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# Increasing population-level HIV testing coverage in western Kenya through tailored strategies to reach key populations

By

Adrienne J. Mocello

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Epidemiology

in the

Graduate Division

of the

University of California, Berkeley

Committee in Charge:

Professor Arthur L. Reingold, Chair
Professor Starley B. Shade
Professor Stefano M. Bertozzi

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Abstract

Increasing population-level HIV testing coverage in western Kenya through tailored strategies to reach key populations

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Adrienne J. Mocello

Doctor of Philosophy in Epidemiology

University of California, Berkeley

Professor Arthur L. Reingold, Chair

In 2014, the Joint United Nations Programme on HIV/AIDS (UNAIDS) established the 90-90-90 target for the year 2020, the goal of which is for 90% of all people with HIV (PWH) to know their status; among those diagnosed, for 90% to be receiving antiretroviral therapy; and for 90% of treated individuals to achieve sustained viral suppression. Some countries struggled to reach these targets, and among countries that achieved the first step in the cascade of care outlined above, HIV testing is not evenly accessed among some demographic sub-groups.

In sub-Saharan Africa, HIV testing gaps persist in men and among key populations, including children and adolescents, people living in informal urban settlements, and vulnerable women. High proportions of a population who remain untreated for HIV infection, or who receive delayed treatment, remain at risk for onward transmission and impede progress toward meeting national and global HIV control goals. On an individual level, untreated HIV infection leads to poorer clinical outcomes and an increased risk of mortality. Now, in 2021, we set our eyes on the new UNAIDS targets, which seek to increase the levels of coverage in the HIV cascade of care to 95% by the year 2030. Ensuring that HIV testing is equally accessible to all, regardless of age, gender, or socioeconomic status, is a necessary first step toward reaching these goals, as well as toward achieving a just distribution of health and wellbeing among all global citizens.

This dissertation aims to quantify gaps in HIV testing and to identify effective testing strategies among three key populations in western Kenya: infants, children, and adolescents; residents of informal urban settlements; and vulnerable women living in an informal settlement, including widows and separated/divorced women.

Chapter 1 assesses the impacts of a large programmatic initiative implemented in 138 HIV care and treatment facilities in western Kenya, with the goal of increasing pediatric HIV testing and antiretroviral treatment. This analysis demonstrates that a suite of interventions, including family-based testing, text messaging, and community outreach, responded to gaps in HIV testing and increased identification of youth living with HIV in a resource-limited, high-incidence setting. Chapter 2 describes the implementation of a hybrid HIV testing approach in an informal

urban settlement in western Kenya. This analysis found that the hybrid strategy was effective at reaching the 90% HIV testing target in an urban setting, at identifying previously-undiagnosed men and youth living with HIV, and at linking identified PWH to care and treatment. Using data from the same initiative, Chapter 3 explores differences in HIV testing behaviors and outcomes among women living in an informal urban settlement in western Kenya. This analysis found that widows and separated/divorced women living in an informal settlement are at increased risk of having a previously-unidentified HIV infection and poorer overall health, and that a multi-disease community health campaign was an effective strategy to engage them in HIV testing.

Findings from this dissertation highlight gaps and disparities in the progress toward HIV testing targets and may be used to inform strategies to further engage key populations in HIV testing, in order to equitably work toward control of the global HIV epidemic.

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## I. DEDICATION

For my beloved brother, Kevin. I miss you every day. I know you would be proud, as I am of you.

## II. ACKNOWLEDGEMENTS

I would like to thank my colleagues at Family AIDS Care & Education Services and the Kenya Medical Research Institute for their enthusiastic support of my decision to pursue my doctoral degree. To Craig Cohen, Jayne Kulzer, Cinthia Blat, and Mary Guzé, I appreciate all of your contributions to our work as a team as well as my journey toward becoming a more independent researcher. My very deep thanks go to the health facility staff and the KEMRI-FACES team in Kenya for their guidance and incredible efforts in carrying out the ACT and CHI initiatives.

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I would also like to acknowledge and thank Claire Snell-Rood for her incredibly helpful insight during the early development of my dissertation focus. You taught me a new way to think about the world and to see my place in it. And special thanks to Sandi McCoy for helping me learn that I love to teach.

I am so appreciative of my PhD cohort at Berkeley for their comradery and valuable feedback on this work. In particular, I would not have wanted to take this journey without my wonderful friend, Kieran O'Brien, in whom I found such a kind, intelligent, and kindred spirit. I value beyond measure the fact that we could share our challenges and successes with each other.

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My deepest gratitude goes to the people of western Kenya and the residents of the Obunga settlement for your grace in sharing your lives with us.

Finally, I would like to thank the co-authors of the publications included in this dissertation: Hong-Ha Truong, Nicollate Okoko, Dave Ouma, Dena Bushman, Kevin Kadede, Julie Kadima, Eric Ating'a, Duncan Obunge, George Nyanaro, Lisa Abuogi, Cinthia Blat, Mary Guzé, Jayne Kulzer, Starley Shade, Elizabeth Bukusi, Francesca Odhiambo, and Craig Cohen.

## III. INTRODUCTION

### Progress toward UNAIDS 90-90-90 target

In 2014, the Joint United Nations Programme on HIV/AIDS (UNAIDS) established the 90-90-90 target for the year 2020, the goal of which is for 90% of all people living with HIV (PLHIV) to know their status; among those diagnosed, for 90% to be receiving antiretroviral therapy (ART); and for 90% of treated individuals to achieve sustained viral suppression.[1] Now, nearing the end of 2020, some countries are struggling to reach these targets[2]; and among countries that are near achieving the first step in the UNAIDS cascade of care outlined above, HIV testing is not evenly accessed among demographic sub-groups. In sub-Saharan Africa (SSA), testing gaps persist among men[3,4] and among key and vulnerable populations, including children[5–9] and people living in informal urban settlements.[10] High proportions of a population who remain untreated or who receive delayed treatment for HIV will impede progress toward national and global HIV control goals.[11]

### HIV in Kenya

The prevalence of HIV infection in Kenyan adults of reproductive age ranges by county from 4% to 28%,[12] with a national prevalence in 2018 estimated at 4.9% among adults 15-64 years of age.[13] Homa Bay, Migori, and Kisumu counties in the Nyanza region of western Kenya have among the highest prevalences of HIV infection in the country, with 20.7%, 13.3%, and 16.3% of adults living with HIV, respectively.[12] Combined, these three counties contributed 36.7% (n=2,432) of incident pediatric HIV cases in Kenya in 2015, despite representing just 5.1% of the country's overall population. The Global Burden of Disease Study 2015 estimated that between 2005 and 2015 Kenya experienced the greatest annual increase in HIV incidence rate (6%) in SSA, while most countries saw declines in the incidence of HIV infection.[14] It is estimated that 79.5% of adult Kenyans living with HIV in 2018 knew their HIV status.[13] In the most recent Kenya Demographic and Health Survey, HIV testing coverage was lower among men (72%) than women (85%) and was lower among adolescents than older adults.[15] Effective strategies to identify and link HIV-positive individuals to care are critical in this region, particularly among demographic groups whose testing coverage is lagging.

### Infants, Children, and Adolescents

Since 2000, the global incidence of HIV among infants, children, and adolescents has declined 58%.[16] Despite this trend, the burden of pediatric HIV remains significant, with 160,000 new annual infections globally in 2018 and 1.7 million children <15 years old living with HIV, 90% of them in SSA.[16] Identification of children living with HIV remains a key barrier to achieving global HIV targets, including ART coverage. The prevalence of undiagnosed HIV infection in SSA is substantially higher in children and adolescents than in adults.[5] For adolescents in particular, lack of diagnosis and low adherence have resulted in increasing HIV-related mortality rates in high burden HIV settings such as SSA, despite decreasing mortality in all other age groups.[6] Early diagnosis and linkage to care are essential to improve the clinical outcomes of children with HIV and to reduce childhood mortality in Africa, where AIDS remains the leading cause of death among adolescents.[7]

Efforts to decrease the incidence of pediatric HIV infection in SSA, and in Kenya specifically, have not been completely successful. In Kenya, 8,000 new pediatric HIV infections and 4,300 pediatric AIDS-related deaths were recorded in 2017.[12] To combat these trends, local governments and partners in SSA have implemented strategies to decrease the incidence of pediatric HIV and to increase HIV testing among this key population, with a focus on identification of HIV-exposed infants through prevention of mother-to-child HIV transmission (PMTCT) programs.[7] Studies in Kenya and Cameroon have found text-based reminders to be an effective tool for engaging HIV-exposed infants in care.[17,18] Interventions that have increased testing of HIV-exposed infants in other settings include the integration of maternal and child health services;[19,20] birth testing as implemented in South Africa;[21] routine opt-out HIV testing for children accessing primary care services in Zimbabwe;[22] and the delivery of psychosocial support from mentor mothers, women with HIV who act as peer counselors for PMTCT clients.[23(p)]

However, fewer than 50% of HIV-exposed infants are tested by six weeks of age, and only half of those receive necessary repeat testing through 18 months of age.[8,9] And while integrated maternal and child health services promote detection and testing of HIV-exposed infants,[24] it is recognized that additional testing strategies throughout childhood and adolescence are needed. Yet many strategies targeting youth have incorporated without modification interventions designed for adult populations.[25,26] Efforts are required to ensure that evidence-based interventions and policies comprehensively address the specific needs of pediatric populations.

Strategies to increase the uptake and yield (i.e. proportion of newly-identified children with HIV per number tested) of HIV testing and counselling (HTC) among older children and adolescents include provider-initiated testing and counselling (PITC), family-centered testing, and community-based testing (at home and schools). These approaches have achieved varying acceptance, uptake, and yield. PITC has achieved the highest rates of uptake and yield, while home-based HTC has had generally high uptake (>90%), particularly among adolescents.[25] Family-centered testing, in which an adult patient with HIV acts as an index case for testing of all at-risk contacts including sexual partners, children and adolescents, has demonstrated variable uptake depending on testing venue (i.e. clinic vs. home-based).[25,27–29] In Zimbabwe, family testing with added incentives for index adults, including fixed financial and lottery-based incentives, increased testing of children.[30] School-linked testing has not been widely used due to barriers in acceptability related to issues of confidentiality and parental consent. In Kenya, an adolescent-focused package of care included health worker capacity building and adolescent-friendly hours.[31] The optimal approach to improve the number tested and the newly identified with HIV among infants, children, and adolescents is not clear and likely varies by setting.

*The Accelerating Children's HIV/AIDS Treatment Initiative*

The Accelerating Children's HIV/AIDS Treatment (ACT) initiative was launched in 2014 in nine priority countries in Africa (Cameroon, the Democratic Republic of Congo, Kenya, Lesotho, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe) and aimed to provide a strategic response to the HIV treatment gap for children.[32] ACT was a two-year, public-private partnership from September 2014-2016 supported by a co-investment of $200 million from the

U.S. President's Emergency Plan for AIDS Relief (PEPFAR) and the Children's Investment Fund Foundation. Countries were selected based on three criteria: lowest pediatric ART coverage, highest pediatric HIV burden, and greatest disparity between adult and pediatric ART coverage. A total of over 100 partners implemented ACT, with up to 35 partners in each country, representing a variety of economic, geographic, and clinical settings.[32] Funding from the ACT initiative enabled the development of key interventions designed to achieve the 90-90-90 targets of increasing HIV testing, linkage to care, and ART initiation among infants, children, and adolescents. Its ultimate goal was to initiate an additional 300,000 children under the age of 19 living with HIV on ART.

**Informal Urban Settlements**

In 2014, 56% of the urban Kenyan population lived in an informal settlement, i.e., slum.[33] Although there are health advantages to residing in an urban area, such as easier access to health care facilities, people living in an informal urban settlement have a markedly higher prevalence of HIV infection (12%) compared to Kenyans living in non-slum urban (6.5%) and rural areas (5.1%).[34] Residents of informal urban settlements are more likely to engage in transactional sexual activity and drug use and to have multiple sexual partners, and are less likely to have intact families, all risk factors for HIV acquisition and transmission.[35] From 2006 to 2011, ~19% of Kenyans initiating HIV care presented with advanced HIV disease.[36] Among settlement-dwellers in Nairobi who initiated HIV care, 33% presented with advanced disease, close to double the risk of late entry to care seen in the general population.[10] Patients who enter HIV care with advanced disease experience worse immune recovery in response to treatment with ART,[37] are at increased risk of transmitting HIV before/after initiating care,[38] and have reduced life expectancy.[39] Presentation with advanced HIV disease may result from delayed diagnosis or delayed linkage to care.[10] This suggests that settlement-dwellers have been missed by current HIV testing strategies implemented in urban areas.

In addition, most previous studies of HIV in informal settlements in Kenya have included only settlements in Nairobi, typically focusing on Kibera, the largest informal settlement in Nairobi.[10,35,40–42] A cross-sectional survey of settlements in Nairobi found higher rates of HIV testing in Kibera than in smaller settlements.[41] This finding may be due to a higher concentration of funding for studies and interventions in that settlement due to its size and location. Residents of smaller informal settlements and those located in other cities in Kenya may differ in their HIV care-seeking behaviors and opportunities. Because of these differences, findings from the previously described studies of informal settlements in Nairobi may not be generalizable to interventions on HIV testing and linkage to care based in other Kenyan cities.

Family AIDS Care & Education Services (FACES) is a family-focused, comprehensive HIV prevention, care, and treatment program that has provided services and support in the Nyanza region since 2004. In 2016, FACES began providing HIV services to populations living in informal urban settlements in Kisumu, the third largest city in Kenya. FACES currently utilizes the same testing strategies for residents of informal urban settlements as for its general clinic population, including elective testing, provider-initiated testing, and community outreach. It is not known if the current HIV testing strategies employed by FACES are effective for the population living in informal urban settlements in Kisumu.

*Community-based hybrid HIV testing*

Community-based hybrid HIV testing to reach HIV-positive individuals unaware of their status and to achieve population-wide testing coverage has been conducted successfully in rural settings in East Africa.[3,43] The hybrid HIV testing services (HTS) strategy combines community mobilization and sensitization; community mapping and a household census; multi-disease community health campaigns (CHCs); and tracking activities to offer home-based HIV testing.[43] Hybrid HTS has demonstrated efficacy in reaching previously untested PLHIV in a rural setting, but to our knowledge has not been implemented in an urban setting.

From December 7, 2017 through September 30, 2018, FACES implemented the Community Health Initiative (CHI) program to assess the impact of an urban population-based HIV testing campaign on HIV testing coverage, linkage to care, and antiretroviral coverage in the Obunga informal settlement in Kisumu, Kenya. A census of the Obunga population was conducted by CHI team members between January 25, 2018 and March 3, 2018. Each household and all household members were enumerated, and sociodemographic data were collected for each individual. All settlement residents were invited to attend any of a series of multi-disease CHCs that offered screenings for HIV, tuberculosis, malaria, hypertension, and diabetes mellitus. Other services provided included treatment for acute illnesses, referral for follow-up of chronic illnesses, and voluntary medical male circumcision. Residents who did not attend a CHC were tracked and offered HIV testing in their homes. CHC services were offered free-of-charge and were also available to non-residents.

**HIV risk among widows in East Africa**

Widowed Kenyan women have been found to be at increased risk of HIV acquisition and transmission[44] and have an exceptionally high HIV prevalence of 63%.[45] Marginalized by social practices such as widow inheritance, widow cleansing and the stripping of assets, these women are often forced to engage in transactional sex as a means to earn income.[46] Women in western Kenya, including widows, have been shown to engage in high levels of migration within the country, who, possibly in response to changing attitudes toward widow inheritance, are increasingly migrating from rural to urban areas.[44,47] In western Kenya, the rural beach villages surrounding Lake Victoria have been a main migration destination for women, due to the availability of employment within the fish trade.[47] Women engaged in the fish trade exhibit a high degree of mobility between the beaches and Kisumu, where they often maintain a residence.[47]

Given the high prevalence and incidence of HIV among widows in Kenya and their extreme cultural and economic marginalization, additional research is needed to elucidate their HIV and healthcare needs, particularly in the context of informal urban settlements where widows live at the confluence of poverty and HIV risk.

# 1. Chapter 1: Improvements in Pediatric and Adolescent HIV Testing and Identification in Western Kenya under the Accelerating Children's HIV/AIDS Treatment Initiative

## 1.1. Abstract

Pediatric HIV remains a significant global concern, with 160,000 new infections annually. Accelerating Children's HIV/AIDS Treatment (ACT) provided a strategic response to the "treatment gap" for children. We examined whether activities under ACT increased testing and identification of youth living with HIV (YLWH).

Family AIDS Care & Education Services implemented ACT across 130 health facilities in western Kenya between October 2015-September 2016, providing: HIV-testing counselors and space; training on the Family Information Table (FIT) and chart audits; community outreach testing; and text message reminders for pregnant women. We analyzed the number of youths tested and identified with HIV over time and between intervention and control sites using interrupted time series analysis.

We tested 268,312 youths (7,183 infants <18 months; 145,833 children 18 months to 9 years; and 115,296 adolescents 10-14 years). Mean monthly number tested per health facility increased from 2.8 to 7.2 ($p<0.0001$) in infants, 44.8 to 142.0 ($p<0.0001$) in children, and 30.1 to 123.3 ($p<0.0001$) in adolescents. Mean monthly number identified with HIV per facility increased from 0.06 to 0.37 ($p<0.0001$) in infants; 0.34 to 0.62 ($p=0.008$) in children; and 0.17 to 0.26 ($p=0.04$) in adolescents, resulting in 1,328 diagnoses.

Among infants, FIT training was associated with increased HIV testing over time, incidence rate ratio (IRR)=3.85 (95% confidence interval [CI] 2.16-6.84; $p\leq0.0001$). Text messaging increased testing, IRR=2.10 (95% CI 1.57-2.80; $p\leq0.0001$) and identification of HIV in infants, IRR=1.83 (95% CI 1.06-3.18; $p=0.0381$) and older children, IRR=2.25 (95% CI 1.62, 3.13; $p<0.0001$). Chart audits increased testing over time among adolescents (IRR=2.11; 95% CI 1.21-3.66; $p=0.0082$). Outreach was associated with identification of adolescents with HIV, IRR=1.58 (95% CI 1.22-2.06; $p=0.0005$).

In lower-income settings, targeted interventions effective at reaching YLWH can help optimize resource allocation to address gaps in testing and identification to further reduce HIV-related morbidity and mortality.

## 1.2. Introduction

Since 2000, the global incidence of HIV among youth has declined 58%.[16] However, the burden of pediatric HIV remains significant, with 160,000 new annual infections globally in 2018 and 1.7 million children <15 years old living with HIV, 90% of them in sub-Saharan Africa (SSA).[16] Identification of youth living with HIV (YLWH) remains a key barrier to achieving global HIV targets, including antiretroviral therapy coverage. The prevalence of undiagnosed HIV infection in SSA is substantially higher in children and adolescents compared to adults.[5] For adolescents, lack of diagnosis as well as adherence challenges have resulted in increasing mortality rates in high-burden HIV settings such as SSA, despite decreasing mortality in all other age groups.[6]

Early diagnosis and linkage to care are essential to improve the clinical outcomes of YLWH and to reduce childhood mortality in Africa, where AIDS is still the leading cause of death among adolescents.[7]

To combat these trends, local governments and partners in SSA have implemented strategies to increase HIV testing among youth, with a focus on identifying HIV-exposed infants.[7] However, <25% of exposed infants receive the necessary testing through 18 months of age,[9] and many older children experience gaps in testing following infancy.[48] While integrated maternal and child health services promote detection and testing of HIV-exposed infants,[24] many strategies targeting older children are incorporated without modification within interventions designed for adult populations.[25] Interventions to increase the uptake and yield (proportion of newly-identified children with HIV per number tested) of HIV testing and counselling (HTC) among older children and adolescents include provider-initiated testing and counselling (PITC), family-centered testing, and community-based testing (at home and schools). PITC has achieved the highest rates of uptake and yield while home-based HTC has had generally high uptake (>90%), particularly among adolescents.[25,26] Family-centered testing, in which an adult patient with HIV serves as an index case for testing of all at-risk contacts including children and sexual partners, has demonstrated variable uptake.[25,27,28] School-linked testing has not been widely used due to barriers surrounding confidentiality and parental consent. The optimal approach to improve the number of youths tested and identified with HIV is not clear and likely varies by setting.

Recognizing that HIV testing provides a fundamental link to life-saving HIV treatment across all populations,[49] the Accelerating Children's HIV/AIDS Treatment (ACT) initiative launched in 2014 in nine priority countries in Africa, including Kenya, aimed to provide a strategic response to the "treatment gap" for infants, children, and adolescents. ACT was a two-year, public-private partnership from September 2014-2016 supported by a co-investment of $200 million from the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) and the Children's Investment Fund Foundation. The ACT initiative enabled the development of key interventions designed to achieve these targets. This study examined whether activities under the ACT initiative increased HIV testing and identification of YLWH in three high-prevalence counties in western Kenya.

## 1.3. Methods

### Setting and population

Efforts to decrease the incidence of pediatric HIV in SSA have not been completely successful. In Kenya, 8,000 new pediatric HIV infections and 4,300 pediatric AIDS-related deaths were recorded in 2017.[12] Homabay, Migori, and Kisumu counties in western Kenya have among the highest adult HIV prevalence in the country (20.7%, 13.3%, and 16.3%, respectively).[12] Combined, these counties contributed 36.7% (n=2,432) of incident pediatric HIV cases in 2015, despite representing 5.1% of the country's overall population.

To address continued high rates of HIV transmission in Kenya, HTC services are free at all Ministry of Health (MOH) facilities, approximately 90% of which provide HIV treatment services. Additionally, in 2016 the Kenyan government adopted the WHO-recommended test-

and-treat strategy, through which anyone who tests positive for HIV is immediately eligible for antiretroviral treatment.

Family AIDS Care & Education Services (FACES), a family-focused, comprehensive HIV prevention, care, and treatment program, has provided services in western Kenya since 2004. FACES implemented activities under the ACT initiative between October 2015 and September 2016 in 138 FACES-supported MOH clinics in Homabay, Kisumu, and Migori counties. To increase pediatric case finding, FACES, through the ACT initiative, invested heavily in additional HTC personnel and training while strengthening lab and testing infrastructure. FACES prioritized saturation of facility-based testing complemented by aggressive community outreach and testing of HIV-exposed infants and other at-risk family members.

**Interventions**

We implemented six interventions (Table 1) to increase HIV testing and identification of YLWH:

1. Add HTC counselors at clinics with insufficient counseling staff for the catchment population
2. Improve HTC space to accommodate increased HTC target volume
3. Medical chart audits to identify pediatric household members overlooked for HIV testing - retrospectively enter data into an electronic database from the Family Information Table (FIT), a tool used to identify HIV-exposed children and sexual partners in the households adult HIV patients[29]
4. Refresher training on FIT
5. Text message reminders for testing of HIV-exposed infants (TextIT)[50]
6. Community outreach testing to reach vulnerable children

**Study design**

From October 1, 2015 through September 30, 2016, we prospectively evaluated whether individual activities under the ACT initiative increased pediatric and adolescent HIV testing and identification of YLWH at FACES-supported MOH HIV care and treatment health facilities, with program-wide targets to test 107,772 youths over the implementation period, based on facility catchment populations.

**Sample**

Our study sample included 130 facilities that provided pediatric HIV services during the study period and for which data were available. Individual ACT interventions were implemented in a convenience sample of clinics, based on program needs and scale-up feasibility. Sites received a variable number of interventions (median=3). We deployed an additional 60 HTC counselors across 42 health facilities (Appendix Table 2); 44 facilities received improvements to HTC space. We conducted FIT chart audits in 95 facilities and refresher trainings at 99 facilities. Community outreach testing events were held at 120 sites. TextIT was implemented in two waves of 10 facilities.

## Measures

Outcomes - We prospectively collected aggregate outcome data by site for infants (from birth up to 18 months of age), children (aged 18 months to 9 years), and adolescents (10 to 14 years). For each age group, we obtained monthly number tested for HIV and number identified with HIV.

Interventions - For each intervention and month of the initiative period, we coded a facility as on treatment if it was actively delivering that intervention. For months in which the intervention was not conducted, the facility was coded as a control. Thus, a facility could contribute time both as an intervention site and as a control. Community outreach is the only intervention where control time could follow intervention time.

Covariates - Facilities were categorized by geographic location (urban, peri-urban, rural) and health facility tier, reflecting the level of care provided (dispensary, comprehensive outpatient, subcounty/county hospital). Facilities reported which months they experienced rapid testing kit stockouts.

## Analysis

We describe participating facilities by county, geographic location, facility type, and number of HTC counselors. We calculated the overall distribution of gender within the FACES-supported patient population and the mean and interquartile range of monthly pediatric HIV tests per facility during the ACT period, stratified by age group.

We conducted an interrupted time series (ITS) analysis by fitting multivariable negative binomial regression models to estimate mean monthly numbers tested per site and incidence rate ratios (IRRs) comparing monthly number tested at intervention versus control sites. An ITS analysis quantifies changes in the level of an outcome immediately following an intervention ("step effect") and the subsequent trend over time ("trend effect").[51] To assess trend effects, we interacted calendar month with each intervention except outreach, which we hypothesized would display only step effects due to the time-limited nature of the events. We conducted a sensitivity analysis to see if outreach displayed a lagged step effect within three months. We applied backward elimination and retained interaction terms significant at $p<0.05$ in the model. Models were built within a generalized estimating equations framework assuming an autoregressive correlation structure to account for repeated measures and adjusted for geographic location, health facility tier, and rapid testing kit stockouts. We fitted independent models for infants, children, and adolescents and used an identical modeling strategy to estimate mean numbers identified with HIV. Analyses were conducted using SAS 9.4 (Cary, NC).

## Ethical review

Data were collected through the MOH and FACES program on routine forms, approved annually by: the KEMRI Ethical Review Committee; University of California San Francisco Committee on Human Research; Associate Director for Science, Division of Global HIV/AIDS, Centers for Disease Control and Prevention. Aggregated data were analyzed and consent was not required from individual patients.

## 1.4. Results

FACES health facility and patient characteristics are shown in Appendix Table 1. The majority of facilities were located in the rural counties of Homabay and Migori, and two-thirds were smaller dispensaries. Thirty-five percent of facilities had at least one HTC counselor. The clinic population was evenly split by gender. Between October 1, 2015 and September 30, 2016, we tested 268,312 youths for HIV including: 7,183 infants, with a median of 2 infants per facility per month (IQR 0-5); 145,833 children (median=64, IQR 23-114); and 115,296 adolescents (median=44, IQR 16-84). The testing target was surpassed by 56% for youths <15 years old and by more than 100% among adolescents age 10 to 14 years. During the same period, we identified 1,328 YLWH: 225 infants (test yield=3.1%), 759 children (test yield=0.52%), and 344 adolescents (test yield=0.30%).

We saw increases across all age groups in the number tested (Figure 1). The mean monthly number of infants tested per facility increased from 2.8 in October 2015 to 7.2 in September 2016 ($p<0.0001$). For children, the mean number tested per month increased from 44.8 to 142.0 ($p<0.0001$). Among adolescents, the number tested per facility per month increased fourfold, from 30.1 to 123.3 ($p<0.0001$).

We also saw increases in the number of youths identified with HIV (Figure 2). The mean number of infants identified increased six-fold (0.06 to 0.37 per facility per month; $p<0.0001$), resulting in an increase in yield of 3.78% (95% confidence interval [CI] 0.54-7.03; $p=0.02$). Identification of children with HIV also increased (from 0.34 to 0.62 per facility per month; $p=0.008$). There is some evidence of a decline in yield among children during the study period (-0.71%, 95% CI -1.42% to 0.01%; $p=0.052$). Finally, we observed more modest increases in mean number of adolescents identified, from 0.17 to 0.26 per facility per month ($p=0.04$). Monthly yield among adolescents decreased slightly during the study period (-1.07%; 95% CI -2.06% to -0.07%; $p=0.04$).

Multivariable associations between individual interventions and HIV testing are shown by age group in Table 2. Chart audits were associated with a step increase in infant HIV testing (IRR=1.31; 95% CI 1.10-1.55; $p=0.0025$), while FIT training displayed an initial decrease followed by a significant trend increase (IRR=3.85; 95% CI 2.16-6.84; $p<0.0001$). TextIT produced an immediate increase in infant HIV testing (IRR=2.10; 95% CI 1.57-2.80; $p<0.0001$). In children, HTC space improvements were associated with a step increase in HIV testing (IRR=1.32; 95% CI 1.15-1.52; $p=0.0001$). Chart audits displayed an initial decrease (IRR=0.69; 95% CI 0.52-0.91; $p=0.0099$) followed by an increasing trend (IRR=2.07; 95% CI 1.20-3.57; $p=0.0091$). Conversely, FIT training had an immediate effect on child HIV testing (IRR=1.65; 95% CI 1.24-2.20; $p=0.0005$), which waned over time (IRR=0.36; 95% CI 0.20-0.63; $p=0.0004$). TextIT was an effective strategy for increasing testing in children (IRR=1.72; 95% CI 1.35-2.17; $p<0.0001$), as were outreach activities (IRR=1.39; 95% CI 1.26-1.53; $p<0.0001$). In adolescent testing, HTC space was associated with a step increase (IRR=1.34; 95% CI 1.12-1.60; $p<0.0001$), while chart audits displayed a significant increasing trend (IRR=2.11; 95% CI 1.21-3.66; $p=0.0082$). FIT training displayed a pattern parallel to that observed in younger children, with an immediate effect (IRR=2.37; 95% CI 1.63-3.42; $p<0.0001$) that reversed over time (IRR=0.19; 95% CI 0.10-0.35; $p<0.0001$). Outreach produced an immediate increase in

adolescent testing (IRR=1.56; 95% CI 1.39-1.74; p<0.0001), while TextIT was associated with an increase over time.

Associations between interventions and identification of HIV positives are shown in Table 3. Addition of HTC counselors displayed an initial increase in infants identified with HIV (IRR=1.61; 95% CI 1.08, 2.40; p=0.0202), while FIT training produced an increase over time (IRR=5.42; 95% CI 1.06-27.77; p=0.0427). TextIT was associated with an immediate increase in identification of HIV in infants (IRR=1.83; 95% CI=1.06-3.18; p=0.0310), as well as among children (IRR=2.25; 95% CI 1.62-3.13; p<0.0001) and adolescents (IRR=2.52; 95% CI 1.61-3.96; p<0.0001). Outreach was an effective strategy for identifying adolescents with HIV (IRR=1.58; 95% CI 1.22-2.06; p=0.0005). Results were similar when we assumed that the effect of outreach persisted for an additional two months, except in identification of children with HIV (IRR=1.31; 95% CI 1.04-1.66; p=0.0238).

## 1.5. Discussion

This study indicates that activities implemented under the ACT initiative increased HIV testing and identification of YLWH in three high-prevalence counties in western Kenya. Over the 12-month ACT initiative, over 250,000 infants and children <15 years old were tested for HIV, yielding 1,328 new HIV diagnoses. The mean monthly number of youths tested for HIV increased significantly across all age groups, with a three to four-fold increase in testing volume between the pre- and post-ACT periods. The average number of infants, children, and adolescents with HIV identified each month also increased, with the most marked increase in HIV diagnoses among infants <18 months old. This corresponds to overall trends in pediatric HIV testing and identification in SSA during the ACT period. Zambia reported a 238% increase in HIV testing among children and an increase of 198% among adolescents, while Zimbabwe experienced similar improvements of 461% and 210%, respectively.[52] These data from Kenya add to the literature supporting the effectiveness of the ACT initiative in multiple populations.

Among infants, chart audits were associated with increased testing, and FIT training displayed increases in testing and identification. Chart audits were associated with an initial decrease in HIV testing in children and adolescents followed by increasing trends. This initial decrease may have occurred because staff diverted time from clinical activities in order to audit charts. This investment was recouped as previously untested children were identified and reached for testing. Conversely, FIT training demonstrated a step increase that waned over time, suggesting the need for routine trainings. These findings support our previous finding that family member testing was instrumental in reaching eligible children in outpatient primary care in western Kenya.[29] Home-based family testing in Uganda produced a six-fold increase in testing uptake among 6 to 14 year-olds.[53,54] Results from the ACT initiative support the use of family-centered testing and refresher trainings as simple, effective programmatic strategies to reach children of all ages not identified by other testing approaches.

Adding HTC counselors was positively associated with identification of infants with HIV, while HTC space improvements displayed increases in child and adolescent testing. In Kenya, an adolescent-focused package of care included health worker capacity building and adolescent-friendly hours.[31] Additional outreach activities increased HIV testing among children and

adolescents and, importantly, identified adolescents with HIV. A combination of enhanced testing space, structured protocols, and directed activities appear to effectively use counselors.

Facilities that implemented text message reminders for pregnant and postpartum women with HIV saw increases in the number of infants tested and identified with HIV. These effects carried forward, with increases also observed in children and adolescents. One theory for the effectiveness of TextIT is that, by fostering a relationship during pregnancy, mothers realize the importance of HIV testing and subsequently bring their older children for testing. Our findings corroborate those of other studies that have found text-based reminders to be effective for engaging HIV-exposed infants in care.[17,18] Effective interventions for increasing testing of HIV-exposed infants in other settings include integration of maternal and child health services,[19,20] birth testing as implemented in South Africa,[21] routine opt-out HIV testing for children accessing primary care in Zimbabwe,[22] and peer counseling from "mentor mothers" living with HIV.[23(p)]

This study took place in a limited geographic region within western Kenya, with heavy investment from PEPFAR, therefore results may not be generalizable to a broader Kenyan context. Additionally, the ACT initiative was implemented within the programmatic framework of FACES-supported clinics. This observational design may have been underpowered to detect real effects of some interventions analyzed. Finally, we analyzed aggregate data and thus were not able to calculate the proportion of youths newly-diagnosed with HIV who were linked to care.

## 1.6. Conclusions

We highlight a suite of interventions that responded to gaps in HIV testing and increased identification of YLWH in a resource-limited, high-prevalence setting. Recent successes in pediatric and adolescent HIV testing and identification notwithstanding, many in SSA remain undiagnosed and at considerable danger for HIV-related mortality and morbidity. While yield appeared to decrease among children and adolescents, knowing which interventions are effective at reaching YLWH can help target scarce resources. Optimizing the family unit to increase testing reach and care cascade entry, through consistent updating of family information of index adult patients and routine audits of medical charts, is critical. Text messaging is an effective, low-cost approach to engaging HIV-exposed infants and older youth in testing services. Outreach succeeds in identifying adolescents with HIV, who are at increased risk of HIV-related morbidity and mortality. Further evaluation might identify challenges to implementation of individual interventions and optimize resource allocation to address gaps in identification of YLWH to further reduce HIV-related morbidity and mortality.

## 1.7. Figures and Tables

**Figure 1. Mean HIV Testing Volume per Facility per Month of ACT Initiative, by Age Group**

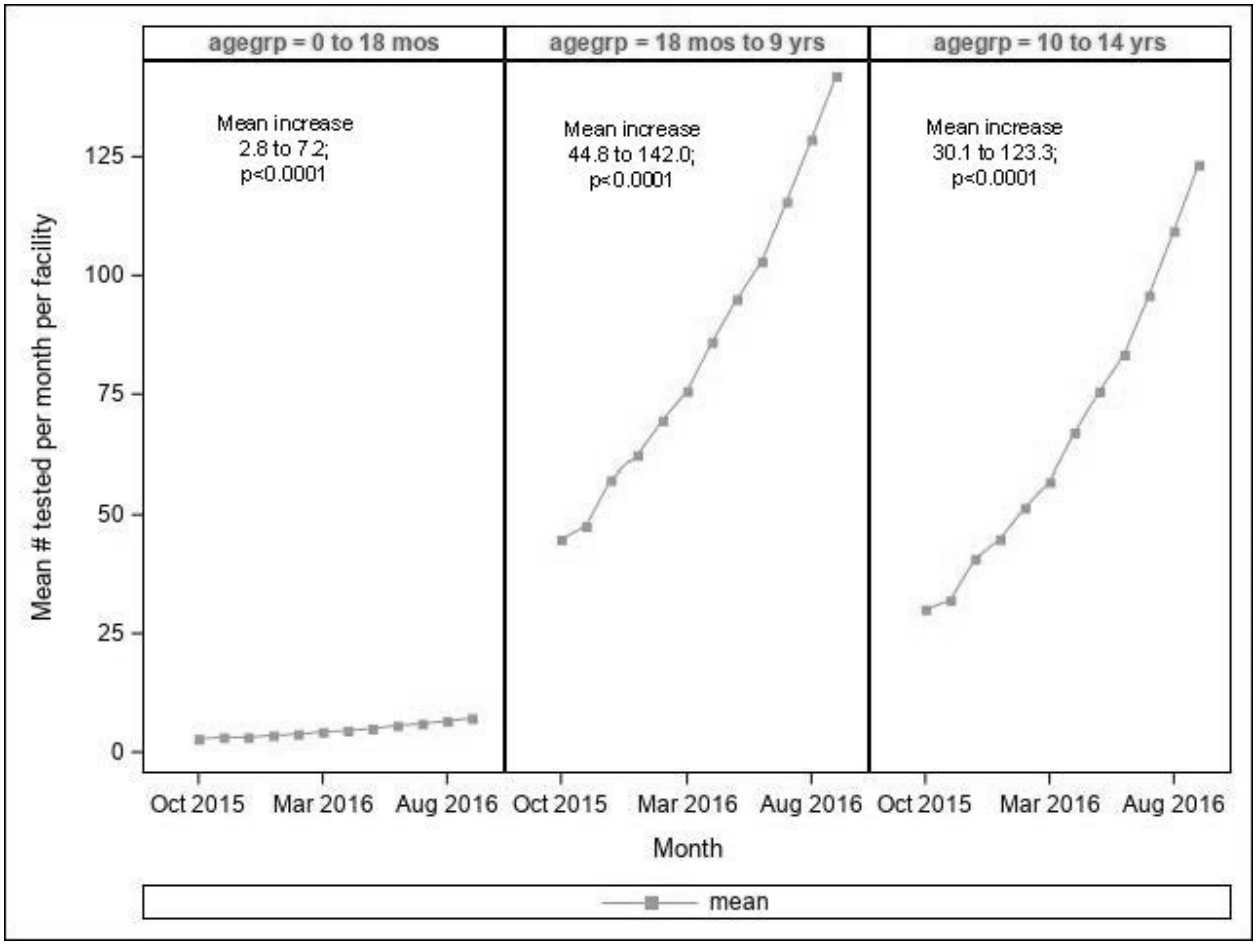


**Figure 2. Mean Number Identified with HIV per Facility per Month of ACT Initiative, by Age Group**

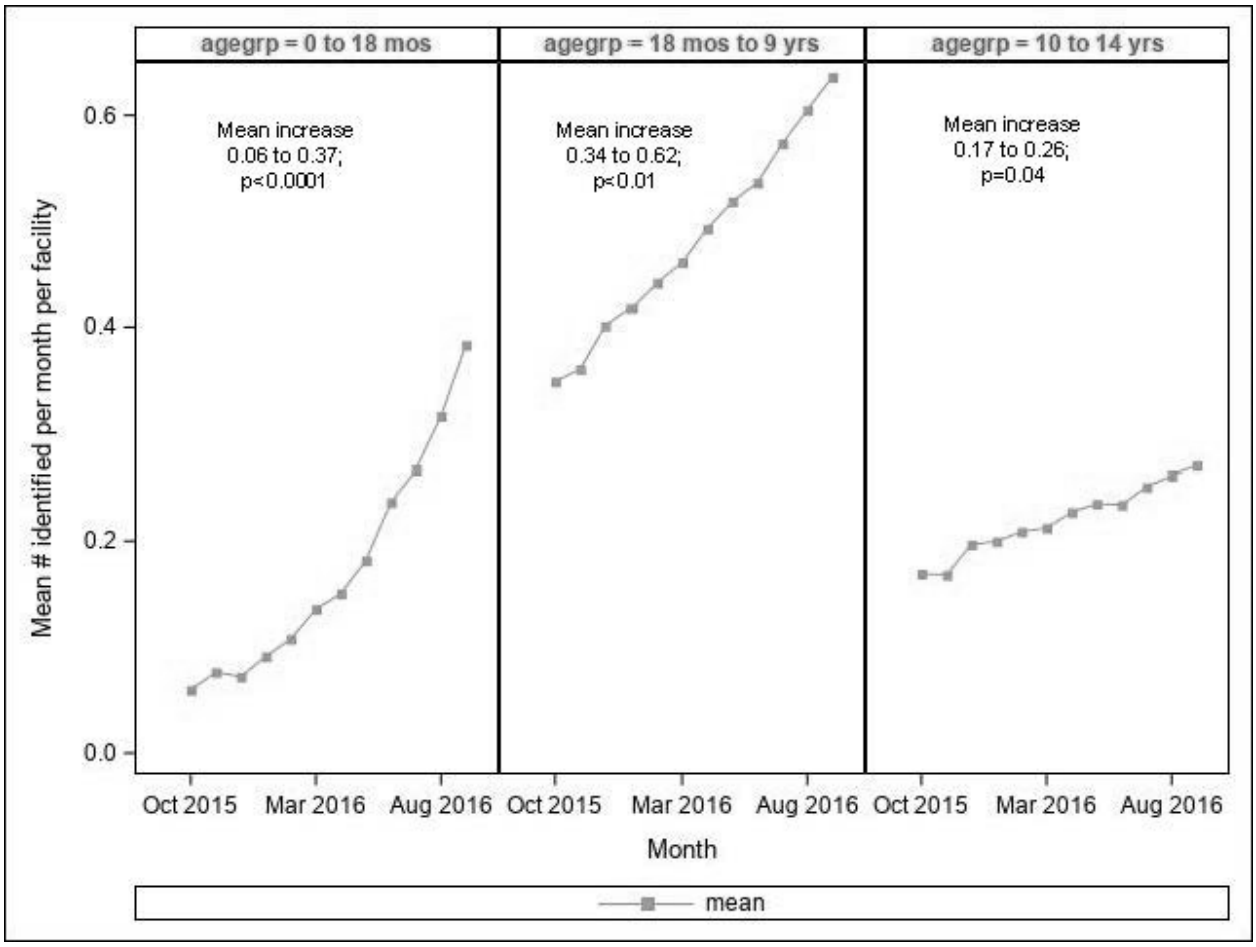


**Table 1 – Description of ACT Interventions**

| Intervention | Description |
|---|---|
| Add HTC counselors | Identified facilities with an insufficient number of counselors per catchment population size. Hired counselors with HTC counseling training, to achieve a maximum of 15 clients per counselor per day. Certified trainers conducted a refresher training for all new and existing counselors using an MOH-approved curriculum on pediatric HIV testing, followed by a 2-day hands-on practicum to demonstrate applied skills. Counselors were also trained on changes to HIV test kit protocols. We used human resources records to determine the number and hire dates of HTS counselors. |
| Improve HTC space | Identified facilities with insufficient space to accommodate the increased HTC target volume. Renovated and allocated areas for HTC, including structural modifications to existing clinic space or creation of additional testing space using tents, tables, and chairs. |
| FIT chart audits | Retrospective medical chart audits to enter all preexisting FIT data into an electronic database. Identified and tracked pediatric household members overlooked for HIV testing. HIV testing was conducted in the clinic or in the home. |
| FIT refresher training | Clinic staff at all sites received a refresher training on use of the Family Information Table, which is located in every patient file and should be reviewed at every clinic visit to ensure testing of all eligible household members. |
| Text message reminders for testing of HIV-exposed infants (TextIT) | We registered pregnant women with HIV in an automated reminder system, TextIT, and assigned a study nurse for case management. Participants received a series of up to 14 text messages containing wellness reminders on topics including prenatal care, PMTCT prophylaxis, and the importance of giving birth in a healthcare facility. Participants received messages every two weeks from 28-38 weeks gestation and then weekly until 40 weeks gestation. Weekly reminders to bring the infant for HIV testing were sent for the first six weeks post-delivery. |
| Community outreach testing | Outreach activities leveraged existing MOH-led community-based clinical service events that targeted maternal and child health, immunization, and women. We assigned additional HTC staff based on local HIV prevalence. Activities also focused on areas frequented by adolescents (e.g. churches, discos and night dances during funerals, popularly known as 'disco matangas') and calendar events such as World AIDS Day and World TB Day. We recorded the number and location of events conducted per month. We held 1699 outreach events with a median of 2 events per month/ facility, and tested 27,249 youths <15 years. |

**Table 2 – Multivariable Associations between Individual Interventions and HIV Testing, by Age Group**

| Intervention | Step Effect<br><br>Adjusted* IRR<br>(95% CI) | p-value | Trend Effect<br><br>Adjusted IRR<br>(95% CI) | p-value |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 1.06 (0.83, 1.36) | 0.6133 | Not retained in full model | |
| HTC Space | 0.90 (0.73, 1.09) | 0.2731 | Not retained in full model | |
| Chart Audits | 1.31 (1.10, 1.55) | 0.0025 | Not retained in full model | |
| FIT Training | 0.37 (0.26, 0.54) | <0.0001 | 3.85 (2.16, 6.84) | <0.0001 |
| TextIT | 2.10 (1.57, 2.80) | <0.0001 | Not retained in full model | |
| Outreach | 1.07 (0.95, 1.20) | 0.2649 | No trend effect hypothesized | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 0.90 (0.77, 1.06) | 0.2017 | Not retained in full model | |
| HTC Space | 1.32 (1.15, 1.52) | 0.0001 | Not retained in full model | |
| Chart Audits | 0.69 (0.52, 0.91) | 0.0099 | 2.07 (1.20, 3.57) | 0.0091 |
| FIT Training | 1.65 (1.24, 2.20) | 0.0005 | 0.36 (0.20, 0.63) | 0.0004 |
| TextIT | 1.72 (1.35, 2.17) | <0.0001 | Not retained in full model | |
| Outreach | 1.39 (1.26, 1.53) | <0.0001 | No trend effect hypothesized | |
| **Age Group: 10 to 14 years** | | | | |
| HTC Counselors | 1.00 (0.82, 1.22) | 0.9865 | Not retained in full model | |
| HTC Space | 1.34 (1.12, 1.60) | <0.0001 | Not retained in full model | |
| Chart Audits | 0.75 (0.56, 1.01) | 0.0580 | 2.11 (1.21, 3.66) | 0.0082 |
| FIT Training | 2.37 (1.63, 3.42) | <0.0001 | 0.19 (0.10, 0.35) | <0.0001 |
| TextIT | 1.10 (0.72, 1.69) | 0.6655 | 1.94 (1.14, 3.30) | 0.0149 |
| Outreach | 1.56 (1.39, 1.74) | <0.0001 | No trend effect hypothesized | |

* All models adjusted for geographic location, health facility tier, and HIV rapid testing kit stockouts

**Table 3 - Multivariable Associations between Individual Interventions and Identification of HIV Positives, by Age Group**

| Intervention | Step Effect<br>Adjusted* IRR<br>(95% CI) | p-value | Trend Effect<br>Adjusted IRR<br>(95% CI) | p-value |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 1.61 (1.08, 2.40) | 0.0202 | Not retained in full model | |
| HTC Space | 1.10 (0.72, 1.69) | 0.6532 | Not retained in full model | |
| Chart Audits | 0.86 (0.57, 1.30) | 0.4776 | Not retained in full model | |
| FIT Training | 0.46 (0.15, 1.41) | 0.1762 | 5.42 (1.06, 27.77) | 0.0427 |
| TextIT | 1.83 (1.06, 3.18) | 0.0310 | Not retained in full model | |
| Outreach | 0.87 (0.58, 1.30) | 0.4920 | No trend effect hypothesized | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 1.19 (0.94, 1.50) | 0.1435 | Not retained in full model | |
| HTC Space | 0.84 (0.67, 1.07) | 0.1575 | Not retained in full model | |
| Chart Audits | 1.16 (0.85, 1.60) | 0.3470 | Not retained in full model | |
| FIT Training | 0.82 (0.61, 1.10) | 0.1889 | Not retained in full model | |
| TextIT | 2.25 (1.62, 3.13) | <0.0001 | Not retained in full model | |
| Outreach | 1.11 (0.92, 1.34) | 0.2557 | No trend effect hypothesized | |
| **Age Group: 10 to 14 years** | | | | |
| HTC Counselors | 0.94 (0.67, 1.33) | 0.7423 | Not retained in full model | |
| HTC Space | 1.29 (0.89, 1.88) | 0.1800 | Not retained in full model | |
| Chart Audits | 1.22 (0.89, 1.67) | 0.2257 | Not retained in full model | |
| FIT Training | 0.68 (0.45, 1.03) | 0.0713 | Not retained in full model | |
| TextIT | 2.52 (1.61, 3.96) | <0.0001 | Not retained in full model | |
| Outreach | 1.58 (1.22, 2.06) | 0.0005 | No trend effect hypothesized | |

* All models adjusted for geographic location, health facility tier, and HIV rapid testing kit stockouts

## 1.8. Supplemental Material

## Supplemental Table 1 – FACES Health Facility and Patient Characteristics

| | N | % |
|---|---|---|
| County | | |
| Homa Bay | 54 | 37.8 |
| Kisumu | 15 | 10.4 |
| Migori | 74 | 51.8 |
| Geographic Location | | |
| Rural | 122 | 85.3 |
| Peri-urban | 12 | 8.4 |
| Urban | 9 | 6.3 |
| Health facility tier | | |
| Dispensary | 95 | 66.4 |
| Comprehensive Outpatient | 37 | 25.9 |
| Subcounty/County Hospital | 11 | 7.7 |
| Number of HTC counselors per facility | | |
| 0 | 93 | 65.0 |
| 1 | 45 | 31.5 |
| 2+ | 5 | 3.5 |
| Patient Gender* | | |
| Female | | 51.7 |
| Male | | 48.3 |
| | | |
| | **Total N** | **Median (IQR) per facility/month** |
| Number of Youth Tested | | |
| Infants <18 months | 7,183 | 2 (0, 5) |
| Children 18 months-9 years | 145,833 | 64 (23, 114) |
| Adolescents 10-14 years | 115,296 | 44 (16, 84) |
| Total | 268,312 | |
| | | |
| | **Total N** | **Yield (%)** |
| Number of Youth Identified with HIV | | |
| Infants <18 months | 225 | 3.1 |
| Children 18 months-9 years | 759 | 0.52 |
| Adolescents 10-14 years | 344 | 0.30 |
| Total | 1,328 | |

* Proportions estimated based on a subset of facilities with electronic medical record data. Numbers are not available for the full patient population in FACES-supported facilities in 2015.

## Supplemental Table 2 – Implementation of ACT Interventions

| Intervention | Number of Sites | Roll-out period<br># Intervention months (% of total time) |
|---|---|---|
| Add HTC counselors | N=42 | Sep2015 – Oct2015<br>Intervention months = 504 (32%) |
| Improve HTC space | N=44 | Oct2015 – May2016<br>Intervention months = 383 (25%) |
| FIT chart audits | N=100 | Oct2015 – Feb2016<br>Intervention months = 712 (46%) |
| FIT refresher training | N=99 | Oct2015 – Jun2016<br>Intervention months = 953 (61%) |
| Text message reminders for testing of HIV-exposed infants (TextIT) | N=20 | Sep2015 (10 sites)<br>Feb2016 (10 sites)<br>Intervention months = 200 (13%) |
| Community outreach testing | N=114 | Oct2015 – Sep2016<br>Intervention months = 576 (37%) |

**Supplemental Table 3 - Bivariate Associations between Individual Interventions and HIV Testing, by Age Group**

| Intervention | Step Effect<br>IRR (95% CI) | p-value | Trend Effect<br>IRR (95% CI) | p-value |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 1.82 (1.10, 2.99) | 0.0190 | 1.01 (0.66, 1.55) | 0.9636 |
| HTC Space | 0.73 (0.30, 1.77) | 0.4864 | 2.18 (0.68, 7.02) | 0.1905 |
| Chart Audits | 0.93 (0.66, 1.31) | 0.6913 | 3.30 (1.71, 6.37) | 0.0004 |
| FIT Training | 0.60 (0.29, 1.21) | 0.1549 | 4.08 (1.57, 10.58) | 0.0038 |
| TextIT | 2.51 (1.06, 5.93) | 0.0357 | 2.15 (0.72, 6.42) | 0.1689 |
| Outreach | 1.09 (0.96, 1.24) | 0.1830 | No trend effect hypothesized | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 1.34 (0.93, 1.93) | 0.1169 | 0.84 (0.62, 1.14) | 0.2526 |
| HTC Space | 1.36 (1.04, 1.79) | 0.0263 | 1.02 (0.71, 1.46) | 0.9135 |
| Chart Audits | 0.74 (0.52, 1.05) | 0.0901 | 2.47 (1.58, 3.85) | <0.0001 |
| FIT Training | 1.33 (0.92, 1.92) | 0.1248 | 0.65 (0.39, 1.08) | 0.0995 |
| TextIT | 1.82 (1.19, 2.79) | 0.0060 | 1.32 (0.84, 2.06) | 0.2262 |
| Outreach | 1.41 (1.25, 1.58) | <0.0001 | No trend effect hypothesized | |
| **Age Group: 10 to 14 years** | | | | |
| HTC Counselors | 1.17 (0.84, 1.65) | 0.3548 | 1.11 (0.83, 1.48) | 0.4725 |
| HTC Space | 1.91 (1.42, 2.59) | <0.0001 | 0.68 (0.49, 0.94) | 0.0192 |
| Chart Audits | 0.95 (0.74, 1.22) | 0.6850 | 2.27 (1.56, 3.31) | <0.0001 |
| FIT Training | 2.10 (1.54, 2.87) | <0.0001 | 0.34 (0.21, 0.54) | <0.0001 |
| TextIT | 1.30 (0.88, 1.93) | 0.1878 | 2.43 (1.64, 3.59) | <0.0001 |
| Outreach | 1.63 (1.43, 1.87) | <.0001 | No trend effect hypothesized | |

**Supplemental Table 4 - Bivariate Associations between Individual Interventions and Identification of HIV Positives, by Age Group**

| Intervention | Step Effect<br>IRR (95% CI) | p-value | Trend Effect<br>IRR (95% CI) | p-value |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 2.88 (0.93, 8.92) | 0.0666 | 0.76 (0.15, 3.88) | 0.7428 |
| HTC Space | 0.96 (0.15, 6.07) | 0.9652 | 1.69 (0.13, 21.38) | 0.6856 |
| Chart Audits | 0.61 (0.18, 2.09) | 0.4287 | 3.78 (0.67, 21.39) | 0.1325 |
| FIT Training | 0.41 (0.13, 1.35) | 0.1443 | 9.75 (1.62, 58.61) | 0.0128 |
| TextIT | 2.00 (0.37, 10.78) | 0.4190 | 2.14 (0.22, 20.52) | 0.5104 |
| Outreach | 1.10 (0.68, 1.78) | 0.6862 | No trend effect hypothesized | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 1.39 (0.77, 2.53) | 0.2741 | 1.42 (0.77, 2.61) | 0.2636 |
| HTC Space | 0.51 (0.30, 0.86) | 0.0117 | 2.19 (1.07, 4.46) | 0.0316 |
| Chart Audits | 1.27 (0.82, 1.96) | 0.2879 | 1.31 (0.61, 2.80) | 0.4877 |
| FIT Training | 1.31 (0.76, 2.27) | 0.3366 | 0.83 (0.38, 1.78) | 0.6293 |
| TextIT | 2.37 (1.36, 4.12) | 0.0024 | 1.96 (0.96, 4.03) | 0.0656 |
| Outreach | 1.28 (1.01, 1.63) | 0.0415 | No trend effect hypothesized | |
| **Age Group: 10 to 14 years** | | | | |
| HTC Counselors | 2.16 (1.09, 4.30) | 0.0282 | 0.60 (0.32, 1.11) | 0.1024 |
| HTC Space | 1.15 (0.48, 2.79) | 0.7491 | 1.07 (0.36, 3.16) | 0.8967 |
| Chart Audits | 1.48 (0.86, 2.55) | 0.1600 | 1.59 (0.67, 3.75) | 0.2935 |
| FIT Training | 2.87 (1.32, 6.21) | 0.0076 | 0.23 (0.07, 0.71) | 0.0107 |
| TextIT | 4.48 (3.03, 6.63) | <0.0001 | Failed to converge | |
| Outreach | 1.88 (1.32, 2.68) | 0.0005 | No trend effect hypothesized | |

**Supplemental Table 5 - Multivariable Associations between Individual Interventions and HIV Testing, by Age Group**

| Intervention | **Step Effect** Adjusted IRR (95% CI) | **p-value** | **Trend Effect** Adjusted IRR (95% CI) | **p-value** |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 1.06 (0.83, 1.36) | 0.6133 | Not retained in full model | |
| HTC Space | 0.90 (0.73, 1.09) | 0.2731 | Not retained in full model | |
| Chart Audits | 1.31 (1.10, 1.55) | 0.0025 | Not retained in full model | |
| FIT Training | 0.37 (0.26, 0.54) | <0.0001 | 3.85 (2.16, 6.84) | <0.0001 |
| TextIT | 2.10 (1.57, 2.80) | <0.0001 | Not retained in full model | |
| Outreach | 1.07 (0.95, 1.20) | 0.2649 | No trend effect modeled | |
| Calendar Time (month) | 1.60 (1.02, 2.52) | 0.0400 | | |
| Rapid Testing Kit Stockout | 0.88 (0.73, 1.05) | 0.1594 | | |
| Geographic Location | | | | |
| Rural | Ref | | | |
| Peri-urban | 0.99 (0.57, 1.72) | 0.9734 | | |
| Urban | 3.00 (1.48, 6.12) | 0.0024 | | |
| Health Facility Tier | | | | |
| Dispensary | Ref | | | |
| Comprehensive Outpatient | 1.12 (0.83, 1.52) | 0.4423 | | |
| Subcounty Hospital | 2.15 (1.53, 3.01) | <0.0001 | | |
| County Hospital | 1.99 (1.06, 3.74) | 0.0326 | | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 0.90 (0.77, 1.06) | 0.2017 | Not retained in full model | |
| HTC Space | 1.32 (1.15, 1.52) | 0.0001 | Not retained in full model | |
| Chart Audits | 0.69 (0.52, 0.91) | 0.0099 | 2.07 (1.20, 3.57) | 0.0091 |
| FIT Training | 1.65 (1.24, 2.20) | 0.0005 | 0.36 (0.20, 0.63) | 0.0004 |
| TextIT | 1.72 (1.35, 2.17) | <0.0001 | Not retained in full model | |
| Outreach | 1.39 (1.26, 1.53) | <0.0001 | No trend effect modeled | |
| Calendar Time (month) | 3.26 (2.49, 4.27) | <0.0001 | | |
| Rapid Testing Kit Stockout | 1.14 (0.99, 1.31) | 0.0614 | | |
| Geographic Location | | | | |
| Rural | Ref | | | |
| Peri-urban | 0.63 (0.45, 0.88) | 0.0066 | | |
| Urban | 1.36 (0.93, 1.99) | 0.1161 | | |

| | | | | |
|---|---|---|---|---|
| Health Facility Tier | | | | |
| Dispensary | Ref | | | |
| Comprehensive Outpatient | 0.97 (0.81, 1.15) | 0.7224 | | |
| Subcounty Hospital | 1.10 (0.85, 1.41) | 0.4738 | | |
| County Hospital | 2.90 (1.71, 4.94) | <0.0001 | | |
| **Age Group: 10 to 14 years** | | | | |
| HTC Counselors | 1.00 (0.82, 1.22) | 0.9865 | Not retained in full model | |
| HTC Space | 1.34 (1.12, 1.60) | <.0001 | Not retained in full model | |
| Chart Audits | 0.75 (0.56, 1.01) | 0.0580 | 2.11 (1.21, 3.66) | 0.0082 |
| FIT Training | 2.37 (1.63, 3.42) | <0.0001 | 0.19 (0.10, 0.35) | <0.0001 |
| TextIT | 1.10 (0.72, 1.69) | 0.6655 | 1.94 (1.14, 3.30) | 0.0149 |
| Outreach | 1.56 (1.39, 1.74) | <0.0001 | No trend effect modeled | |
| Calendar Time (month) | 4.63 (3.47, 6.18) | <0.0001 | | |
| Rapid Testing Kit Stockout | 1.23 (1.05, 1.44) | 0.0104 | | |
| Geographic Location | | | | |
| Rural | Ref | | | |
| Peri-urban | 0.51 (0.35, 0.73) | 0.0002 | | |
| Urban | 1.04 (0.58, 1.88) | 0.8835 | | |
| Health Facility Tier | | | | |
| Dispensary | Ref | | | |
| Comprehensive Outpatient | 1.13 (0.89, 1.44) | 0.3008 | | |
| Subcounty Hospital | 1.65 (1.12, 2.43) | 0.0116 | | |
| County Hospital | 2.56 (1.08, 6.08) | 0.0334 | | |

**Supplemental Table 6 - Multivariable Associations between Individual Interventions and Identification of HIV Positives, by Age Group**

| Intervention | Step Effect<br>Adjusted IRR (95% CI) | p-value | Trend Effect<br>Adjusted IRR (95% CI) | p-value |
|---|---|---|---|---|
| **Age Group: <18 months** | | | | |
| HTC Counselors | 1.61 (1.08, 2.40) | 0.0202 | Not retained in full model | |
| HTC Space | 1.10 (0.72, 1.69) | 0.6532 | Not retained in full model | |
| Chart Audits | 0.86 (0.57, 1.30) | 0.4776 | Not retained in full model | |
| FIT Training | 0.46 (0.15, 1.41) | 0.1762 | 5.42 (1.06, 27.77) | 0.0427 |
| TextIT | 1.83 (1.06, 3.18) | 0.0310 | Not retained in full model | |
| Outreach | 0.87 (0.58, 1.30) | 0.4920 | Not modeled | |
| Calendar Time (month) | 2.81 (1.04, 7.59) | 0.0416 | | |
| Rapid Testing Kit Stockout | 0.65 (0.40, 1.07) | 0.0927 | | |
| Geographic Location | | | | |
| Rural | Ref | | | |
| Peri-urban | 0.44 (0.20, 1.00) | 0.0494 | | |
| Urban | 2.22 (1.17, 4.22) | 0.0147 | | |
| Health Facility Tier | | | | |
| Dispensary | Ref | | | |
| Comprehensive Outpatient | 0.93 (0.61, 1.42) | 0.7397 | | |
| Subcounty Hospital | 1.54 (0.85, 2.77) | 0.1513 | | |
| County Hospital | 1.37 (0.67, 2.80) | 0.3839 | | |
| **Age Group: 18 months to 9 years** | | | | |
| HTC Counselors | 1.19 (0.94, 1.50) | 0.1435 | Not retained in full model | |
| HTC Space | 0.84 (0.67, 1.07) | 0.1575 | Not retained in full model | |
| Chart Audits | 1.16 (0.85, 1.60) | 0.3470 | Not retained in full model | |
| FIT Training | 0.82 (0.61, 1.10) | 0.1889 | Not retained in full model | |
| TextIT | 2.25 (1.62, 3.13) | <0.0001 | Not retained in full model | |
| Outreach | 1.11 (0.92, 1.34) | 0.2557 | Not modeled | |
| Calendar Time (month) | 1.93 (1.24, 3.01) | 0.0038 | | |
| Rapid Testing Kit Stockout | 1.15 (0.84, 1.56) | 0.3843 | | |
| Geographic Location | | | | |
| Rural | Ref | | | |
| Peri-urban | 0.98 (0.68, 1.42) | 0.9278 | | |
| Urban | 2.12 (1.32, 3.41) | 0.0018 | | |

| | | | |
|---|---|---|---|
| Health Facility Tier | | | |
| Dispensary | Ref | | |
| Comprehensive Outpatient | 0.83 (0.64, 1.08) | 0.1649 | |
| Subcounty Hospital | 1.19 (0.87, 1.62) | 0.2806 | |
| County Hospital | 2.22 (1.37, 3.59) | 0.0012 | |
| **Age Group: 10 to 14 years** | | | |
| HTC Counselors | 0.94 (0.67, 1.33) | 0.7423 | Not retained in full model |
| HTC Space | 1.29 (0.89, 1.88) | 0.1800 | Not retained in full model |
| Chart Audits | 1.22 (0.89, 1.67) | 0.2257 | Not retained in full model |
| FIT Training | 0.68 (0.45, 1.03) | 0.0713 | Not retained in full model |
| TextIT | 2.52 (1.61, 3.96) | <0.0001 | Not retained in full model |
| Outreach | 1.58 (1.22, 2.06) | 0.0005 | Not modeled |
| Calendar Time (month) | 1.61 (0.81, 3.20) | 0.1770 | |
| Rapid Testing Kit Stockout | 1.34 (0.82, 2.20) | 0.2486 | |
| Geographic Location | | | |
| Rural | Ref | | |
| Peri-urban | 1.14 (0.62, 2.07) | 0.6744 | |
| Urban | 1.76 (1.09, 2.85) | 0.0218 | |
| Health Facility Tier | | | |
| Dispensary | Ref | | |
| Comprehensive Outpatient | 0.95 (0.64, 1.43) | 0.8201 | |
| Subcounty Hospital | 1.25 (0.76, 2.07) | 0.3777 | |
| County Hospital | 4.30 (2.22, 8.32) | <0.0001 | |

# 2. Chapter 2. Community-based HIV testing services in an urban setting in western Kenya: a programme implementation study

## 2.1. Abstract

Some countries are struggling to reach the UNAIDS testing target, especially among men and youth. To identify persons unaware of their HIV-positive status and achieve testing saturation, we implemented a hybrid HIV testing approach in an urban informal settlement in Western Kenya.

The Community Health Initiative (CHI) conducted community mapping, household census, multi-disease community health campaigns (CHCs), and home-based tracking in 2018 in the informal settlement of Obunga, located in Kisumu, Kenya. The implementation location was chosen in consultation with CDC Kenya in response to the HIV testing services (HTS) needs of the community. The program components were modeled after our previous implementation in Homa Bay County. Health and counseling services were tailored for men and youth to encourage their participation. We calculated the previously unidentified fraction (PUF), which is the proportion of newly identified persons living with HIV (PLWH) out of all previously identified and newly identified PLWH.

CHI reached a total of 23,584 persons, of whom 11,526 (49%) were males and 5,635 (24%) were youth ages 15-24. Of 12,768 HTS-eligible individuals, 12,407 (97%) accepted testing, including 3,917 (32%) first-time testers. There were 101 newly identified PLWH out of 1,248 total HIV-positive persons, representing an 8·1% PUF. The PUF was higher among men (9·8%) and youth (15·3%). Ninety-four newly identified persons (93%) initiated same-day treatment.
The community-based hybrid HIV testing approach was successfully implemented for the first time in an urban setting. Innovative approaches that make HIV testing more accessible and acceptable, particularly to men and youth, are critical for achieving testing and treatment saturation. Focusing on identifying persons unaware of their HIV-positive status in combination with monitoring the PUF has the potential to achieve the UNAIDS Fast Track commitments to end AIDS by 2030.

## 2.2. Introduction

Some countries are still struggling to reach the UNAIDS 90% testing target, especially among men and youth.[1,15,55–60] In Kenya, there are approximately 1·5 million persons living with HIV (PLWH).[61] In 2018, HIV prevalence was estimated at 4·9% among adults 15-64 years of age. HIV prevalence was higher among women (6·6%) than men (3·1%) and in rural areas (5·0%) than urban settings (4·7%).[61] There were approximately 36,000 new infections among adults ≥15 years old.[61] In the most recent Kenya Demographic and Health Survey, testing coverage was lower among men (72%) than women (85%) and was lower among adolescents than older adults, a pattern observed in other countries in sub-Saharan Africa.[3,15,55–60]

Kisumu County in Western Kenya had an estimated HIV prevalence of 17·5% in 2018, which was 3·6 times higher than nationally and second highest of all counties.[61] Of 112,862 PLWH ≥15 years old in 2017, 16,771 (14·9%) were youth ages 15-24.[12] In 2017, the national incidence in

Kenya was 0.18% and Kisumu was one of five counties with an HIV incidence of >0.26.[62] There were 4,012 new HIV infections in Kisumu County, the third highest nationally accounting for 7·6% of all new infections in Kenya.[12] There were 3,396 new HIV infections among persons ≥15 years old, of which 1,630 were among youth.[12]

Community-based hybrid HIV testing to identify persons unaware of their HIV-positive status and achieve testing saturation has been conducted successfully in rural settings in East Africa.[3,43] The hybrid HIV testing services (HTS) approach entails a household census, multi-disease community health campaigns (CHCs) and tracking activities to offer home-based HTS.[43] Prior to the testing initiative described in this paper, Family AIDS Care & Education Services (FACES) implemented a similar program in 2016 in the rural setting of Homa Bay County, Kenya.[29,43] The program tested 9,463 persons and 115 persons were newly identified as HIV-positive.[43]

In Kenya, persons living in urban settings, such as Nairobi and Kisumu counties, have a higher risk of HIV infection than those living in more rural areas.[12,62–64] Though there are health advantages of residing in urban areas, such as easier access to health care facilities, persons living in peri-urban areas and urban informal settlements, i.e., slums, often have higher rates of morbidity and mortality compared to persons living in more privileged urban neighborhoods and rural areas.[65] We describe the uptake of HIV testing and linkage to care and treatment through the implementation of the Community Health Initiative (CHI) in an urban informal settlement setting in Western Kenya.

## 2.3. Methods

Program design and participants

The CHI program was implemented in the urban informal settlement of Obunga located in Kisumu, Kenya, from 7 December 2017 through 30 September 2018. Our team, comprised of over 100 staff members, conducted community mobilization and sensitization, community mapping, household census, multi-disease CHCs and tracking activities to offer home-based HTS. The program activities are presented in Figure 1. Residents of Obunga were eligible for all program components. Health services offered at the CHCs in addition to HTS included screening, testing and provision of referrals for tuberculosis, malaria, hypertension and diabetes, and were available to both residents and nonresidents in the coverage area.

Procedures

Community mapping identified community landmarks and health facilities and recorded GPS coordinates in order to inform the subsequent census, CHCs and tracking activities. Community landmarks for location purposes included the village chief's office, churches, shops, railway flyovers, bypasses and junctions. The CHI team worked with local administrative and community leaders to conduct the community mapping.

We conducted a household census to enumerate and obtain demographic and fingerprint data from all persons residing in Obunga during the implementation of the census and CHCs. Enumeration also took place at CHCs for residents not located during the census. During

enumeration, the head of household provided names of household members, defined as persons who usually lived in the home. For each household, we recorded GPS coordinates and noted locator information (e.g., landmarks) to facilitate the tracking process. We made up to three attempts to reach each household or individual household members.

CHI held a total of 52 multi-disease CHCs in mobile tents throughout the program coverage area, their locations determined using household distribution data gathered during the census. We held CHCs throughout the week including weekends, with the days varying from week to week. CHCs operated all day until dusk, with a few continuing until midnight to accommodate attendees who might not be able to attend during the daytime. To encourage participation of men and youth, CHCs provided tailored health and counseling services, musical entertainment and live screenings of the World Cup football competition.

Residents enumerated during the census who did not attend a CHC were tracked using GPS data in order to offer home-based HTS and TB screening. During tracking, we made up to three attempts to reach each individual. Verbal consent was obtained during the census by program staff who explained that demographic and fingerprint data collected would be used to confirm an individual's identity when that person attended a CHC. Verbal consent was also obtained for collection of demographic and fingerprint data from nonresidents who attended the CHCs and residents who were not previously enumerated during the census.

HIV testing was conducted by certified HTS counselors. HIV testing eligibility criteria for the CHCs and tracking activities were based on the 2015 national guidelines in Kenya.[18] Persons age ≥15 years who were not previously identified PLWH were eligible for HIV testing. Children <15 years who reported being sexually active or for whom testing was requested by a parent or guardian, and persons who tested within the past 3 months but reported a recent risk were also eligible for testing. Classification of previously identified PLWH was based on self-report and verified by presenting their clinic cards or answering verification questions posed by HIV test counselors.

Newly identified PLWH at the CHCs and through tracking activities were provided with referrals for linkage to care at the health facility of their choosing and same-day antiretroviral therapy (ART) initiation. Newly identified PLWH were also offered partner notification services (PNS) per national guidelines.

Statistical analysis

Statistical analysis was performed using SAS software version 9·4 (SAS Institute Inc., Cary, NC, USA). Frequencies and proportions were used to describe demographic characteristics, HIV yield and previously unidentified fraction (PUF). HIV yield is the proportion of newly identified PLWH out of the total number of persons tested. The PUF is the proportion of newly identified PLWH out of all previously identified and newly identified PLWH.[43] We also calculated the PUF+, which additionally includes newly identified and previously identified PLWH reached through PNS. Demographic factors of newly identified PLWH were assessed with Fisher's Exact Test or the Chi-square test. Differences by HIV testing status (first-time vs. repeat testers) were analyzed with multivariate logistic regression. Covariates included sex, categorical age, highest

education level, marital status and residency status. Persons with unknown education level and marital status were excluded from the multivariable analysis. Program data analysis was conducted with the approval of the institutional review boards at the University of California and the Kenya Medical Research Institute.

Role of the funding source

The funder 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.

## 2.4. Results

The CHI program reached a total of 23,584 persons, as presented in Figure 1. We engaged 22,685 residents and nonresidents through the CHCs and tracking activities. There were 899 enumerated residents who did not attend a CHC and could not be contacted through tracking. The census enumerated 16,734 residents who belonged to 4,509 households. At the CHCs, we enumerated an additional 540 residents who belonged to an existing household and 4,277 residents who reported belonging to a household not enumerated during the census. During tracking, we could not locate 165 enumerated residents and 276 enumerated residents who were located declined to complete the survey and HTS.

Of the 12,769 HTS-eligible individuals, 12,407 (97·2%) accepted testing (10,110 at CHCs and 2,297 during tracking). Of those tested, 6,498 (52·4%) were women and 8,180 (65·9%) were ≥15 years old, as detailed in Table 1. Individuals ineligible for testing included 1,147 previously identified PLWH and 3,136 children <15 years old who did not have parental/guardian consent for testing, as detailed in Figure 2.

Of the 362 HTS-eligible individuals who were not tested: 169 (46·7%) were women and 193 (53·3%) were men; 34 (9·4%) were 15-19 years old, 62 (17·1%) were 20-24 years old, 125 (34·5%) were 25-34 years old, 94 (26·0%) were 35-49 years old and 47 (13·0%) were ≥50 years old; and 295 (81·5%) were residents, of whom 227 attended a CHC. Compared to persons who accepted testing, HTS-eligible individuals who did not test were more likely to be male than female ($p=0·036$), persons ≥25 years old than youths ages 15-24 years old ($p<0·0001$) and nonresidents than residents ($p=0·038$).

Among the 12,407 persons tested, 101 were newly identified as HIV-positive, of whom 91 attended the CHCs and 10 were located through tracking. As shown in Table 1, 66 (65·4%) were female, 39 (38·6%) were 25-34 years of age and 92 (91·1%) were residents. HIV yield overall was 0·81%, and was higher among females than males (1·02% vs. 0·59%; $p=0·0088$) and similar between residents and nonresidents (0·84% vs. 0·61%; $p=0·35$). HIV yield increased with older age ($p<0·0001$) and was highest among the 25-34 and 35-49 age groups. The CHI team linked 94 (93·1%) newly identified PLWH to same-day ART initiation.

There were 1,147 previously identified PLWH, of whom 826 (72·0%) were females, 435 (37·9%) were 35-49 years old and 995 (86·8%) were residents. Among these individuals, 1,105

(96·3%) reported ever using ART, of whom 1,095 reported currently being on treatment, as shown in Figure 2. The CHI team linked to treatment 15 of the 52 previously identified PLWH who reported not currently being on ART.

Newly identified PLWH represented a PUF of 8·1% of the total 1,248 PLWH, which comprised of 1,147 previously identified PLWH plus 101 newly identified PLWH, as presented in Table 1. The PUF was comparable between males and females (9·8% vs. 7·4%; p=0·15) and between residents and nonresidents (8·5% vs. 5·6%; p=0·21). The PUF decreased with older age (p=0·0003) and was highest among the 20-24 age group at 17·2%. The PUF was 15.3% for youth.

Overall, of 12,407 individuals who accepted testing, 3,917 (31·6%) were first-time testers and 8,470 (68·3%) were repeat testers; 0·56% of first-time testers (22 people) were newly identified PLWH compared to of 0·93% of repeat testers (79 people). Among first-time testers, 1,425 (36·4%) were ≥15 years old and 2,492 (63·6%) were <15 years old. Table 2 presents the demographic characteristics of first-time testers ≥15 years old, of whom 725 (50·9%) were male and 525 (36·8%) were adolescents ages 15-19 years, including 251 adolescent boys. In the multivariate analysis, sex, age, highest education level completed, marital status and residency were associated with first-time HIV testing. First-time testers were more likely to be males than females (aOR=1·19; 95% CI 1·08, 1·38), adolescents compared to persons 25-34 years old (aOR=2·63; 95% CI 2·14, 3·26), persons with no schooling than those with tertiary/vocational education (aOR=2·14; 95% CI 1·34, 3·40), widowed compared to married persons (aOR=1·64; 95% CI 1·18, 2·27) and residents than nonresidents (aOR=1·54; 95% CI 1·28, 1·85).

There were 61 newly identified PLWH who accepted PNS. The 39 male (63·9%) and 22 female (36·1%) index cases referred 144 contacts (mean=2·4, range=1-8), of whom 63 (43·8%) were sexual partners within the past three months and 81 (56·2%) were children. Of the sexual partners, 27 (42·9%) were women, 10 (16·7%) were youth, and 25 (41·7%) were 25-34 years old. Thirteen named contacts (9·0%) were previously identified PLWH, including two children. PNS tracking activities reached 66 contacts (45·8%) who accepted testing. Five individuals (7·6%), all sexual partners, were newly identified PLWH and all initiated same-day ART. With the additional PLWH identified through PNS, the PUF+ increased to 8·4%.

Of the 15,468 individuals who attended the CHCs, 13,248 were residents and 2,220 were nonresidents. Overall, female residents and nonresidents ≥15 years were more likely to attend the CHCs, be eligible for HIV testing and accept testing. Residents compared to nonresidents were less likely to be ≥15 years old than <15 years old (59·4% vs. 76·1%; p<0·0001) and more likely to be females than males (56·5% vs. 52·3%; p=0·0003). With respect to HIV testing eligibility, 8,909 residents (67·2%) and 1,545 nonresidents (69·6%) were eligible. Eligibility status could not be documented for 383 residents and 76 nonresidents attending the first few CHCs due to technical difficulties with the electronic HTS data collection tool. Among CHC attendees eligible for HIV testing, residents compared to nonresidents were less likely to be ≥15 years old than <15 years old (66·9% vs. 81·4%; p<0·0001) and more likely to be females than males (54·6% vs. 49·8%; p=0·0005).

Of individuals eligible for HIV testing at the CHCs, 8,632 residents (96·9%) and 1,478 nonresidents (95·7%) accepted services. Residents compared to nonresidents were less likely to be ≥15 years old than <15 years old (65·9% vs. 80·6%; p<0·0001) and more likely to be females than males (54·8% vs. 50·2%; p=0·0009). Among residents, there were 82 newly identified PLWH and 865 previously identified PLWH. Among nonresidents, there were 9 newly identified PLWH and 152 previously identified PLWH. HIV yield was similar between residents and nonresidents (0·84% vs 0·61%; p=0·57), as was the PUF (8·7% vs 5·6%; p=0·19)

Among Obunga residents tested at CHCs, there were 82 newly identified PLWH and 865 previously identified PLWH. There were 10 newly identified PLWH and 130 previously identified PLWH among residents who tested during tracking. HIV yield was higher among residents tested at the CHCs than during tracking (0·95% vs. 0·44%; p=0·016), whereas the PUF was similar (8·7% vs. 7·1%; p=0·55).

## 2.5. Discussion

We successfully implemented a community-based hybrid HIV testing approach for the first time in an urban setting characterized by a high risk, impoverished and highly mobile population. CHI provided HIV testing in the informal settlement of Obunga and identified PLWH previously unaware of their status, thereby enabling linkage to care and same-day treatment and reducing onward transmission risk. We enumerated over 90% of Obunga residents and over 97% of persons eligible for HTS accepted testing, with nearly one-third being first-time testers.[66] Among persons newly identified with HIV, 93% initiated ART the same day as part of the campaign. CHI successfully reached the UNAIDS testing and treatment targets.[1]

The program reached many first-time testers, nearly half of whom were men and one-fifth were youth. CHCs held during weekends and evenings likely increased attendance among men and youth who might not have attended otherwise due to work and school responsibilities. Offering live music and World Cup screenings likely helped attract men and youth who might not else have visited the CHCs. Tailored health and counseling services helped men and youth feel more at ease getting their health care needs addressed and questions answered in a comfortable setting. We observed through our experiences implementing community-based hybrid HTS in both rural and urban settings that this strategy increased testing uptake among men and youth, thus lending support to prior recommendations to expand these approaches.[15,43,60,67]

We observed a parallel decline in the PUF and first-time testers among older individuals. The downward inflection in the PUF and first-time testing started with the 35-49 age group. Taken together, these observations likely reflect the fact that persons engaging in behaviors that put them at higher risk for HIV infection were more likely to have a prior testing history and thus previously identified as HIV-positive. There was also a notable increase in HIV yield starting with the 20-24 age group and continuing to rise with the 24-34 and 35-49 age groups.

HIV yield was higher among Obunga residents tested at CHCs than during tracking, a similar observation to what we found in Homa Bay County.[43] These findings could reflect that persons who perceived themselves at higher risk for HIV infection may have actively sought out testing at CHCs, whereas those who perceived themselves to be at lower risk were tested during the

tracking activities. These results may also indicate CHCs are more efficient at reaching persons who are unaware of their HIV infection status.

Studies have shown that persons whose mobility is related to their work are often at higher risk for HIV.[68] The residents of Obunga are considered to be a mobile population, since many have jobs that at times require them to work outside of their community. We observed a similar pattern in our prior testing initiative in Homa Bay County, where HIV yield was higher in the fishing community of Rusinga, whose residents were more mobile than those living in the farming community of Lambwe.[43] Many of the nonresidents who attended the CHCs work in Obunga but live in neighboring informal settlements. Their daily presence makes them a part of the Obunga social network and thus could potentially contribute to the HIV transmission chains in the community.

The observation of a PUF of 8·1% overall, 9·8% among males and 15·3% among youth are important findings since individuals unaware of their infection status pose a tremendous risk of sexual and vertical HIV transmission. The overall PUF was higher than the 7.2% observed in rural Homa Bay County.[43] Our approach of identifying persons unaware of their HIV-positive status in combination with ascertaining the PUF aligns with the UNAIDS concept of incidence/prevalence ratio.[69] The PUF can be used as a metric to compare the utility of different HIV testing platforms, e.g. facility-based vs. community-based testing and PNS, in order to maximize testing efficiency, reach populations lagging behind in testing saturation and increase the first '90'. Therefore, using the PUF metric has the potential to help target HIV testing approaches to reduce the number of persons unaware of their HIV-positive status and link newly diagnosed persons to care and treatment.

We recognize several limitations with the CHI program. We experienced technical difficulties with the electronic HTS data collection tool at early CHCs and could not document eligibility status for some attendees. We were unable to ascertain HIV status of persons eligible for testing but refused, could not be located during tracking or had unknown reasons for not being tested, which may have impacted the HIV yield and PUF. Some CHCs were held in April and May during the rainy season which likely deterred some people from attending on days with heavy rainfall and flooding. Programmatic data were collected using standardized HIV reporting forms issued by the Ministry of Health, therefore additional variables could not be added. Aspects of data collection were incomplete since the testing program was not designed to be a research study. We were unable to calculate a comprehensive cascade for all persons reached by the program because it was not possible to determine a denominator for nonresidents attending CHCs. We conducted data cleaning to remove duplicate records of enumerated individuals who attended more than one CHC but may have missed those who provided different names and demographic information. Residency status was self-reported, thus some individuals presenting at CHCs who reported belonging to a household not enumerated during the census may not have been residents, which would result in misclassification of residency status. There are no estimates available of the Obunga population in 2018, however, we believe our program enumerated >90% of the residents in Obunga based on 2019 census data.[66]

Increasing uptake of HIV testing among individuals who never tested or remain at higher risk for incident infection remains challenging. We applied lessons learned from our prior community-

based hybrid HTS program in the rural setting of Homa Bay County in order to refine our implementation approach in the urban informal settlement setting of Kisumu County.[43] For instance, we scheduled more weekend and evening CHCs in Obunga based on feedback from our Homa Bay clients that these times were more convenient. We also introduced live streaming of the World Cup games and continued to host live bands at the CHCs in Obunga because we observed our Homa Bay clients enjoying the entertainment while waiting for services. Our experiences in these rural and peri-urban settings can help inform efficient implementation of community-based HTS approaches in urban and rural regions of sub-Saharan Africa. Our results showed that offering HTS at CHCs in combination with follow-up home visits is an effective strategy for reaching first-time testers, particularly men and youth.

## 2.6. Conclusions

Innovative HTS strategies that make HIV testing more accessible and acceptable to the community are critical for achieving testing saturation and exceeding the first '90' target. Government agencies, national ministries of health and public health programs can use the PUF and PUF+ as metrics to assess and compare the impact of different HTS strategies to identify PLWH who are unaware of their serostatus and determine the population-level knowledge of HIV serostatus. An evaluation of three universal test and treat (UTT) trials in sub-Saharan Africa found that a comprehensive strategy that started with universal HIV testing and rapid linkage to care and treatment led to more rapid increases in population-level viral suppression and decreases in HIV incidence than the status quo.[70] HTS strategies focused on identifying persons unaware of their HIV-positive status in combination with monitoring the PUF has the potential to achieve the UNAIDS Fast Track commitments to end AIDS by 2030.[71]

## 2.7. Figures and Tables

**Figure 1. Community Health Initiative (CHI) Activities, Kisumu, Kenya, 2018**

**Figure 1: Community Health Initiative (CHI) Activities, Kisumu, Kenya, 2018**

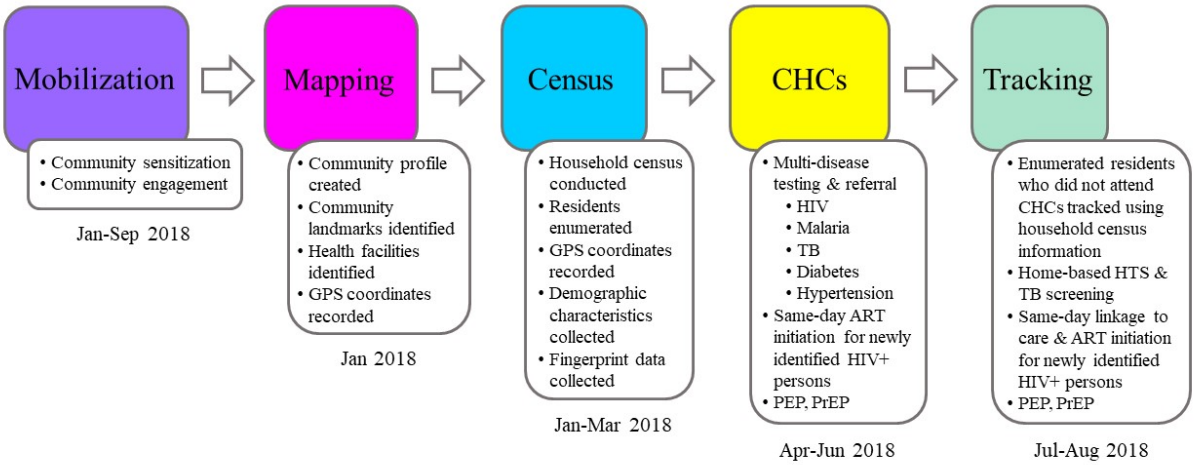


**Figure 2. Flow Diagram of Community Health Initiative (CHI), Kisumu, Kenya, 2018**

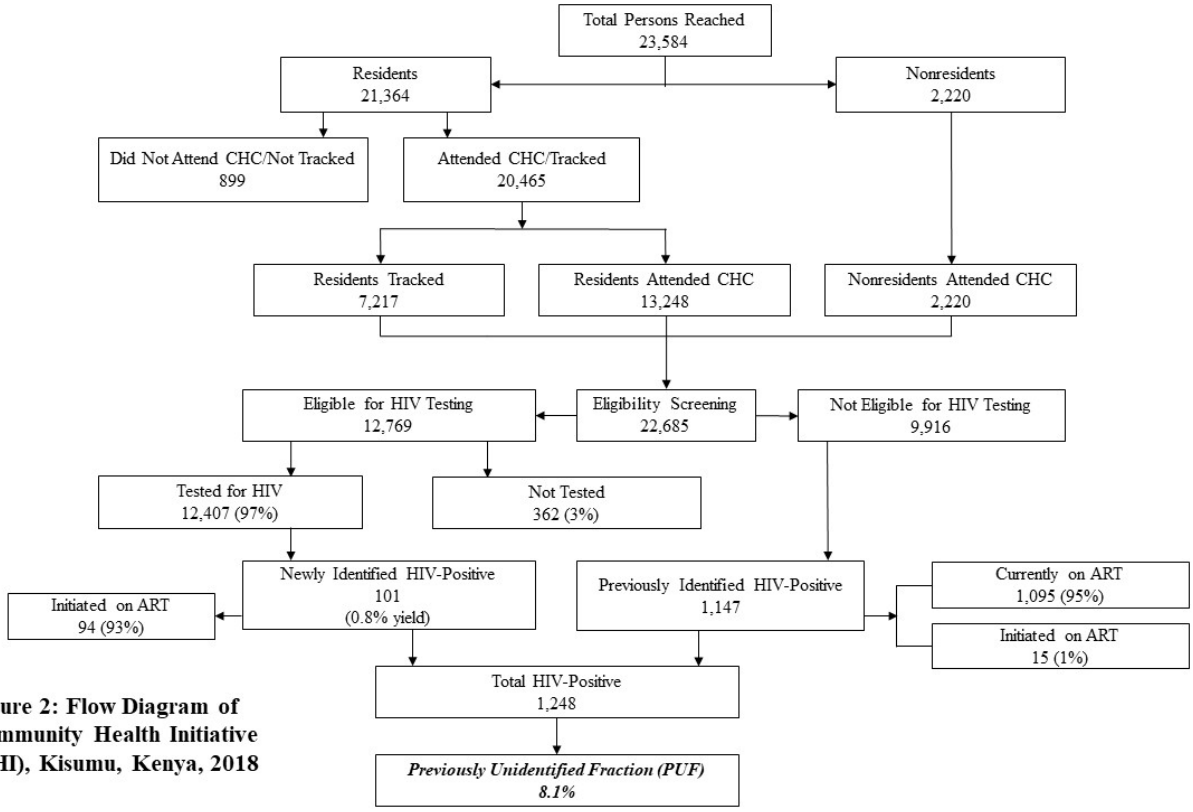



**Figure 2: Flow Diagram of Community Health Initiative (CHI), Kisumu, Kenya, 2018**

**Table 1. Demographic characteristics of persons who accepted HIV testing, newly identified and previously identified HIV-positive persons, HIV yield, and previously unidentified fraction (PUF), Community Health Initiative (CHI), Kisumu, Kenya, 2018**

| Demographic Characteristics | Testers N (%) | Newly Identified HIV-Positive N (%) | Previously Identified HIV-Positive N (%) | HIV Yield | PUF |
|---|---|---|---|---|---|
| **Overall** | 12,407 | 101 | 1,147 | 0·81% | 8·1% |
| **Sex** | | | | | |
| Male | 5,909 (47·6) | 35 (34·7) | 321 (28·0) | 0·59% | 9·8% |
| Female | 6,498 (52·4) | 66 (65·3) | 826 (72·0) | 1·02% | 7·4% |
| **Age (years)** | | | | | |
| 0-9 | 2,875 (23·2) | 6 (5·9) | 36 (3·1) | 0·21% | 14·3% |
| 10-14 | 1,352 (10·9) | 3 (3·0) | 22 (1·9) | 0·22% | 12·0% |
| 15-19 | 1,652 (13·3) | 3 (3·0) | 32 (2·8) | 0·18% | 8·6% |
| 20-24 | 1,831 (14·8) | 21 (20·8) | 101 (8·8) | 1·15% | 17·2% |
| 25-34 | 2,623 (21·1) | 39 (38·6) | 389 (33·9) | 1·49% | 9·1% |
| 35-49 | 1,441 (11·6) | 21 (20·8) | 435 (37·9) | 1·46% | 4·6% |
| ≥ 50 | 633 (5·1) | 8 (7·9) | 132 (11·5) | 1·26% | 5·7% |
| **Education (highest)** | | | | | |
| No school | 276 (2·2) | 1 (1·0) | 31 (2·7) | 0·36% | 3·1% |
| Some primary | 3,798 (30·6) | 29 (28·7) | 330 (28·8) | 0·76% | 8·1% |
| Completed primary | 1,938 (15·6) | 29 (28·7) | 368 (32·1) | 1·50% | 7·3% |
| Some secondary | 2,044 (16·5) | 15 (14·8) | 171 (14·9) | 0·73% | 8·1% |
| Completed secondary | 1,812 (14·6) | 21 (20·8) | 160 (13·9) | 1·16% | 11·6% |
| University/Post-graduate | 291 (2·4) | 0 (0·0) | 14 (1·2) | 0·0% | 0·0% |
| Tertiary/Vocational | 590 (4·8) | 3 (3·0) | 48 (4·2) | 0·51% | 5·9% |
| Refused/Unknown | 40 (0·3) | 0 (0·0) | 3 (0·3) | 0·0% | 0·0% |
| Not applicable [α] | 1,618 (13·0) | 3 (3·0) | 22 (1·9) | 0·19% | 12·0% |
| **Marital Status** | | | | | |
| Single | 3,332 (26·9) | 20 (19·8) | 126 (11·0) | 0·60% | 13·7% |
| Married | 4,622 (37·2) | 61 (60·4) | 645 (56·2) | 1·32% | 8·6% |
| Widowed | 270 (2·2) | 6 (5·9) | 135 (11·8) | 2·22% | 4·3% |
| Divorced/Separated | 179 (1·4) | 5 (5·0) | 66 (5·8) | 2·79% | 7·0% |
| Refused/unknown | 32 (0·3) | 0 (0·0) | 123 (10·7) | 0·00% | 0·00% |
| Not applicable [β] | 3,972 (32·0) | 9 (8·9) | 52 (4·5) | 0·23% | 14·8% |

| | | | | | |
|---|---|---|---|---|---|
| **Residency (Obunga)** | | | | | |
| Resident | 10,929 (88·1) | 92 (91·1) | 995 (86·8) | 0·84% | 8·5% |
| Nonresident | 1,478 (11·9) | 9 (8·9) | 152 (13·2) | 0·61% | 5·6% |

[α] not collected for children ≤6 years old

[β] not collected for children <13 years old

**Table 2. Demographic characteristics of persons aged ≥ 15 years who accepted HIV testing, stratified by first-time and repeat testing status, Community Health Initiative (CHI), Kisumu, Kenya, 2018**

| Demographic Characteristics | First-Time Testers N=1,425 (%) | Repeat Testers N=6,748 (%) | Adjusted Odds Ratio (95% CI) | p-value |
|---|---|---|---|---|
| **Sex** | | | | |
| Male | 725 (50·9) | 3,173 (47·0) | 1·22 (1·08, 1·38) | 0·0018 |
| Female | 700 (49·1) | 3,575 (53·0) | ref | - |
| **Age** | | | | |
| 15-19 | 525 (36·8) | 1,126 (16·7) | 2·63 (2·14, 3·26) | < 0·0001 |
| 20-24 | 244 (17·1) | 1,587 (23·5) | 1·05 (0·87, 1·28) | 0·5977 |
| 25-34 | 303 (21·3) | 2,319 (34·4) | ref | - |
| 35-49 | 199 (14·0) | 1,239 (18·4) | 1·27 (1·04, 1·55) | 0·0176 |
| ≥ 50 | 154 (10·8) | 477 (7·1) | 2·06 (1·60, 2·66) | < 0·0001 |
| **Education (highest) *** | | | | |
| No school | 44 (3·1) | 101 (1·5) | 2·14 (1·34, 3·40) | 0·0014 |
| Some primary | 330 (23·2) | 1,085 (16·2) | 1·50 (1·13, 1·99) | 0·0052 |
| Completed primary | 262 (18·4) | 1,644 (24·5) | 1·11 (0·84, 1·47) | 0·4764 |
| Some secondary | 414 (29·1) | 1,567 (23·3) | 1·11 (0·84, 1·47) | 0·4593 |
| Completed secondary | 230 (16·2) | 1,579 (23·5) | 0·92 (0·70, 1·22) | 0·5703 |
| University/Post-graduate | 65 (4·6) | 226 (3·4) | 1·91 (1·31, 2·77) | 0·0007 |
| Tertiary/Vocational | 76 (5·4) | 514 (7·6) | ref | - |
| **Marital Status *** | | | | |
| Single | 730 (51·7) | 2,345 (34·8) | 1·52 (1·27, 1·81) | < 0·0001 |
| Married | 577 (40·9) | 4,041 (60·0) | ref | - |
| Widowed | 72 (5·1) | 197 (2·9) | 1·64 (1·18, 2·27) | 0·0033 |
| Divorced/Separated | 32 (2·3) | 147 (2·2) | 1·45 (0·97, 2·18) | 0·0700 |
| **Residency (Obunga)** | | | | |
| Resident | 1,267 (88·9) | 5,716 (84·7) | 1·54 (1·28, 1·85) | < 0·0001 |
| Nonresident | 158 (11·1) | 1,032 (15·3) | ref | - |

* persons with unknown education level and marital status excluded from multivariable analysis

# 3. Chapter 3: Differences in HIV testing behaviors and outcomes in women living in an informal urban settlement in western Kenya

## 3.1. Abstract

Progress toward global HIV testing targets has been inequitably achieved across some populations, particularly among key groups, including socially and economically vulnerable women. Using data from a community health initiative that employed a hybrid HIV testing approach, we explored differences in HIV testing behaviors and outcomes in women living in an informal urban settlement in western Kenya.

The Community Health Initiative involved community mapping, a household census, a series of multi-disease health campaigns, and home-based tracking in the informal urban settlement of Obunga in Kisumu, Kenya. Community residents were invited to attend any of 52 multi-disease community health campaigns (CHCs) that were held throughout the program coverage area over a two-month period. HIV testing by certified counsellors was one of the health services available. Among all adult female residents, we analyzed sociodemographic predictors of failing to attend a CHC, with marital status as the primary predictor. Among female CHC attendees, we describe reason for attending, who encouraged her to attend, eligibility for HIV testing, acceptance of testing, and HIV test result.

Among 5,668 women enumerated during the census, 4,231 (75.0%) attended a CHC. Widows were the most likely to attend (80.2%), while never-married women were least likely to attend (64.6%). The most common reason for attending a CHC was ill health, reported by 85.4% of widows compared to 70.5% of married women. Women across all strata of marital status were equally likely to accept HIV testing (94% to 97%), when eligible. Separated/divorced women had the highest HIV testing yield (5.5%), followed by widows (3.0%), never-married women (2.0%), and married women (1.4%). In multivariable analysis, significant predictors of failing to attend a CHC included married status, younger age, and increasing educational attainment. Migration outside the community was associated with a higher probability of attending a CHC (OR=2.02, 95% CI 1.52, 2.68; p<0.0001).

While widows and separated/divorced women represented only 9.4% of the total eligible women who attended a CHC, they accounted for 20% of the newly-identified PWH. Considering the high prevalence of HIV infection in these two groups, creating targeted programs to facilitate HIV testing among widowed and separated/divorced women living in informal urban settlements would have important impacts on both individual and community health.

## 3.2. Introduction

Even as countries achieve the HIV testing target established by the Joint United Nations Programme on HIV/AIDS (UNAIDS) of 90% of all people with HIV (PWH) being aware of their status by the year 2020,[2] this progress is not evenly distributed throughout the population. In sub-Saharan Africa, disparities in HIV prevalence and testing coverage persist among key populations, including children,[5–9] widows and separated/divorced women[72], and people living in informal urban settlements (i.e. slums).[10,73] Although there are health advantages to residing in

an urban area, such as greater access to health care facilities, residents of informal urban settlements are more likely to: engage in drug use and transactional sexual activity; have multiple sexual partners; and have fractured families; all of which are risk factors for acquisition and transmission of HIV infection.[35,74]

In 2014, 56% of the urban population of Kenya lived in an informal settlement.[33] Residents of two informal settlements in Nairobi surveyed in 2008 had a markedly higher prevalence of HIV infection (12%), compared to Kenyans living in non-slum urban (6.5%) and rural areas (5.1%).[75] In addition, settlement dwellers who enter HIV care have been found to have almost double the risk of doing so at an advanced stage of HIV infection compared with PWH in the general population (33% vs. to 19%).[10] Presentation with advanced HIV disease may result from delayed diagnosis or delayed linkage to care.[10] This disparity suggests that settlement dwellers may have been missed by mainstream HIV testing strategies implemented in urban areas, putting them at risk for poorer treatment outcomes,[37] reduced life expectancy,[39] and increased risk of onward transmission of HIV.[38]

Widowed Kenyan women also are at increased risk of acquisition and transmission of HIV and have an exceptionally high prevalence of HIV infection, as high as 63% in rural areas.[44,45] Widows in Kenya are socially and economically marginalized and put at increased risk of HIV acquisition by a number of social practices. During "widow cleansing", a woman is coerced into engaging in a sexual cleansing ritual following the death of her husband.[76,77] These rituals are often performed by a professional widow cleanser, many of whom are infected with HIV and put the woman at risk of HIV acquisition. "Widow inheritance" involves the forced remarriage of a woman to a relative of her deceased husband.[45,76] While this tradition arose in some tribes as a means to provide care and resources for a widow and her children, it increasingly results in the woman being trapped in a nonconsensual sexual relationship while receiving little to no economic support.[45,76] In asset stripping, the relatives of a woman's deceased husband take possession of the marital property and forcibly evict the widow from her home.[46] Victims of these practices are often forced to engage in transactional sex as a means of survival, thus compounding their risk of HIV acquisition.[46] Widows in Kenya are increasingly migrating from rural to urban areas, possibly in order to avoid these practices.[44,47]

In western Kenya, which includes some of the counties with the highest HIV prevalence in the country (ranging from 13.3-20.7%),[12] the rural beach villages surrounding Lake Victoria have been a main migration destination for women, due to the availability of employment within the fish trade.[47] Women engaged in the fish trade exhibit a high degree of mobility between the beaches and Kisumu, the third largest city in Kenya, where they often maintain a residence.[47] It is likely that many of these women end up living in informal settlements. In 2005-2006, the city of Kisumu had ten distinct informal settlements with an estimated 72,433 households.[78] Obunga, the third largest informal settlement in Kisumu, had approximately 6,600 households.[78]

Most previous studies of HIV infection in informal settlements in Kenya have included only settlements in Nairobi.[10,35,40–42,73] In 2018, Kisumu county had a significantly higher prevalence of HIV infection (16.3%) than Nairobi (6.1%);[12] thus, research based in settlements in other regions is needed. While some studies have examined the association between gender and marital status as predictors of HIV infection, they have not addressed the combined risks of

widowed women living in informal settlements in Kisumu.[10,35,44] We sought to assess the characteristics of women living in an informal urban settlement in Kisumu and to develop a deeper understanding of their patterns of accessing HIV testing, as well as how these behaviors differ by marital status. Such knowledge could be used to tailor programs to ensure that all women in informal urban settlements in Kisumu are able to access HIV testing and treatment, particularly the most vulnerable women. By facilitating HIV testing in these at-risk groups, we could interrupt one pathway for HIV transmission in this high-risk population, while improving individual clinical outcomes for women with HIV infection and co-infections.

## 3.3. Methods

*Population and Sample*

Family AIDS Care & Education Services (FACES) is a family-focused, comprehensive HIV prevention, care, and treatment program that has provided services and support in western Kenya since 2004. In 2016, FACES began providing HIV services to populations living in informal urban settlements in Kisumu. From December 7, 2017 through September 30, 2018, FACES implemented the Community Health Initiative (CHI) to assess the impact of an urban, population-based HIV testing campaign on HIV testing coverage, linkage to care, and antiretroviral therapy coverage in the Obunga informal settlement in Kisumu.[79] Community-based hybrid HIV testing combines community mobilization and sensitization; community mapping and a household census; multi-disease community health campaigns (CHCs); and tracking activities to offer home-based HIV testing.[43] This strategy has been used successfully to reach HIV-positive individuals unaware of their status and to achieve population-wide testing coverage in both rural and urban settings in East Africa.[3,43,79]

A census of the Obunga population was conducted by CHI team members between January 2018 and March 2018. All households and household members were enumerated, and sociodemographic data were collected for each individual. All settlement residents were invited to attend any of a series of multi-disease CHCs that offered testing for HIV and tuberculosis and screening for malaria, hypertension, and diabetes mellitus. HIV testing eligibility criteria were based on the 2015 Kenyan national guidelines.[80] Other services provided included treatment for acute illnesses, referral for follow-up of chronic diseases, and voluntary medical male circumcision. Attendees completed an in-depth health and behavior questionnaire. Residents who did not attend a CHC were tracked and, if found, offered HIV testing in their homes and administered the in-depth questionnaire. CHC services were offered free-of-charge and were also available to non-residents.

To assess the relationship between marital status and HIV/healthcare access behaviors among women, we analyzed data from CHI restricted to females >=18 years of age residing in the Obunga settlement between January to June 2018 (n=5,668). A woman was considered a resident if she was enumerated during the census or if she attended a CHC and self-identified as a settlement resident. Program data analysis was done with the approval of the institutional review boards (IRB) at Kenya Medical Research Institute (KEMRI) and the University of California San Francisco (UCSF; San Francisco, CA, USA), and an IRB reliance between UCSF and the University of California Berkeley.

*Measures*

Our primary predictor of interest was marital status, categorized as never-married, married, widowed, or divorced/separated. We defined the primary outcome as attendance at any CHC during the program period (client attended CHC; client tracked and found; client tracked and informant found; could not locate client/informant; and client found and refused participation). Secondary outcomes included: reason for CHC attendance; who encouraged the client to attend; prior HIV testing history (yes/no); time (months) since prior HIV test; acceptance of HIV testing at the CHC; and HIV test result. The following potential covariates were considered:

- Age (in years, categorical: 18-24, 25-34, 35-49, 50+)
- Educational attainment (no school, any primary, any secondary, tertiary/ vocational, university/post-graduate)
- Occupation (unemployed, shopkeeper/market vendor, housewife, student, hotel/restaurant worker, fishing/fishmonger, household worker, factory worker, teacher, farmer, healthcare worker, other, disabled, refused/unknown)
- Any time residing outside of the settlement in the preceding 12 months (yes/no)
- Parity (number of live births ever)
- Live birth in the preceding 12 months (yes/no)
- Current pregnancy status (pregnant/not pregnant)
- Number of sexual partners in the preceding three months (0, 1, 2+ partners)

*Statistical Analysis*

Using data from the CHI census and CHC attendance/tracking data, we examined the relationship between marital status and the primary outcome, CHC attendance. Using data from the in-depth questionnaire administered during the CHC, we assessed the association between marital status and the following healthcare access variables: reason for CHC attendance; who encouraged the client to attend; any prior HIV test; time since previous HIV test; acceptance of HIV testing at the CHC; and HIV test result. We conducted a sensitivity analysis to compare the distribution of marital status, age, educational attainment, and migration history between attendees who were enumerated during the census vs. settlement residents identified at a CHC. Statistical analyses were performed with SAS software version 9.4 (SAS Institute, Cary, NC).

We generated frequencies and proportions to describe categorical marital status, age, educational attainment, occupation, and migration in the previous 12 months among all adult female residents of the Obunga settlement. For women who attended a CHC and completed the detailed survey, we generated: frequencies and proportions for categorical variables (number of sexual partners in the previous three months, current pregnancy status, any live birth in the previous 12 months, ever tested for HIV, and most recent HIV test result); and median and interquartile range (IQR) for parity and months since last HIV test. In bivariate analysis of all female residents, we used the Chi-squared test to assess the relationship between marital status and CHC attendance. Among women who attended a CHC, we used the Chi-squared test to examine associations between marital status and reason for attending (feeling unwell vs. wanting to stay/keep family healthy); who encouraged the client to attend a CHC; eligibility for HIV testing; acceptance of

HIV testing; and HIV test result. We used the Chi-squared test to compare the demographic characteristics of women enumerated during the census and residents identified at a CHC.

Using multivariable logistic regression, we assessed whether marital status was an independent predictor of attendance at a CHC (yes/no), controlling for potential confounders collected during the census (i.e. age, educational attainment, and any outside migration in the past year). We excluded individuals with unknown marital status (n=9) or education attainment (n=25). We conducted secondary analysis using multivariable logistic regression to assess whether marital status is an independent predictor of reason for CHC attendance (feeling unwell vs. wishing to stay healthy), controlling for age, educational attainment, parity, live birth in previous 12 months, and number of sexual partners. Finally, we analyzed the relationship between marital status and HIV test result among women tested at a CHC. Because detection of a new HIV infection was a rare event, we implemented penalized likelihood estimation for this analysis in order to generate non-biased estimates.[81] We initially included additional variables in this final model (i.e. age, educational attainment, parity, live birth in the previous 12 months, number of sexual partners, migration history, and ever tested for HIV). Using backward elimination, we applied the likelihood ratio test to select the most parsimonious model. Our ultimate analysis included two predictors: marital status and current pregnancy.

### 3.4. Results

The Community Health Initiative identified a total of 5,668 women 18 years or older residing in the Obunga settlement in January, 2018. The majority (63.6%; Table 1) were married, while 25.6% were never married, 7.0% were widowed, and 3.8% were separated/divorced. Thirty-eight percent were between 18 and 24 years of age, and roughly half had received more than a primary education. Overall, 22.7% of respondents were unemployed. The most common occupations included shopkeeper/market vendor (15.5%), housewife (14.4%), student (8.8%), and hotel/restaurant worker (5.8%). Only 6.8% of the women reached had lived outside of the settlement for at least one month in the previous 12 months.

In Supplemental Table 1, we present findings from our analysis of the demographic characteristics of settlement residents who were identified at a CHC compared to CHC attendees enumerated during the census. We found that women missed during the census were more likely to be never-married (26.7%) compared to enumerated women (19.9%; $p<0.0001$) and younger (38.9% vs. 34.7% 18-to-24 years old; $p=0.003$). Residents identified at a CHC were less likely to be employed (72.2% vs. 78/8%; $p<0.0001$). However, these women were also more likely to have received tertiary or university education (12.4%) compared to enumerated women (6.7%; $p<0.0001$). Most strikingly, 18.4% of women identified at a CHC reported living outside the settlement in the past year compared to just 2.8% of census-identified women ($p<0.0001$).

Among women who attended a CHC, the majority (78.8%) had one sexual partner in the prior three months. Attendees reported a median of two live births (IQR=1,3), with 16% having given birth in the previous year and 250 (5.9%) currently pregnant. Eighty-seven percent of women had ever been tested for HIV, with a median of 4.4 months since her last test. Among those previously tested, 619 (16.7%) had a positive test result.

We observed important differences in these characteristics when women were stratified by marital status. Widowed women were older than other female settlement residents, with 49.1% aged 50 years or older, compared to 4.2% of married women ($p<0.0001$). Widows were significantly less likely to have received more than a primary education (22.0%) compared to married women (46.6%; $p<0.0001$) and were more likely to be employed in the fishing industry (10.8% and 3.2%, respectively). Widowed women were least likely (3.8%) to have lived outside the community for one month or more in the previous year. Among CHC attendees, 30.3% of widows reported being sexually active in the prior three months. Widows reported the highest median number of lifetime live births (4.0; $p<0.0001$) and the lowest probability of ever having been tested for HIV (78.6%; $p<0.0001$). Among women tested, a greater time had elapsed for widows since their most recent test (median=13.3 months) compared to married women (median=4.3months; $p<0.0001$). Widows also had the highest prevalence of HIV infection (37.8%), followed closely by separated/divorced women (29.8%).

Program outcomes also varied by marital status (Table 2). Widowed women were most likely to attend a CHC (80.2%), compared to married women (78.9%; $p< 0.0001$), followed by separated/divorced women (75.9%) and never-married women (64.6%). The most commonly given reason for attending a CHC was "I am feeling sick, and I want to be tested", with 85.4% of widows giving this reason, compared to 70.5% of married women. Friends and neighbors encouraged the plurality of women (28-34%) to attend. Local councilors were also pivotal in this role, particularly for widowed women (26.5%). Among women who attended a CHC, never-married women were most likely to be eligible for HIV testing (76.8%; $p<0.0001$). All groups had similarly high levels of HIV testing acceptance (94% to 97%; $p=0.48$). Of those who accepted HIV testing, separated/divorced women had the highest yield of HIV positivity (5.5%), followed by widows (3.0%), never-married women (2.0%), and married women (1.4%).

Table 3a includes results of our analysis of the relationship between marital status and attendance at a CHC. Controlling for covariates, widows had 0.90 times the odds of attending a CHC compared to married women (95% CI 0.67, 1.22; $p=0.50$), followed by separated/divorced women (OR=0.78; 95% CI 0.56, 1.08; $p=0.13$) and never-married women (OR=0.54; 95% CI 0.46, 0.62; $p<0.0001$). We observed a U-shaped association between age and CHC attendance; compared to 25-to-34 year-olds, the youngest women had 0.86 times the odds of attending a CHC (95% CI 1.00, 1.35; $p=0.047$), while 35-to-49 year-olds had 0.81 times the odds (95% CI 0.67, 0.97; $p=0.047$). Compared to women who attained no higher than a primary education, women with additional schooling were less likely to attend a CHC. Women with any secondary education had 0.76 times the odds of attending (95% CI 0.66, 0.87; $p<0.0001$). Those who attended tertiary/vocational school or university had, respectively, 0.47 times the odds (95% CI 0.38, 0.59; $p<0.0001$) and 0.72 times the odds (95% CI 0.50, 1.04; $p=0.078$) of attending. Migration outside the settlement in the past year was associated with a higher probability of attending a CHC compared to those who reported no migration (OR=2.02; 95% CI 1.52, 2.68; $p<0.0001$).

In our secondary multivariable analysis of women who attended a CHC, marital status was associated with reason for attending (Table 3b). Widowed women had 1.46 times the odds of attending a CHC because they felt unwell and wanted to be tested for HIV, compared to married women (95% CI 0.98, 2.15; $p=0.06$), who were more likely to attend in order to keep themselves

and their families healthy. Separated/divorced women were also more likely to attend a CHC due to poor health (OR=1.56; 95% CI 1.01, 2.40; p=0.046). There was a trend toward increasing attendance due to poor health with increasing age, with women 50 years and older having the highest odds of being unwell compared to 25-to-34 year-olds (OR=2.65; 95% CI 1.72, 4.08; p<0.0001). Greater educational attainment was associated with attending a CHC in order to maintain health. Each additional live birth in a woman's lifetime increased her odds of attending due to feeling unwell by 4% (95% CI 1.01, 1.07; p=0.004), while women who gave birth in the previous 12 months were less motivated by poor health to attend, compared to those who had not recently given birth (OR=0.77; 95% CI 0.64, 0.94; p=0.008). Number of recent sexual partners was not associated with reason for attending a CHC.

We found only two predictors of receiving a positive HIV test at a CHC to be statistically significant, marital status and current pregnancy at the time of the CHC (Table 3c). Widowed women had 2.58 times the odds of receiving a positive HIV test result compared to married women (95% CI 1.00, 6.66; p=0.049). Separated/divorced women had the highest probability of testing positive for HIV (OR=4.92; 95% CI 1.88, 12.83; p=0.001), while never-married women had 1.59 times the odds of testing positive (95% CI 0.83, 3.06; p=0.16). Women who were pregnant at the time of CHC attendance had 3.02 times the odds of testing positive for HIV, compared to non-pregnant women (95% CI 1.20, 7.63; p=0.019).

### 3.5. Discussion

We described the demographic characteristics of women living in an informal urban settlement in western Kenya and assessed whether marital status was a predictor of attendance at a multi-disease community health campaign focused on achieving community HIV testing saturation. We examined motivators of attendance at a CHC and HIV testing result at the campaign. We found that 75% of female settlement residents attended a CHC and that the probability of attending among widows and separated/divorced women was not different from that of married women. Never-married women were less likely to attend (65%), which is consistent with findings from previous population-based HIV testing campaigns and likely due to their younger age.[3] Widowed women were more likely to indicate that poor health was their primary reason for attending a CHC, compared to married women who attended in order to maintain their and their family's health. Friends were instrumental in motivating all women to attend a CHC. However, among widows, local councilors played an important role in encouraging their attendance, compared to all other women, who were more likely to be influenced by a family member. HIV testing was accepted by the majority of eligible women. HIV testing yield (i.e. proportion positive for HIV) was highest among widows (3.0%) and separated/divorced women (5.5%). While widows and separated/divorced women represented only 9.4% of the total eligible women who attended a CHC, they accounted for 20% of the newly-identified PWH.

The community-based hybrid HIV testing model has been found to be effective at increasing population HIV-testing coverage in rural areas in east Africa.[3,43] However, one point of concern in previous research was the challenge of capturing people of unstable residence in population-wide testing efforts.[3] This poses the question as to whether this approach would be appropriate for residents of informal urban settlements, who have been shown to have a high degree of mobility. The main results from the Community Health Initiative in the Obunga settlement found that the hybrid strategy was successful in achieving >90% overall testing coverage in an urban

area, in particular succeeding in reaching groups previously lagging in their testing coverage, including men and youth.[79] Findings from our additional analysis of the CHI data show that the hybrid approach was effective at engaging women in attending a community health campaign, including widows and highly-mobile women who had been absent during the initial community census.

We found that widowed and separated/divorced women were more likely to report attending a CHC because of poor health, after adjusting for age and other confounders. This points to a potential unmet health care need in these women, especially considering the high prevalence of HIV infection among widows. We additionally saw differences in who encouraged women to attend a CHC, with widows being the least likely to report being counseled to attend a CHC by a family member. Widows are often the head of their household[82] and migrate to urban areas to pursue economic opportunities[44,47] and to escape oppressive traditional practices surrounding widowhood.[76] As such, they are less likely to have relatives nearby to offer guidance and support around health-related issues. In contrast, widows were most likely to be influenced by local councilors. Settlement leadership is often aware of the needs of individual community members and could potentially be leveraged for future efforts to increase engagement in HIV testing and care among widows and separated/divorced women.

The CHI initiative was effective at engaging women in HIV testing and identifying women with previously undiagnosed HIV infection. Acceptance of HIV testing among eligible female CHI attendees was >90% in all marital groups, resulting in 50 newly-identified HIV infections at a CHC. Using data from a population-based sample of 15-to-49 year-old women, the most recent Kenya AIDS Indicator Survey (2012) found disparities in HIV testing coverage among women by marital status.[83] Never-married women had the lowest testing coverage (59%), compared to married (78%), separated/divorced women (79%), and widows (72%). While HIV testing coverage has increased across the board due to the emphasis on the UNAIDS 90-90-90 targets,[1] we observed persisting disparities in the proportion ever tested for HIV, with widowed and separated/divorced women achieving smaller gains (7% in both groups), compared to married (12%) and never-married women (25%). Self-reported HIV positivity was highest among widows and separated/divorced women, which is in accord with previous estimates of HIV prevalence in these groups in sub-Saharan Africa.[72] Given the high prevalence of HIV infection among widows and separated/divorced women in Kenya, women in these vulnerable groups living in the Obunga settlement are still at risk for late diagnosis of HIV infection and the corresponding negative sequelae. We found marital status to be one of the only significant predictors of a new HIV diagnosis during a CHC, with widowed women having 2.58 times the odds of testing positive at a CHC compared to married women, and separated/divorced women having 4.92 times the odds of testing positive. This aligns with the findings of previous research.[72] The CHI initiative appears to be an effective way to address persisting disparities in HIV testing and diagnosis among socially and economically marginalized women.

This study has several notable limitations. While every effort was made during the census to capture all households and residents, of the 5,668 women who attended a CHC and indicated being a resident of Obunga, almost one in four (N=1,309) had not been captured during the census. Individuals first identified at a CHC may have recently migrated to the settlement or have been away for school/work during the census. In our secondary analysis, we found that women missed during the census were much more likely to have lived outside the community for at least one month during the previous year. Inclusion of these women in our analytic sample

provides a more complete view of the total female membership of the Obunga settlement. However, women who spend more time outside the community are also more likely to have been absent during the CHCs. If additional women are missing from our data and are inherently different from the women we captured, our estimates of CHC attendance and characteristics associated with a new positive HIV test may be biased. In addition, some misclassification of self-reported marital status may have occurred. If a woman had remarried and reported her status as "married", this could obscure the risks she experienced from being previously widowed or separated/divorced. Finally, questions on forced and transactional sex were not included in the survey implemented at the CHCs. These unmeasured potential confounders would likely have been important to consider in our multivariable analyses.

While we must take into account these limitations, this study has many strengths. This analysis addresses gaps and limitations in the previous research on the relationship between residence in an informal urban settlement, marital status, and HIV care seeking-behaviors. Muhula et al. measured rates of clinic-based vs. community-based HIV testing in informal settlements in Nairobi, but did not analyze risk factors for failure to test.[35] Van der Kop et al. assessed indicators for presentation with advanced HIV disease among residents of two informal settlements in Nairobi, but did not include marital status as a covariate.[10] The current study elucidates risk factors for failing to take advantage of an advertised community health campaign that included HIV testing. In addition, because the CHI initiative was implemented in Kisumu county, where the adult prevalence of HIV infection is significantly higher compared to these previous studies conducted in Nairobi, our study broadens the knowledge concerning the needs of settlement dwellers in varied settings. Finally, Camlin et al. elucidated the migration patterns of widows and the associated risks of HIV acquisition,[44] but less is known about HIV testing and care patterns among this population. Our findings add to our understanding of the lives of these women, as well as separated/divorced women, once they arrive in an informal settlement.

### 3.6. Conclusions

We estimated the proportion of the widowed population of women living in the Obunga settlement (7.0%) to be close to double that of the general population (3.7%).[15] Considering the over-representation of widows in the Obunga settlement and their strikingly higher prevalence of HIV infection, creating programs for this group of women in Obunga and other settlements to facilitate linkage to HIV testing and continuity of care – including community health campaigns - would have important impacts on both individual and community health. Additional research to understand the experiences of women who may have been missed by the Community Health Initiative would further strengthen our inferences on the impact of this program and help us to ensure that our efforts are reaching all women in the community. Understanding the barriers to and facilitators of HIV testing and linkage to care that widows experience will help shed light on interventions to engage and retain them in care and improve their clinical outcomes. Further exploration is warranted of the HIV care needs of separated/divorced women, who we observed to be represented in the Obunga population and also yielded a high proportion of new diagnoses among those tested. Information gathered through this project can be used to tailor clinical and outreach services to ensure that these vulnerable, high-risk populations of women receive the most appropriate and equitable care, thus intervening on an important pathway fueling the continued transmission of HIV in this informal settlement and surrounding communities.

### 3.7. Tables

**Table 1 - Characteristics of women 18 years and older residing in the Obunga settlement, stratified by marital status**

| | **Overall** N (%) | **Married** N (%) | **Never married** N (%) | **Widowed** N (%) | **Separated/ Divorced** N (%) | **p-value** |
|---|---|---|---|---|---|---|
| **Enumerated women** | N = 5,668 | 3,603 (63.6) | 1,449 (25.6) | 399 (7.0) | 217 (3.8) | |
| **Age (years)** | | | | | | |
| 18 to 24 | 2,150 (37.9) | 1,128 (31.3) | 1,003 (69.2) | 3 (0.8) | 16 (7.4) | <0.0001 |
| 25 to 34 | 2,145 (37.8) | 1,615 (44.8) | 365 (25.2) | 53 (13.3) | 112 (51.6) | |
| 35 to 49 | 1,002 (17.7) | 710 (19.7) | 75 (5.2) | 147 (36.8) | 70 (32.3) | |
| 50+ | 371 (6.6) | 150 (4.2) | 6 (0.4) | 196 (49.1) | 19 (8.8) | |
| **Educational Attainment** | | | | | | |
| No school | 132 (2.3) | 50 (1.4) | 16 (1.1) | 61 (15.3) | 5 (2.3) | <0.0001 |
| Any primary | 2,612 (46.1) | 1,855 (51.5) | 374 (25.8) | 245 (61.4) | 138 (63.6) | |
| Any secondary | 2,335 (41.2) | 1,390 (38.6) | 810 (55.9) | 73 (18.3) | 62 (28.6) | |
| Tertiary/vocational | 413 (7.3) | 232 (6.4) | 166 (11.5) | 10 (2.5) | 5 (2.3) | |
| University/post-graduate | 151 (2.7) | 59 (1.6) | 83 (5.7) | 5 (1.2) | 4 (1.8) | |
| Unknown | 25 (0.4) | 17 (0.5) | 0 (0) | 5 (1.2) | 3 (1.4) | |
| **Occupation** | | | | | | |
| Unemployed | 1,287 (22.7) | 730 (20.3) | 438 (30.2) | 84 (21.0) | 35 (16.1) | <0.0001 |
| Shopkeeper/market vendor | 878 (15.5) | 624 (17.3) | 117 (8.1) | 89 (22.3) | 48 (22.1) | |
| Housewife | 814 (14.4) | 787 (21.8) | 11 (0.8) | 14 (3.5) | 2 (0.9) | |
| Student | 500 (8.8) | 31 (0.9) | 469 (32.4) | 0 (0) | 0 (0) | |
| Hotel/restaurant worker | 330 (5.8) | 200 (5.6) | 78 (5.4) | 32 (8.0) | 20 (9.2) | |
| Fishing/fishmonger | 182 (3.2) | 115 (3.2) | 12 (0.8) | 43 (10.8) | 12 (5.5) | |
| Household worker | 152 (2.7) | 82 (2.3) | 36 (2.5) | 19 (4.8) | 15 (6.9) | |
| Factory worker | 137 (2.4) | 77 (2.1) | 40 (2.8) | 7 (1.8) | 13 (6.0) | |
| Teacher | 129 (2.3) | 94 (2.6) | 29 (2.0) | 5 (1.2) | 1 (0.5) | |
| Farmer | 61 (1.1) | 43 (1.2) | 2 (0.1) | 15 (3.8) | 1 (0.5) | |
| Healthcare worker | 52 (0.9) | 30 (0.8) | 17 (1.2) | 5 (1.2) | 0 (0) | |
| Other | 1,139 (20.1) | 784 (21.8) | 199 (13.7) | 86 (21.6) | 70 (32.3) | |
| Disabled | 1 (0.02) | 0 (0) | 1 (0.1) | 0 (0) | 0 (0) | |
| Refused/unknown | 6 (0.1) | 6 (0.2) | 0 (0) | 0 (0) | 0 (0) | |
| **Lived outside the community in the previous 12 months** | | | | | | |
| Yes | 386 (6.8) | 212 (5.9) | 144 (9.9) | 15 (3.8) | 15 (6.9) | <0.0001 |
| No | 5,282 (93.2) | 3,391 (94.1) | 1,305 (90.1) | 384 (96.2) | 202 (93.1) | |

| | **Overall** N (%) | **Married** N (%) | **Never married** N (%) | **Widowed** N (%) | **Separated/ Divorced** N (%) | **p-value** |
|---|---|---|---|---|---|---|
| **Women who attended a CHC** | N = 4,245 | 2,831 (66.7) | 933 (22.0) | 317 (7.5) | 164 (3.9) | |
| **Number of sexual partners in the previous 3 months** | | | | | | |
| No partners | 781 (18.4) | 186 (6.67) | 305 (32.7) | 221 (69.7) | 69 (42.1) | <0.0001 |
| 1 partner | 3,346 (78.8) | 2,596 (91.7) | 573 (61.4) | 91 (28.7) | 86 (52.4) | |
| More than 1 partner | 118 (2.8) | 49 (1.7) | 55 (5.9) | 5 (1.6) | 9 (5.5) | |
| **Parity** - median (IQR) | 2 (1, 3) | 2 (1, 3) | 1 (0, 1) | 4 (2, 5) | 3 (2, 4) | <0.0001 |
| **Live birth in the previous 12 months** | | | | | | |
| Yes | 675 (15.9) | 567 (20.0) | 85 (9.1) | 6 (1.9) | 17 (10.4) | <0.0001 |
| No | 3,570 (84.1) | 2,264 (90.0) | 848 (90.9) | 311 (98.1) | 147 (89.6) | |
| **Currently pregnant** | | | | | | |
| Yes | 250 (5.9) | 218 (7.7) | 29 (3.1) | 3 (1.0) | 0 (0) | <0.0001 |
| No | 3,995 (94.1) | 2,613 (92.3) | 904 (96.9) | 314 (99.0) | 164 (100) | |
| **Ever Tested for HIV** | | | | | | |
| Yes | 3,708 (87.4) | 2,538 (89.6) | 780 (83.6) | 249 (78.6) | 141 (86.0) | <0.0001 |
| No/Refused/Un | 537 (12.6) | 293 (10.4) | 153 (16.4) | 68 (21.4) | 23 (14.0) | |
| **Months Since Last HIV Test** - median (IQR) | 4.4 (2.1, 14.0) | 4.3 (2.0, 13.7) | 4.4 (2.1, 12.4) | 13.3 (3.9, 46.1) | 7.9 (2.4, 35.1) | <0.0001 |
| **Most recent HIV test result** | | | | | | |
| Positive | 619 (16.7) | 400 (15.8) | 83 (10.6) | 94 (37.8) | 42 (29.8) | <0.0001 |

**Table 2 – Community health campaign outcomes, stratified by marital status**

| | **Married** N (%) | **Never Married** N (%) | **Widowed** N (%) | **Separated/ Divorced** N (%) | **p-value** |
|---|---|---|---|---|---|
| **CHC Attendance Outcome** | N=3,587 | N=1,444 | N=395 | N=216 | |
| Attended CHC | 2,831 (78.9) | 933 (64.6) | 317 (80.2) | 164 (75.9) | <0.0001 |
| Tracked - found client | 430 (12.0) | 274 (19.0) | 58 (14.7) | 26 (12.0) | |
| Tracked - found informant | 314 (8.8) | 223 (15.4) | 17 (4.3) | 25 (11.6) | |
| Tracked - could not locate | 1 (0.1) | 4 (0.3) | 0 (0) | 1 (0.5) | |
| Tracked - refused participation | 11 (0.3) | 10 (0.7) | 3 (0.8) | 0 (0) | |
| **Reason attended CHC** | | | | | |
| I am feeling sick, and I want to be tested | 1882 (70.5) | 542 (61.2) | 257 (85.4) | 124 (81.6) | <0.0001 |
| I am feeling well, and I want to stay healthy (or keep my family healthy) and be tested | 633 (23.7) | 273 (30.8) | 28 (9.3) | 22 (14.5) | |
| I heard about the lottery/prizes available here, and I hope to win a prize | 9 (0.3) | 2 (0.2) | 1 (0.3) | 1 (0.7) | |
| Someone told me or encouraged me to come | 66 (2.5) | 41 (4.6) | 7 (2.3) | 3 (2.0) | |
| I was interested in finding out what services are being offered | 78 (2.9) | 28 (3.2) | 8 (2.7) | 2 (1.3) | |
| **Who encouraged to attend CHC** | | | | | |
| Husband/wife | 197 (7.0) | 18 (1.9) | 6 (1.9) | 2 (1.2) | <0.0001 |
| Another family member | 425 (15.0) | 244 (26.2) | 30 (9.5) | 25 (15.2) | |
| Friend/neighbor | 823 (29.1) | 264 (28.3) | 101 (31.9) | 56 (34.2) | |
| Local councilor | 554 (19.6) | 177 (19.0) | 84 (26.5) | 28 (17.1) | |
| Religious leader | 45 (1.6) | 19 (2.0) | 6 (1.9) | 5 (3.0) | |
| Other (mobilizers, self) | 787 (27.8) | 211 (22.6) | 90 (28.4) | 48 (29.3) | |
| **Eligible for HIV testing at CHC** | 1964 (69.4) | 717 (76.8) | 184 (58.0) | 96 (58.5) | <0.0001 |
| **Accepted HIV testing at CHC** | 1877 (95.6) | 691 (96.4) | 173 (94.0) | 93 (96.9) | 0.48 |
| **Positive HIV test result during CHC** | 26 (1.4) | 14 (2.0) | 5 (3.0) | 5 (5.5) | 0.02 |

**Table 3a – Multivariable analysis of attendance at a community health campaign**

| | **Attended CHC** N (%) | **Did not attend** N (%) | **Adjusted odds ratio** (95% CI) | **p-value** |
|---|---|---|---|---|
| **Marital status** | N=4,231 | N=1,412 | | |
| Married | 2,823 (78.7) | 763 (21.3) | Ref | |
| Never-married | 933 (64.4) | 516 (35.6) | 0.54 (0.46, 0.62) | <0.0001 |
| Widowed | 313 (79.4) | 81 (20.6) | 0.90 (0.67, 1.22) | 0.5055 |
| Separated/divorced | 162 (75.7) | 52 (24.3) | 0.78 (0.56, 1.08) | 0.1296 |
| **Age (years)** | | | | |
| 18 to 24 | 1,527 (71.0) | 623 (30.0) | 0.86 (0.74, 1.00) | 0.0471 |
| 25 to 34 | 1,661 (77.6) | 478 (22.4) | Ref | |
| 35 to 49 | 742 (75.1) | 246 (24.9) | 0.81 (0.67, 0.97) | 0.0229 |
| 50+ | 301 (82.2) | 65 (17.8) | 1.16 (0.83, 1.62) | 0.3753 |
| **Educational Attainment** | | | | |
| No school | 107 (81.1) | 25 (18.9) | 0.97 (0.60, 1.55) | 0.8861 |
| Any primary | 2,081 (79.7) | 531 (20.3) | Ref | |
| Any secondary | 1,684 (72.1) | 651 (27.9) | 0.76 (0.66, 0.87) | <0.0001 |
| Tertiary/vocational | 255 (61.7) | 158 (38.3) | 0.47 (0.38, 0.59) | <0.0001 |
| University/post-graduate | 104 (68.9) | 47 (31.1) | 0.72 (0.50, 1.04) | 0.0784 |
| **Any outside migration in the past year** | | | | |
| No | 3,909 (74.3) | 1,349 (25.7) | Ref | |
| Yes | 322 (83.6) | 63 (16.4) | 2.02 (1.52, 2.68) | <0.0001 |

**Table 3b – Multivariable analysis of reason for attending a community health campaign**

| | **Feeling unwell*** N (%) | **To stay healthy** N (%) | **Adjusted odds ratio** (95% CI) | **p-value** |
|---|---|---|---|---|
| **Marital status** | N=2,796 | N=1,198 | | |
| Married | 1878 (70.6) | 782 (29.4) | Ref | |
| Never-married | 542 (61.2) | 344 (38.8) | 0.84 (0.70, 1.02) | 0.0771 |
| Widowed | 254 (85.2) | 44 (14.8) | 1.46 (0.98, 2.15) | 0.0600 |
| Separated/divorced | 122 (81.3) | 28 (18.7) | 1.56 (1.01, 2.40) | 0.0455 |
| **Age (years)** | | | | |
| 18 to 24 | 910 (63.0) | 535 (37.0) | 0.90 (0.76, 1.06) | 0.2075 |
| 25 to 34 | 1085 (69.4) | 479 (30.6) | Ref | |
| 35 to 49 | 552 (78.7) | 149 (21.3) | 1.41 (1.13, 1.76) | 0.0025 |
| 50+ | 249 (87.7) | 35 (12.3) | 2.65 (1.72, 4.08) | <0.0001 |
| **Educational Attainment** | | | | |
| No school | 84 (85.7) | 14 (14.3) | 1.48 (0.81, 2.72) | 0.2047 |
| Any primary | 1460 (73.7) | 522 (26.3) | Ref | |
| Any secondary | 1044 (66.3) | 530 (33.7) | 0.84 (0.72, 0.98) | 0.0247 |
| Tertiary/vocational | 140 (58.3) | 100 (41.7) | 0.61 (0.46, 0.81) | 0.0006 |
| University/post-graduate | 68 (68.0) | 32 (32.0) | 0.98 (0.63, 1.53) | 0.9302 |
| **Parity** - median (IQR) | 2 (1, 3) | 2 (1, 3) | 1.04 (1.01, 1.07) | 0.0045 |
| **Live birth in the previous 12 months** | | | | |
| No | 2397 (71.1) | 976 (28.9) | Ref | |
| Yes | 399 (64.2) | 222 (35.8) | 0.77 (0.64, 0.94) | 0.0078 |
| **Number of sexual partners** | | | | |
| No partners | 509 (69.6) | 222 (30.4) | Ref | |
| 1 partner | 2206 (69.9) | 948 (30.1) | 1.13 (0.89, 1.44) | 0.3199 |
| 2+ partners | 81 (74.3) | 28 (25.7) | 1.46 (0.90, 2.38) | 0.1242 |

* Reason for CHC attendance missing for 237 women

**Table 3c – Multivariable analysis of HIV test result at a community health campaign**

| | **Positive test result** N (%) | **Negative test result** N (%) | **Adjusted odds ratio** (95% CI) | **p-value** |
|---|---|---|---|---|
| **Marital status** | N = 50 | N = 2,769 | | |
| Married | 26 (1.4) | 1,842 (98.6) | Ref | |
| Never-married | 14 (2.0) | 677 (98.0) | 1.59 (0.83, 3.06) | 0.1618 |
| Widowed | 5 (3.0) | 164 (97.0) | 2.58 (1.00, 6.66) | 0.0491 |
| Separated/divorced | 5 (5.5) | 86 (94.5) | 4.92 (1.88, 12.83) | 0.0011 |
| **Currently pregnant** | | | | |
| No | 45 (1.7) | 2,637 (98.3) | Ref | |
| Yes | 5 (3.6) | 132 (96.4) | 3.02 (1.20, 7.63) | 0.0190 |

## 3.8. Supplemental Material

**Supplemental Table 1 – Characteristics of community health campaign attendees, by enumeration source**

| | **Claimed to be a resident** N (%) | **Enumerated** N (%) | **p-value** |
|---|---|---|---|
| **Marital Status** | N=1,309 | N=2,936 | |
| Married | 795 (60.7) | 2,036 (69.4) | <0.0001 |
| Never-married | 349 (26.7) | 584 (19.9) | |
| Widowed | 98 (7.5) | 219 (7.5) | |
| Separated/divorced | 67 (5.1) | 97 (3.3) | |
| **Age (years)** | | | |
| 18 to 24 | 509 (38.9) | 1,018 (34.7) | 0.003 |
| 25 to 34 | 459 (35.1) | 1,206 (41.1) | |
| 35 to 49 | 242 (18.5) | 508 (17.3) | |
| 50+ | 99 (7.6) | 204 (7.0) | |
| **Educational Attainment** | | | |
| No school | 42 (3.2) | 65 (2.2) | <0.0001 |
| Any primary | 630 (48.1) | 1,451 (49.4) | |
| Any secondary | 473 (36.1) | 1,211 (41.2) | |
| Tertiary/vocational | 95 (7.3) | 160 (5.4) | |
| University/post-graduate | 67 (5.1) | 37 (1.3) | |
| Unknown | 2 (0.2) | 12 (0.4) | |
| **Employed** | | | |
| Yes | 945 (72.2) | 2,311 (78.8) | <0.0001 |
| No | 363 (27.8) | 622 (21.2) | |
| **Lived outside the community in the previous 12 months** | | | |
| Yes | 241 (18.4) | 81 (2.8) | <0.0001 |
| No | 1,068 (81.6) | 2,855 (97.2) | |

## IV. CONCLUSION

Despite heartening progress toward the UNAIDS 90% HIV testing targets, key populations in Kenya continue to lag in their testing coverage. Pediatric HIV infection remains a significant global concern, and the prevalence of undiagnosed HIV infection in sub-Saharan Africa is substantially higher in children and adolescents than in adults. Men have consistently lagged in HIV testing coverage. People living in informal urban settlements reside at the confluence of a number of risk factors for HIV acquisition, including poverty and high rates of migration. Kenyan widows are at significantly heightened risk of HIV infection due to culturally proscribed social and economic marginalization. Effective strategies are needed to continue progress toward the new and more ambitious 2030 95% target and to equitably work toward control of the HIV epidemic. In this dissertation, I sought to synthesize the existing research on efforts aimed at engaging these key populations (youth, men, residents of informal urban settlement, and vulnerable women) in HIV testing and to assess the impacts of a variety of interventions designed to close these testing gaps.

The first chapter examined whether activities implemented under the Accelerating Children's HIV/AIDS Treatment (ACT) initiative in 130 health care facilities in western Kenya increased testing and identification of youth living with HIV (YLWH). Despite numerous strategies in place to reach infants, children, and adolescents in this high HIV-prevalence region, many youth do not receive the HIV testing recommended by national guidelines. Evidence-based interventions are urgently needed to increase access to HIV testing in order to avoid preventable morbidity and mortality among youth in this region. We found that pediatric HIV testing and identification of YLWH increased significantly during the ACT initiative period. Family-centered strategies, text-messaging, and outreach activities were all found to be effective at increasing HIV testing and identification among youth. Sustained funding and targeted implementation of these successful interventions is imperative to continue to close the HIV testing gap among infants, children, and adolescents, and to prevent HIV-related morbidity and mortality. Additional research is needed to determine the effects of the ACT initiative on the downstream outcomes along the HIV cascade of care, including linkage to care, retention on antiretroviral therapy, and sustained viral suppression.

The second chapter presents the results from the multi-disease Community Health Initiative, the first urban application of a community-based, hybrid HIV testing campaign, which took place in the Obunga informal settlement in Kisumu, Kenya in 2018. Residents of informal urban settlements are at increased risk for HIV infection, delayed HIV testing and entry to care, and poorer clinical outcomes. We reached a total of 23,584 persons and achieved a 97% acceptance rate for HIV testing, including 3,917 first-time testers. We newly-identified 101 people with HIV (PWH). In this analysis, we introduced the previously-unidentified fraction (PUF), which is the proportion of newly-identified PWH out of all previously-identified and newly-identified PWH. This new metric is a useful way to quantify the testing gap in different groups. We calculated the PUF to be highest in this population among men and youth. Innovative approaches that make HIV testing more accessible and acceptable, particularly among men and youth, are critical for achieving community testing and treatment saturation. Engaging groups who have historically lagged in their testing coverage is essential to reaching and exceeding the UNAIDS 90% testing

target. Government agencies, national ministries of health, and public health programs can use the PUF to assess and compare the impact of different HIV testing services strategies to identify PLWH who are unaware of their HIV serostatus.

In chapter three, using data from the Community Health Initiative (CHI), I assessed the characteristics of women living in the Obunga settlement. I sought to develop a deeper understanding of women's patterns of accessing HIV testing, as well as how these behaviors differ by marital status, with a focus on widowed women. Because Kenyan widows are socially and economically marginalized by cultural practices such as widow cleansing, widow inheritance, and asset stripping, they are at significantly heightened risk of HIV infection, as well as of migration to urban areas. Indeed, we found that the Obunga settlement had a higher proportion of widows than the general Kenyan population, and that these women had an exceptionally high prevalence of HIV infection. Yet, among women who attended one of our community health campaigns, widows were least likely to report ever having been tested for HIV. Widows were also more likely to report attending a community health campaign due to poor health and had significantly higher HIV test yield, compared to married women. CHI successfully engaged widows in HIV testing and identified previously-undiagnosed widows living with HIV. We also successfully reached separated/divorced women, who had the highest HIV test yield in this population. The hybrid, community-based HIV testing approach is an important tool that can be used to increase HIV testing, particularly among impoverished populations such as those living in informal settlements, to ensure health equity among key populations, including vulnerable women, as countries continue their progress toward the UNAIDS testing targets.

As countries continue to work toward HIV epidemic control, in particular to reach the 5 to 10% of the population that has not yet been reached by HIV testing and treatment efforts, it will be important to consider targeted strategies for engaging key populations. While the overall scope and cost of the ACT and CHI initiatives may be prohibitive for local governments to replicate on the same scale, the success of these strategies in reaching key, underserved populations warrants consideration regarding how to apply the findings from these analyses to create targeted strategies to continue to close these testing gaps on a continued basis.

**Proposed future work**

Qualitative research on the barriers to and facilitators of health and health care access among women and widows in East Africa reinforces and elaborates on the themes identified in chapter three. Widows describe that they must balance the desire to limit their risk of HIV infection against cultural expectations and meeting their livelihood needs.[76] The social structural theory of gender and power addresses power imbalances that derive from gender and sexual inequality.[84] Applied in the context of HIV, power imbalances in male-female relationships heighten women's risk of acquiring HIV.[85] Given the high prevalence and incidence of HIV infection among widows in Kenya and their extreme cultural and economic marginalization, additional research is needed to elucidate their HIV and health care needs, particularly in the context of informal urban settlements where widows live at the confluence of poverty and HIV risk. In a follow-up to chapter three, I have designed and implemented a qualitative study among women living in the Obunga settlement. Using a Social Ecological Model approach, I conducted semi-

structured, key informant interviews with a purposeful sample of female CHI clients who either attended or did not attend a CHC. The Social Ecological Model describes five levels of influence on behavior: individual, interpersonal, institutional, community, and policy. These levels may combine to influence HIV transmission patterns within the context of preventing new HIV infections. The key informant interviews will provide a detailed examination of individual and interpersonal factors and cultural barriers and facilitators that led to the decision to attend or not attend a CHC and that contribute to a broader pattern of accessing health/HIV care services. In my next steps, I will work with local research assistants to code and analyze the data from the key informant interviews. Findings from this analysis could help guide the development and further assessment of targeted HIV services to reach widows and other vulnerable women living in informal urban settlements.

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