducation (aucun, primaire, secondaire / supérieur) et le statut familial. Le niveau de richesse des ménages a été évalué à l'aide de l'indice de richesse des EDS, une mesure composite du niveau de vie basée sur un ensemble d'équipements du ménage (par exemple, télévision, réfrigérateur) et ses caractéristiques (par exemple, type d'accès à l'eau, type de sol).[14] Cet indice de richesse a été classé du plus pauvre au plus riche selon les quintiles de sa distribution.

A chaque participant, il a été demandé s'ils avaient déjà effectué un test de dépistage du VIH et, si oui, quel était le temps écoulé depuis leur dernier test. L'indicateur principal de cette étude le recours auto-déclaré à un test récent (moins de 12 mois) de dépistage du VIH.

Analyse statistique

Premièrement, pour chaque enquête, la proportion de participants rapportant un test récent de dépistage du VIH a été calculée globalement et par quintile de richesse, tout en tenant compte du plan et des pondérations d'échantillonnage.

Deuxièmement, pour chaque vague d'enquête, nous avons évalué les inégalités dans chaque pays sur la base du rang relatif des participants dans la distribution cumulative de l'indice de richesse. Ces inégalités ont été mesurées à la fois sur une échelle relative et absolue. Il est vivement recommandé de mesurer les inégalités de santé à la fois en termes relatifs et absolus, en particulier lors du suivi de tendances temporelles, car les conclusions peuvent diverger lorsqu'elles ne sont fondées que sur l'une ou l'autre de ces échelles.[15] Nous avons utilisé l'indice relatif d'inégalité (en anglais, *relative index of inequality*, RII) et l'indice de pente d'inégalité (en anglais, *slop index of inequality,* SII) pour mesurer les inégalités relatives et absolues, respectivement. [16,17] Le RII exprime le rapport entre le résultat prédit pour les extrêmes de la distribution de richesse (le plus riche et le plus pauvre), tandis que le SII représente la différence absolue dans les proportions prédites pour ces deux extrêmes. Ces deux indicateurs ont été obtenus à l'aide d'une régression de Poisson modifiée avec une variance robuste et une fonction de lien logarithmique pour estimer l'association entre le rang dans la distribution de richesse et le test récent du VIH, et à l'aide d'équations d'estimation généralisées (*Generalized estimating equations*, GEE) permettant de prendre en compte les possibles corrélations dans les observations.[18,19]

Troisièmement, nous avons évalué les tendances temporelles pour les inégalités relatives et absolues dans dépistage récent du VIH. Pour chaque pays, nous avons calculé le ratio entre les RII des enquêtes de la seconde et de la première vague : $RII\ ratio = RII_{post-2008}/RII_{pre-2008}$, ainsi que la différence entre les SII: $SII\ difference\ = SII_{post-2008} - SII_{pre-2008}$, ainsi que les intervalles de confiance (IC) à 95% correspondant. Ces indicateurs de tendances ont été standardisés en fonction du nombre d'années écoulées entre les enquêtes précédentes et les enquêtes ultérieures (Appendice 1). Une valeur de ratio de RII> 1 (respectivement <1) reflète donc des inégalités relatives croissantes (respectivement décroissante), alors qu'une différence SII> 0 (respectivement <0) reflète des inégalités absolues croissantes (respectivement décroissante).

Enfin, nous avons calculé des indicateurs d'inégalités moyens au sein de l'ensemble des pays considérés pour chaque vague d'enquête, ainsi que les indicateurs de tendance, à l'aide de méta-analyses à effets aléatoires.[20] L'hétérogénéité entre pays a été évaluée à l'aide de statistiques I^2.

Les inégalités peuvent différer selon la dimension considérée pour leur mesure. Nous avons donc reproduit toutes les analyses en utilisant le rang relatif dans la distribution cumulative du niveau d'éducation, au lieu de la richesse, et avons présenté les résultats en annexe. Comme les attitudes à l'égard des tests dépendent très probablement du genre, toutes les analyses ont été stratifiées en fonction du sexe. Toutes les analyses ont été effectuées à l'aide du logiciel R version 3.6.0.

Résultats

Population étudiée

Seize pays d'Afrique subsaharienne ont été inclus dans les analyses, à savoir : Sierra Leone, Guinée, Libéria, Côte d'Ivoire, Mali, Niger, Cameroun, République démocratique du Congo (RD Congo), Zambie, Lesotho, Zimbabwe, Rwanda. Malawi, Tanzanie, Kenya et Ethiopie. Les enquêtes de la première vague ont été menées entre 2003 et 2008 et les enquêtes de la seconde vague, entre 2008-09 et 2016, avec une période inter-enquêtes allant de 5 à 11 ans selon le pays (tableau 1).

Les taux de participation ont varié entre 90% et 99,5% chez les femmes et entre 82% et 99,5% chez les hommes. Dans l'ensemble, les données ont été recueillies auprès d'un total de 354 431 femmes et de 183 353 hommes. Dans les enquêtes de la seconde vague, dans chaque pays, la majorité des participants vivaient dans des zones rurales (à l'exception du Libéria, de la Côte d'Ivoire et du Cameroun) et vivaient en union. Parmi toutes les enquêtes, la prévalence du VIH était la plus faible au Niger (0,7% lors de la première vague d'enquête, 0,4% lors de la seconde vague) et la plus élevée au Lesotho (23,0% lors de la première vague d'enquête et 25,0% lors de la seconde vague) (Appendice 2).

Tableau 1: Caractéristiques des enquêtes et des populations, par pays et vague d'enquête. Les pays sont classés d'ouest en est. F: Femme; H: Hommes .

Afrique de l'Ouest et Centrale	Sierra Leone				Guinea				Liberia				Côte d'Ivoire			
Année d'enquête	**2008**		**2013**		**2005**		**2012**		**2007**		**2013**		**2005**		**2011-12**	
Genre	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
****Taux de réponse individuel***	**94**	**93**	**97**	**96**	**97**	**95**	**98**	**97**	**95**	**93**	**98**	**95**	**90**	**88**	**93**	**91**
Taille d'échantillon (n)	7,374	3,280	16,658	7,262	7,954	3,174	9,142	3,782	7,092	6,009	9,239	4,118	5,183	4,503	10,060	5,135
Zone rurale (%)	64.0	62.8	64.4	62.8	68.9	61.4	63.7	60.6	57.7	59.6	39.0	41.4	52.7	53.0	48.6	49.7
Age (%): *15-24 anss*	32.3	28.3	39.4	34.2	35.2	36.1	40	35.9	37.7	36.5	40.3	38.5	45.5	40.8	39.5	33.9
25-34	36.4	25.0	30.8	25.1	29.9	19.5	30.4	24.3	29.9	28.0	30.4	30.3	30.8	31.7	34.1	29.4
≥ 35	31.2	46.7	29.8	40.8	34.9	44.4	29.5	39.8	32.4	35.5	29.3	31.2	23.7	27.5	26.4	36.8
Situation familiale: *En union*	74.9	63.3	65.5	57.1	79.1	59.2	73.6	54.9	64.0	56.8	58.3	53.9	59.0	44.4	62.7	52.7
	19.0	33.3	28.4	39.3	16.5	36.6	22.5	43.3	26.1	37.9	31.0	42.5	32.3	49.7	30.2	42.4
Veuf/séparé	6.1	3.4	6.2	3.5	4.4	4.2	4.0	1.7	9.9	5.3	10.7	3.7	8.7	5.9	7.1	4.9
Niveau d'éducation (%):	65.9	50.1	55.8	42.8	77.5	51.2	67	42.9	42.4	17.6	33.2	12.9	53.9	34.0	53.2	35.9
	13.0	13.8	14.0	12.2	11.4	16.7	13.9	17.9	32.9	33.3	31.1	29.2	26.5	25.1	25.4	26.3
Secondaire	21.1	36.1	30.2	45.0	11.1	32.1	19.1	39.1	24.6	49.1	35.7	57.9	19.6	40.9	21.4	37.8
Prevalence du VIH (%)	1.7	1.1	1.7	1.2	1.9	1.1	2.1	1.4	1.9	1.2	2.4	1.8	6.2	2.8	4.6	3.3
Recours recent au test VIH (%)	5.3	4.8	17.6	8.2	1.3	3.3	4.9	5.1	2.0	2.8	21.6	13.7	4.8	4.4	15.4	9.9
	Mali				**Niger**				**Cameroon**				**Congo DR**			
Année d'enquête	**2006**		**2012-13**		**2006**		**2012**		**2004**		**2011**		**2007**		**2013-14**	
Genre	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
****Taux de réponse individuel***	97	91	96	93	96	92	95	88	94	93	97	96	97	95	99	97
Taille d'échantillon (n)	14,583	4,207	10,424	4,399	9,223	3,549	11,160	3,928	10,656	5,280	15,426	7,191	9,995	4,757	18,827	8,656
Zone rurale (%)	66.3	63.7	75.2	74.9	80.3	74.4	81.2	75.4	45.2	42.7	46.5	45.0	54.6	57.0	61.6	63.0
Age (%): *15-24 anss*	39.6	35.9	35.8	29.1	36.5	31.3	34.2	28.0	46.3	41.2	43.2	39.2	43.1	39.1	41.2	36.4
25-34	31.5	23.1	35.9	24.3	34.1	25.3	37.0	24.8	29.1	27.1	29,7	26.4	30.0	25.6	32.7	26.4
≥ 35	28.8	41.0	28.2	46.7	29.4	43.5	28.8	47.2	24.6	31.6	27.0	34.4	26.9	35.3	26.1	37.2
Situation familiale: *En union*	84.8	65.1	84.6	67.6	86.1	66.5	88.5	69.8	67.2	50.7	62.9	50.3	66.3	56.5	64.2	58.2
	11.8	31.2	13.6	31.6	9.9	31.3	7.9	28.6	24.0	40.1	28.3	45.0	24.3	38.3	26.0	37.5
Veuf/séparé	3.4	3.7	1.8	0.8	4.0	2.2	3.6	1.5	8.7	9.2	8.8	4.8	9.4	5.2	9.7	4.2
Niveau d'éducation (%):	78.2	60.2	75.8	62.0	83.5	68.5	80.1	62.9	22.4	11.5	20.9	9.5	20.8	6.3	15.4	4.1
	11.4	19.3	9.3	13.6	10.4	17.3	11.4	19.3	38.6	36.7	32.9	33.2	38.5	29.9	36.9	22.3
Secondaire	10.3	20.5	14.9	24.4	6.1	14.1	8.5	17.7	39.1	51.8	46.1	57.3	40.6	63.8	47.7	73.6
Prevalence du VIH (%)	1.5	1.1	1.3	0.9	0.7	0.7	0.3	0.4	6.6	3.9	5.6	2.9	1.6	0.9	1.6	0.6
Recours recent au test VIH (%)	3.4	3.5	6.9	6.5	1.0	2.1	8.4	2.7	5.3	7.8	23.6	21.4	4.7	4.5	9.1	7.6

* Sur la base des rapports EDS finaux .

Tableau 1 (suite): Caractéristiques des enquêtes et des populations, par pays et vague d'enquête. Les pays sont classés d'ouest en est. F: Femme; H: Hommes .

Afrique de l'Est et australe	Zambie				Lesotho				Zimbabwe				Rwanda			
Année d'enquête	**2007**		**2013-14**		**2004**		**2014**		**2005-06**		**2015**		**2005**		**2014-15**	
Genre	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
Taux de réponse individuel*	97	91	96	91	94	85	97	94	90	82	96	92	98	97	99.5	99.5
Taille d'échantillon (n)	7,146	6,500	16,411	14,773	7,095	2,797	6,621	2,931	8,907	7,175	9,955	8,396	11,321	4,820	13,497	6,217
Zone rurale (%)	57.9	56.8	53.8	53.9	76.3	78.5	63.5	66.2	60.7	59,5	61,5	64.0	83.0	82.6	80.5	80.0
Age (%): *15-24 anss*	41.2	38.2	40.4	38.4	44.7	44.7	41.8	42.7	46.1	46.8	39,1	41.2	43.6	42.5	38.7	36.6
25-34	33.9	29.7	32.2	26.2	26.2	24.3	31.0	25.4	30.1	27.4	32,9	27.0	28.3	23.7	33.0	30.2
≥ 35	25.0	32.1	27.4	35.4	29.1	31.0	27.3	31.9	23.8	25.8	28	31.8	28.1	33.9	28.3	33.2
***Situation familiale**: En union*	61.6	55.8	60.1	55.1	52.3	42.6	54.6	40.0	57.7	47.7	61.8	51.5	48.7	51.9	51.7	54.2
	26.0	39.3	27.9	40.6	33.4	50.8	33.1	51.5	27.0	47.5	25,2	43.2	37.7	45.6	37.8	43.5
Veuf/séparé	12.4	4.9	12.1	4.3	14.3	6.6	12.4	8.5	15.3	4.9	13.0	5.3	13.7	2.6	10.5	2.3
***Niveau d'éducation (%)**:*	10.4	4.6	8.4	3.8	2.0	17.1	1.0	9.7	4.3	1.5	1.3	0.7	23.4	17.4	12.3	10.9
	54.4	46.3	46.8	40.3	59.3	55.3	38.6	45.2	32.6	27.3	25.8	22.9	67.1	70.3	64.3	65.2
Secondaire	35.1	49.1	44.8	55.9	38.7	27.6	60.4	45.1	63.1	71.2	72.9	76.4	9.6	12.3	23.4	24.0
Prevalence du VIH (%)	15.9	12.2	15.0	11.7	26.0	18.8	29.6	19.5	21.0	14.6	16.7	11.3	3.6	2.2	3.6	2.5
Recours recent au test VIH (%)	20.7	12.9	47.6	39.1	8.0	5.8	59.1	37.9	8.3	7.5	49.3	36.8	12.9	11.7	39.7	36.9
	Malawi				**Tanzanie**				**Kenya**				**Ethiopie**			
Année d'enquête	**2004**		**2015-16**		**2003-04**		**2011-12**		**2003**		**2008-09**		**2005**		**2016**	
Genre	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
Taux de réponse individuel*	96	86	98	95	96	91	96	89	94	86	96	89	96	89	95	86
Taille d'échantillon (n)	11,698	3,261	24,562	7,478	6,863	5,659	10,967	8,352	8,195	3,578	8,444	3,465	14,070	6,033	15,683	12,688
Zone rurale (%)	82.2	79.5	81.7	81.5	69.1	69.7	73.0	74.4	74.9	74.6	74.6	73.9	82.2	84.8	77.8	80.3
Age (%): *15-24 anss*	45.0	37.9	42.4	43.1	41.8	41.8	39.2	42.3	43.3	43.0	41.2	40.6	41.3	39.8	39.2	35.1
25-34	31.1	34.3	31.0	26	33.0	31.1	31.0	26.1	30.1	25.8	31.5	27.2	30.7	24.8	33.8	28.5
≥ 35	23.9	27.8	26.5	30.8	25.2	27.1	29.8	31.5	26.6	31.2	27.3	32.2	28.0	35.5	27.0	36.4
***Situation familiale**: En union*	71.1	63.8	65.7	58.1	63.6	53.1	63.0	53.0	60.0	50.8	58.4	51.4	64.4	56.8	65.2	58,9
	16.8	33.2	21.0	38.3	24.6	41.4	25.5	42.3	29.8	45.0	31.2	44.0	25.0	40.1	25.7	38.6
Veuf/séparé	12.1	3.0	13.3	3.5	11.9	5.5	11.5	4.7	10.2	4.2	10.4	4.6	10.6	3.2	9.1	2.5
***Niveau d'éducation (%)**:*	22.6	11.1	12.1	6.0	22.2	11.2	17.8	9.3	12.7	6.4	8.9	4.1	65.9	42.9	47.8	30.3
	61.9	62.6	62.1	58.5	69.4	77.8	64.7	67.1	58.0	56.7	56.8	51.9	22.2	37.3	35.0	46.5
Secondaire	15.5	26.3	25.8	35.5	8.4	11.0	17.5	23.6	29.3	36.9	34.3	44.1	11.9	19.8	17.2	23.2
Prevalence du VIH (%)	13.9	10.3	11.0	7.2	7.5	6.1	6.2	3.8	8.7	4.7	8.1	4.6	1.7	0.9	1.2	0.6
Recours recent au test VIH (%)	7.5	8.0	44.4	42.3	5.7	8.4	32.5	27.7	7.7	8.1	30.6	23.3	4.0	2.4	21.2	19.7

* Sur la base des rapports EDS finaux .

Dépistage VIH

En considérant simultanément les hommes et les femmes (Figure 1 et Annexe 2), le pourcentage de dépistage du VIH récent était le plus faible au Niger (1,3%) dans la première vague d'enquête et en Guinée (5,0%) dans la seconde. Il était le plus élevé en Zambie (17,0%) dans la première vague et au Lesotho (52,6%) dans la seconde. Pour la première vague d'enquêtes (Tableau 1), les femmes ont rapporté un recours plus élevé que les hommes aux tests récents dans 8 pays sur 16; alors que dans les enquêtes de la seconde vague, les femmes ont rapporté un plus fort recours que les hommes dans 15 pays sur 16. À quelques exceptions près (Lesotho 2014, femmes; Zimbabwe 2015, femmes), le test récent du VIH a été plus fréquemment rapporté dans les zones urbaines que dans les zones rurales (annexe 3).

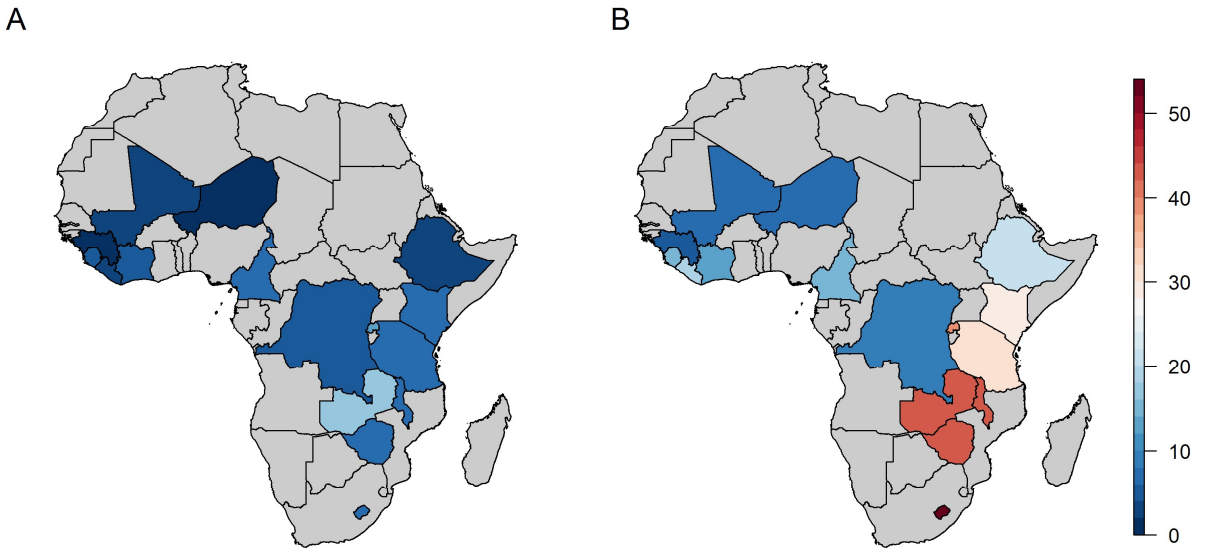

Figure 1: Pourcentage de recours récent (<12 mois) au dépistage du VIH avant (A) et après (B) 2008 dans 16 pays d'Afrique subsaharienne. Les pourcentages sont ceux estimés à partir de la dernière enquête démographique et de santé menée avant et après 2008 (voir le tableau 1 pour l'année d'enquête).

La figure 2 présente, pour chaque pays, la proportion de dépistage récent du VIH par vague d'enquête et genre, et parmi les quintiles de richesse les plus riches et les plus pauvres. Au sein des deux femmes et des hommes, et pour les deux vagues d'enquêtes, nous avons observé une tendance à un plus grand recours au test dans le quintile le plus riche par rapport au quintile le plus pauvre.

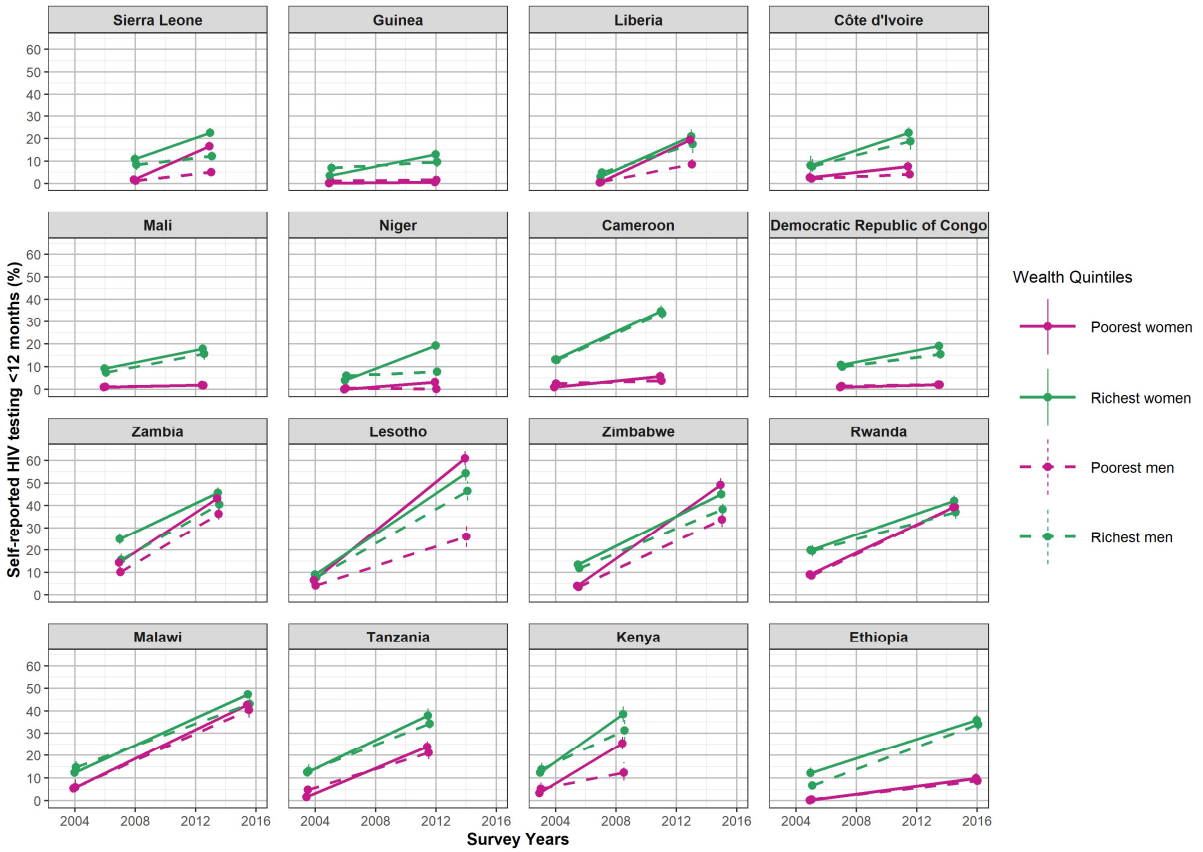

Figure 2: Pourcentage de recours récent (<12 mois) au dépistage du VIH parmi les quintiles de richesse les plus riches et les plus pauvres avant et après 2008, dans 16 pays d'Afrique subsaharienne, en fonction du genre. Les pays sont classés d'ouest en est.

Inégalités liées à la richesse dans le dépistage du VIH

Les tableaux 2 et 3 présentent les inégalités relatives et absolues liées au niveau de richesse, par genre, dans le recours récent au test du VIH. Dans les enquêtes de la première vague, des inégalités relatives en faveur des riches étaient observées dans les 16 pays, à la fois chez les hommes et chez les femmes (toutes les valeurs RII> 1). En moyenne, avant 2008, les femmes les plus riches étaient près de 10 fois plus susceptibles de rapporter un test récent du VIH que les plus pauvres (RII moyen 9,79 , IC 95% 4,24-22,60**)**). Ce ratio a diminué pour atteindre 2,77 après 2008 (IC à 95%: 1,42-5,40; ratio RII standardisé moyen: 0,85.an^{-1}, IC à 95%: 0,80-0,90). Cependant, dans les enquêtes de la seconde vague, les résultats étaient compatibles avec des inégalités persistantes dans 13 pays sur 16. Cette tendance était similaire chez les hommes: nous avons observé d'importantes inégalités relatives en faveur des riches lors des enquêtes de la première vague. Elles ont

considérablement diminué lors de la seconde vague d'enquêtes. Toutefois, les inégalités subsistaient dans les enquêtes de la seconde vague dans 14 pays sur 16, les hommes les plus riches ayant en moyenne 3,5 fois plus de chances de rapporter un test récent que les plus pauvres (RII groupé 3,55, IC 95% 1,85-6,81). Dans les enquêtes de la seconde vague, les inégalités relatives étaient plus marquées en Afrique de l'Ouest et en Afrique centrale que dans l'Afrique de l'Est et en Afrique australe (test de Wilcoxon: femmes, valeur p = 0,007; hommes, valeur $p < 10^{-3}$).

Des inégalités importantes ont également été observées à l'échelle absolue chez les hommes et les femmes dans tous les pays pour les enquêtes antérieures à 2008 (toutes les valeurs SII> 0). Cependant, aucun changement n'a été identifié dans les inégalités absolues chez les femmes (différence moyennes de SII entre les enquêtes pré- et post-2008 0,001.an^{-1}, IC à 95% - 0,006 - 0,008) et dans les enquêtes ultérieures, en moyenne, les femmes les plus riches rapportaient au-dessus de 10 points de pourcentage de plus que le plus pauvre pour le recours récent au test du VIH (SII moyen 0,111 IC 0,046-0,175). Chez les hommes, les inégalités absolues ont augmenté en moyenne entre les enquêtes de la première et de la seconde vague (différence moyenne de SII entre les enquêtes pré- et post-2008 0,007.an^{-1}, IC95% 0,001-0,014).

En considérant simultanément les inégalités relatives et absolues, les pays qui ont réussi à réduire les inégalités relatives et absolues après 2008, tant chez les hommes que les femmes, étaient le Malawi, le Rwanda, la Zambie et le Zimbabwe.

Inégalités dans le dépistage du VIH liées à l'éducation

Les inégalités mesurées en fonction du niveau d'éducation présentaient des tendances similaires à celles basées sur le niveau de richesse : les inégalités relatives moyennes diminuant pour les deux sexes, tandis que les inégalités absolues stagnaient chez les femmes et augmentaient chez les hommes (annexe 4).

Pays	Inégalités relatives			Inégalités absolues		
	RII enquête pre-2008	**RII enquête post-2008**	**Ratio des RII (.an^{-1})**	**SII enquête pre-2008**	**SII enquête post-2008**	**Différence des SII (.an^{-1})**
Sierra Leone	7.1 (4.5;11.4)	1.4 (1.2;1.7)	0.72 (0.66;0.80)	0.11 (0.09;0.14)	0.06 (0.03;0.09)	-0.011 (-0.019;-0.003)
Guinée	135.6 (37.1;496.1)	49.0 (29.2;82.1)	0.86 (0.71;1.06)	0.05 (0.04;0.07)	0.17 (0.14;0.21)	0.017 (0.012;0.022)
Liberia	3.9 (2;7.6)	1.2 (1;1.4)	0.82 (0.73;0.92)	0.03 (0.01;0.04)	0.04 (0;0.07)	0.001 (-0.005;0.008)
Côte d'Ivoire	5.4 (2.6;11)	3.5 (2.8;4.4)	0.94 (0.83;1.05)	0.05 (0.03;0.08)	0.19 (0.16;0.22)	0.021 (0.014;0.027)
Mali	34.3 (18.8;62.5)	25.8 (17.5;38.1)	0.96 (0.86;1.07)	0.10 (0.08;0.13)	0.23 (0.2;0.26)	0.019 (0.013;0.025)
Niger	58.2 (26.1;130.2)	9.4 (7.1;12.5)	0.74 (0.64;0.85)	0.07 (0.05;0.09)	0.23 (0.2;0.26)	0.027 (0.021;0.033)
Cameroun	29 (18.8;44.8)	3.8 (3.1;4.6)	0.75 (0.70;0.80)	0.17 (0.15;0.2)	0.15 (0.13;0.17)	-0.003 (-0.008;0.002)
Congo DR	14.6 (9.4;22.9)	12.9 (8.8;18.9)	0.98 (0.90;1.07)	0.14 (0.11;0.17)	0.16 (0.14;0.19)	0.003 (-0.003;0.009)
Zambie	1.8 (1.4;2.2)	1.1 (1;1.1)	0.92 (0.89;0.96)	0.12 (0.08;0.16)	0.03 (-0.01;0.06)	-0.014 (-0.023;-0.006)
Lesotho	1.4 (1.1;1.9)	0.9 (0.8;0.9)	0.95 (0.92;0.98)	0.03 (0.01;0.05)	-0.1 (-0.14;-0.05)	-0.012 (-0.018;-0.007)
Zimbabwe	5.6 (4.1;7.5)	0.9 (0.9;1.0)	0.83 (0.8;0.86)	0.14 (0.11;0.17)	-0.04 (-0.08;0)	-0.019 (-0.024;-0.014)
Rwanda	1.9 (1.6;2.4)	1.1 (1.0;1.1)	0.94 (0.92;0.96)	0.09 (0.07;0.12)	0.02 (-0.01;0.06)	-0.007 (-0.012;-0.003)
Malawi	2.3 (1.7;3.1)	1.0 (0.9;1.0)	0.93 (0.91;0.95)	0.06 (0.04;0.08)	-0.01 (-0.03;0.02)	-0.005 (-0.008;-0.003)
Tanzanie	9.2 (5.6;15.3)	1.4 (1.2;1.5)	0.79 (0.74;0.84)	0.12 (0.09;0.15)	0.10 (0.07;0.14)	-0.002 (-0.008;0.004)
Kenya	5.5 (4;7.5)	1.6 (1.3;1.8)	0.80 (0.75;0.85)	0.13 (0.11;0.16)	0.14 (0.09;0.18)	0.001 (-0.009;0.01)
Ethiopie	295.9 (170.9;512.6)	4.6 (3.9;5.4)	0.68 (0.65;0.72)	0.38 (0.33;0.43)	0.39 (0.34;0.43)	0.001 (-0.005;0.007)
Estimation moyenne	**9.79 (4.24;22.6)**	**2.77 (1.42;5.40)**	**0.85 (0.80;0.90)**	**0.110 (0.068;0.153)**	**0.111 (0.046;0.175)**	**0.001 (-0.006;0.008)**
I^2	97.75%	99.00%	94.19%	95.72%	97.68%	95.36%

Tableau 2: Inégalités relatives et absolues liées à la richesse dans le recours récent (<12 mois) au dépistage du VIH chez les femmes dans 16 pays d'Afrique subsaharienne. RII: relative inequalities index (indice relative d'inégalité) , SII: slope index of inequalities (indice de pente d'inégalité). Les estimations moyennes et les mesures d'hétérogénéité (I^2) sont estimées à partir de méta-analyses à effets aléatoires. Les ratios des RII et les différences des SII sont standardisés sur le nombre d'années écoulées entre les deux vagues d'enquêtes. Les pays sont classés d'ouest en est.

Pays	Inégalités relatives			Inégalités absolues		
	RII enquête pre-2008	**RII enquête post-2008**	**Ratio des RII ($.an^{-1}$)**	**RII enquête pre-2008**	**RII enquête post-2008**	**Ratio des RII ($.an^{-1}$)**
Sierra Leone	7.5 (3.1;18.0)	2.8 (1.9;4.2)	0.82 (0.68;1)	0.09 (0.05;0.13)	0.09 (0.06;0.13)	0.001 (-0.01;0.012)
Guinée	32.3 (11;95.2)	10.3 (5.3;20.3)	0.85 (0.71;1.02)	0.10 (0.06;0.14)	0.12 (0.08;0.16)	0.002 (-0.006;0.011)
Liberia	10.7 (5.5;20.9)	3.4 (2.4;4.8)	0.83 (0.73;0.93)	0.06 (0.04;0.08)	0.15 (0.11;0.2)	0.015 (0.007;0.023)
Côte d'Ivoire	5.5 (2.5;12.0)	6.6 (4.3;10)	1.03 (0.9;1.18)	0.04 (0.02;0.06)	0.17 (0.13;0.21)	0.02 (0.013;0.027)
Mali	20.7 (8.7;49.1)	20.4 (11.5;36.3)	1.00 (0.85;1.17)	0.10 (0.06;0.13)	0.20 (0.15;0.25)	0.016 (0.007;0.025)
Niger	33.4 (12.6;88.6)	138.3 (47.9;399.4)	1.27 (1.00;1.61)	0.11 (0.07;0.14)	0.16 (0.12;0.21)	0.01 (0.001;0.019)
Cameroun	5.9 (4.1;8.4)	5.5 (4.5;6.7)	0.99 (0.93;1.05)	0.14 (0.11;0.17)	0.35 (0.31;0.39)	0.031 (0.024;0.038)
Congo DR	8.9 (5.2;15.3)	13.8 (8.7;21.9)	1.07 (0.96;1.19)	0.12 (0.09;0.15)	0.17 (0.13;0.2)	0.007 (0;0.014)
Zambie	1.9 (1.4;2.5)	1.2 (1.1;1.3)	0.93 (0.89;0.97)	0.09 (0.05;0.12)	0.06 (0.03;0.09)	-0.004 (-0.012;0.003)
Lesotho	2.7 (1.6;4.7)	1.9 (1.6;2.2)	0.96 (0.91;1.02)	0.05 (0.02;0.08)	0.23 (0.17;0.29)	0.018 (0.011;0.025)
Zimbabwe	4.8 (3.4;6.7)	1.2 (1.1;1.4)	0.87 (0.83;0.9)	0.11 (0.09;0.14)	0.07 (0.03;0.11)	-0.004 (-0.009;0.001)
Rwanda	3.2 (2.3;4.3)	0.9 (0.8;1.1)	0.88 (0.85;0.91)	0.14 (0.1;0.18)	-0.02 (-0.07;0.02)	-0.017 (-0.024;-0.011)
Malawi	3.4 (2.0;5.5)	1.0 (0.9;1.1)	0.90 (0.86;0.94)	0.09 (0.05;0.13)	0.00 (-0.05;0.04)	-0.008 (-0.013;-0.003)
Tanzanie	3.2 (2.3;4.6)	1.7 (1.4;1.9)	0.92 (0.88;0.96)	0.09 (0.06;0.12)	0.13 (0.09;0.17)	0.005 (-0.001;0.011)
Kenya	5.3 (3.4;8.3)	2.3 (1.7;3.0)	0.86 (0.78;0.94)	0.14 (0.1;0.18)	0.20 (0.13;0.26)	0.011 (-0.003;0.024)
Ethiopie	127.6 (56.3;289.2)	4.3 (3.7;5.1)	0.74 (0.68;0.79)	0.16 (0.13;0.2)	0.33 (0.3;0.37)	0.015 (0.011;0.02)
Estimation moyenne	**7.32 (4.09;13.11)**	**3.55 (1.85;6.81)**	**0.91 (0.86;0.96)**	**0.101 (0.083;0.119)**	**0.151 (0.096;0.206)**	**0.007 (0.001;0.014)**
I^2	91.41%	98.27%	80.72%	79.47%	96.02%	92.69%

Tableau 3: Inégalités relatives et absolues liées à la richesse dans le recours récent (<12 mois) au dépistage du VIH chez les hommes dans 16 pays d'Afrique subsaharienne.

RII: relative inequalities index (indice relative d'inégalité) , SII: slope index of inequalities (indice de pente d'inégalité). Les estimations moyennes et les mesures d'hétérogénéité (I^2) sont estimées à partir de méta-analyses à effets aléatoires. Les ratios des RII et les différences des SII sont standardisés sur le nombre d'années écoulées entre les deux vagues d'enquêtes. Les pays sont classés d'ouest en est.

Discussion

À l'aide d'enquêtes transversales répétées conduites en populations, nous présentons ici une évaluation complète des inégalités en matière de dépistage du VIH en Afrique subsaharienne, ainsi que de leurs tendances temporelles au cours des 15 dernières années. Le recours au dépistage du VIH a augmenté entre les enquêtes menées avant et après 2008 dans les 16 pays inclus dans l'analyse. Le dépistage du VIH était plus fréquent dans les zones urbaines que dans les zones rurales presque partout, et ce au cours des deux vagues d'enquêtes. Avant 2008, la participation aux tests était proche de l'équilibre entre les deux sexes. Cependant, après 2008, les femmes rapportaient des probabilités de dépistages récents plus élevés que les hommes dans 15 pays sur 16. Dans l'ensemble, nous avons observé d'importantes inégalités en défaveur des pauvres, tant au niveau relatif qu'au niveau absolu. Les inégalités relatives ont diminué avec le temps chez les hommes et les femmes, tandis que les inégalités absolues se sont stabilisées chez les femmes et ont augmenté chez les hommes. Dans les enquêtes les plus récentes, des inégalités relatives et absolues importantes persistaient dans la majorité des pays.

De manière cohérente avec d'autres observations, nous avons documenté une progression au cours du temps dans le recours au test du VIH à la fois chez les femmes et chez les hommes.[8] En effet, le financement des programmes de lutte contre le VIH, y compris en ce qui concerne le conseil et le dépistage du VIH, a considérablement augmenté pendant la période de développement du traitement en Afrique sub-saharienne.[21] Sur la même période, le développement et la diffusion de nouvelles approches en matière de test du VIH ont permis l'intensification des programmes de dépistage, notamment avec l'extension du dépistage du VIH initié par les prestataires après 2007[22], puis par la suite, avec le développement des approches communautaires de dépistage.[2] Malgré une progression importante du dépistage du VIH au cours des dernières décennies, des efforts sont encore nécessaires pour atteindre l'objectif de 90% des personnes vivant avec le VIH qui connaissent leur statut, en particulier en Afrique de l'Ouest et du Centre.[23]

Nous avons observé qu'après 2008, durant la période de d'expansion du traitement antirétroviral, les femmes rapportaient des proportions de dépistage récent du VIH supérieur à celles des hommes presque partout, tendance qui n'était pas observée avant 2008. Notre analyse ne permet pas de distinguer les contextes de dépistage, mais l'accent mis dans les soins prénataux sur la prévention de la transmission mère-enfant, par la proposition en routine de dépistage initié par les soignants et par le traitement antirétroviral pourrait avoir largement contribué à l'augmentation globale du recours au dépistage chez les femmes.[22] Le manque d'efforts dans la poursuite de l'intégration des services de dépistage du VIH dans d'autres les contextes cliniques pertinents peut expliquer les

inégalités de genre en défaveur des hommes en ce qui concerne le dépistage du VIH, l'accès au traitement et sa couverture[24]. Il a été suggéré que les tests initiés par le prestataire réduisent les inégalités socio-économiques liées à la prise en charge du dépistage du VIH. [6] Les plus grand s niveaux d'inégalités observés chez les hommes par rapport aux femmes dans les enquêtes récentes peuvent donc aussi être liés aux opportunités de dépistage différentes entre les genres.

Les tendances dans les inégalités que nous avons décrites divergeaient selon que les inégalités étaient mesurées sur les échelles relative ou absolue. On pourrait ainsi tirer des conclusions différentes sur l'effet de l'intensification du dépistage du VIH sur les inégalités si l'on ne considérait que les mesures relatives (diminution des inégalités) ou absolues (stagnation ou augmentation). Une telle situation est en fait assez fréquente dans l'étude des inégalités de santé et souligne l'importance d'utiliser simultanément des mesures d'effet absolues et relatives pour quantifier les inégalités.[15,25] Les inégalités relatives tendent à être plus importantes à de faibles niveaux globaux de la variable considérée, tandis que les inégalités absolues tendent être plus importantes à des niveaux intermédiaires.[26] Ainsi, une augmentation des niveaux globaux de dépistage du VIH, à partir de niveaux faible à intermédiaire entre les deux vagues d'enquêtes, est cohérent avec les tendances des inégalités décrites ici, en particulier avec des inégalités absolues qui s'accentuaient dans certains pays d'Afrique occidentale et centrale. Le corollaire implique que les niveaux globaux de dépistage du VIH doivent être pris en compte pour les comparaisons entre différents pays en termes d'inégalités, en particulier si l'on considère les inégalités absolues. Prenons le cas des femmes dans les enquêtes post-2008 : conclure que le Sierra Leone s'en sort mieux en termes d'équité (SII = 0,06) que la Côte d'Ivoire (SII = 0,19) est valable car les niveaux globaux de dépistage récent y sont similaires (17,6% et 15,4%, respectivement). Inversement, il serait erroné de juger que le Sierra Leone fait mieux que le Kenya (SII = 0,14) en termes d'équité, car le niveau global des tests récents est presque deux fois plus élevé dans ce dernier pays (30,6%).

Malgré des progrès accomplis, tout au moins sur l'échelle relative, les inégalités socioéconomiques restent importantes à l'ère du traitement antirétroviral, en particulier chez les hommes. Une meilleure compréhension des sources d'hétérogénéité dans les niveaux des inégalités est nécessaire pour mieux les combattre. Les inégalités que nous avons observées ne reflètent pas uniquement l'accès différentiel aux services de dépistage du VIH dans les zones urbaines par rapport aux zones rurales. En effet, les inégalités socio-économiques subsistaient lors de la prise en compte de ce facteur en analyse multivariée (annexe 3). Le fardeau de l'épidémie de VIH, qui conditionne également le niveau de réponse, semble jouer un rôle dans la tendance observée. En effet, les pays à forte prévalence du VIH, tels que le Lesotho, le Zimbabwe, la Zambie et le Malawi, sont également ceux où les

inégalités étaient les moins marquées. À l'inverse, les pays à faible prévalence tels que le Niger, l'Éthiopie, le Mali ou la République Démocratique du Congo présentaient des disparités plus marquées en ce qui concerne le recours au test du VIH. Les pays à prévalence élevée sont ceux qui ont été propriétarisés pour d'ambitieux programmes de dépistage du VIH, et la prévalence du VIH est également associée aux dépenses consacrées à cette infection.[27] Cela peut suggérer que des efforts faibles à modérés pour promouvoir et proposer le dépistage du VIH peuvent perpétuer les inégalités socio-économiques, alors que de plus amples efforts, même s'ils ne ciblent pas spécifiquement les niveaux socio-économiques inférieurs, peuvent réduire ces inégalités.

Notre analyse comporte plusieurs limites. Nos résultats reposent sur un indicateur auto-déclaré. La validité des auto-déclarations de recours au dépistage du VIH est difficile à évaluer, notamment parce que son exactitude peut varier en fonction du statut VIH.[28,29] Nos mesures d'inégalités reposant sur la quantification d'une association, une fiabilité différentielle de l'auto-déclaration entre groupes socio-économiques pourrait avoir conduit à des résultats biaisés. À notre connaissance, il existe actuellement des preuves limitées concernant la sensibilité et la spécificité du test de dépistage du VIH auto-déclaré en fonction des conditions socio-économiques. Cependant, des éléments obtenus dans d'autres domaines, comme celui du cancer, suggèrent plutôt que la sur-déclaration du dépistage est plus importante chez les groupes défavorisés.[30] Si une telle sur-déclaration s'applique également au dépistage du VIH, cela aurait conduit à une sous-estimation des inégalités pro-riches décrites ici. Cela peut également avoir contribué aux mesures d'inégalités en faveur des plus pauvres observées dans certains pays (pour les femmes au Lesotho ou au Zimbabwe, par exemple). Une autre limitation tient à l'hétérogénéité observée dans les résultats de la méta-analyse, qui nous a empêché de généraliser nos résultats au-delà de l'échantillon de pays inclus dans l'analyse (annexe 5). À notre connaissance, cette étude est la première à décrire les tendances dans les inégalités socio-économiques relatives et absolues dans le recours au dépistage du VIH dans un grand nombre de pays d'Afrique subsaharienne, couvrant une variété de contextes régionaux et épidémiologiques. De plus, notre analyse était basée sur de grandes enquêtes représentatives avec des taux de réponse élevés, et les tendances que nous décrivons étaient cohérentes à travers différentes dimensions utilisées pour les mesures d'inégalité.

En conclusion, cette étude montre que l'augmentation globale de l'utilisation du dépistage du VIH au cours des dernières décennies a masqué des progressions différentes entre groupes socio-économiques définis par le sexe, le lieu de résidence, la richesse ou l'éducation. Sans un accent particulier mis sur l'équité, il est peu probable que les programmes de lutte contre le VIH touchent toutes les couches de la population, en particulier les plus pauvres et les moins instruits. Nos résultats soulignent la nécessité de surveiller et s'attaquer aux inégalités

socio-économiques parmi les autres formes d'inégalités mises en avant dans les programmes de lutte contre le VIH, telles que celles liées au genre et à l'âge afin, afin d'assurer une répartition équitable de leurs avantages.

Déclaration d'intérêts

Nous n'avons aucun conflit d'intérêts à déclarer.

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Pearl Anne ANTE-TESTARD

Socioeconomic inequalities in HIV testing uptake in sub-Saharan Africa:

A multi-country analysis of population-based surveys

Résumé

Le dépistage du VIH est essentiel pour lutter contre le VIH/SIDA. L'augmentation dans le recours global au dépistage en Afrique subsaharienne (ASS) peut cacher d'importantes disparités entre les positions socio-économiques (PSE). L'objectif général de la thèse est d'étudier les inégalités socio-économiques dans le recours au dépistage du VIH par le biais d'une analyse multi-pays des enquêtes de population en ASS. Plus précisément, cette thèse vise à : i) quantifier les inégalités socio-économiques dans le dépistage du VIH et évaluer leurs tendances dans le temps ; ii) explorer la distribution spatiale des inégalités dans le dépistage du VIH à différentes échelles géographiques ; iii) identifier les facteurs contextuels associés aux inégalités dans le dépistage du VIH ; et iv) comprendre les voies médiatrices reliant le PSE au dépistage du VIH au niveau individuel. Les résultats pourraient contribuer au développement de stratégies de dépistage qui ne génèrent ni n'aggravent les inégalités.

Mots-clès : VIH, dépistage du VIH, inégalité socio-économique, Afrique subsaharienne, épidémiologie sociale, enquête en population

Résumé en anglais

HIV testing plays a critical role in the fight against HIV/AIDS. Successful scale-up of HIV testing services in sub-Saharan Africa (SSA) has increased the overall proportion of HIV testing uptake in recent years. However, such an overall increase may hide important disparities across socioeconomic positions (SEP). The overall aim of this thesis is to investigate socioeconomic inequalities in HIV testing uptake through multi-country analysis of nationally representative and standardized population-based surveys in SSA. More specifically, this thesis aimed at: i) quantifying socioeconomic inequalities in HIV testing uptake and assess their trends over time; ii) exploring the spatial distribution of socioeconomic inequalities in HIV testing uptake across various geographical scales; iii) identifying contextual factors associated with socioeconomic inequalities in HIV testing uptake; and iv) understanding the mediating pathways linking SEP to HIV testing uptake at the individual level in several SSA countries. The findings of this thesis may be useful in designing well-tailored HIV testing strategies that do not generate nor worsen inequalities.

Keywords: HIV, HIV testing, socioeconomic inequality, sub-Saharan Africa, social epidemiology, population-based survey