Community-wide HIV testing, linkage case management, and defaulter tracing in Bukoba, Tanzania: pre-intervention and post-intervention, population-based survey evaluation

Claire Steiner, Duncan MacKellar*, Haddi Jatou Cham, Oscar Ernest Rwabiyago, Haruka Maruyama, Omari Msumi, Sherri Pals, Rachel Weber, Gerald Kundi, Johnita Byrd, Kokuhumbya Kazaura, Caitlin Madevu-Matson, Fernando Morales†, Jessica Justman, Thomas Rutachunzibwa, Anath Rwebembera*

Summary

Background Community randomised trials have had mixed success in implementing combination prevention strategies that diagnose 90% of people living with HIV, initiate and retain on antiretroviral therapy (ART) 90% of those diagnosed, and achieve viral load suppression in 90% of those on ART (90-90-90). The Bukoba Combination Prevention Evaluation (BCPE) aimed to achieve 90-90-90 in Bukoba Municipal Council, Tanzania, by scaling up new HIV testing, linkage, and retention interventions.

Method We did population-based, cross-sectional surveys before and after our community-wide intervention in Bukoba—a mixed urban and rural council of approximately 150 000 residents located on the western shore of Lake Victoria in Tanzania. BCPE interventions were implemented in 11 government-supported health-care facilities throughout Bukoba from Oct 1, 2014, to March 31, 2017, when national ART-eligibility guidelines expanded from CD4 counts of less than 350 cells per µL (Oct 1, 2014–Dec 31, 2015) and 500 or less cells per µL (Jan 1, 2016–Sept 30, 2016) to any CD4 cell count (test and treat, Oct 1, 2016–March 31, 2017). We used pre-intervention (Nov 4, 2013–Jan 25, 2014) and post-intervention (June 21, 2017–Sept 20, 2017) population-based household surveys to assess population prevalence of undiagnosed HIV infection and ART coverage, and progress towards 90-90-90, among residents aged 18–49 years.

Findings During the 2·5-year intervention, BCPE did 133 695 HIV tests, diagnosed and linked 3918 people living with HIV to HIV care at 11 Bukoba facilities, and returned to HIV care 604 patients who had stopped care. 4795 and 5067 residents aged 18–49 years participated in pre-intervention and post-intervention surveys. HIV prevalence before and after the intervention was similar: pre-intervention 8·9% (95% CI 7·5–10·4); post-intervention 8·4% (6·9–9·9). Prevalence of undiagnosed HIV infection decreased from 4·7% to 2·0% (prevalence ratio 0·42, 95% CI 0·31–0·57), and current ART use among all people living with HIV increased from 32·2% to 70·9% (2·20, 1·82–2·66) overall, 23·0% to 62·1% among men (2·70, 1·84–3·96), and 16·7% to 64·4% among people aged 18–29 years (3·87, 2·54–5·89). Of 436 and 435 people living with HIV aged 18–49 years who participated in pre-intervention and post-intervention surveys, previous HIV diagnosis increased from 47·4% (41·3–53·4) to 76·2% (71·8–80·6), ART use among diagnosed people living with HIV increased from 68·0% (60·9–75·2) to 93·1% (90·2–96·0), and viral load suppression of those on ART increased from 88·7% (83·6–93·8) to 91·3% (88·6–94·1).

Interpretation BCPE findings suggest scaling up recommended HIV testing, linkage, and retention interventions can help reduce prevalence of undiagnosed HIV infection, increase ART use among all people living with HIV, and make substantial progress towards achieving 90-90-90 in a relatively short period. BCPE facility-based testing and linkage interventions are undergoing national scale up to help achieve 90-90-90 in Tanzania.

Funding US Presidents' Emergency Plan for AIDS Relief.

Introduction

To achieve HIV epidemic control, UNAIDS set targets for countries to diagnose 90% of people living with HIV, initiate and retain on antiretroviral therapy (ART) 90% of those diagnosed, and achieve viral load suppression for 90% of those on ART (90-90-90) by 2020.[1] To help optimise the clinical benefit of ART and potential for epidemic control, WHO recommends that ART should be initiated for all people living with HIV without contraindications within 7 days of diagnosis.[2,3]

In sub-Saharan Africa, Tanzania has an estimated 1·4 million adults living with HIV, of whom only 61% had been diagnosed, 57% were using ART, and 52% were virally suppressed in 2017.[4] ART coverage among HIV-infected men (47%) and people aged 15–24 years (46%) in Tanzania is particularly low, attributed primarily to lower access to or uptake of HIV testing services compared with women and older people.[4–6] Thus, to substantially reduce the estimated 81 000 annual HIV infections in Tanzania, age and sex disparities must be

Lancet HIV 2020

Published Online
September 1, 2020
https://doi.org/10.1016/S2352-3018(20)30199-5

See Online/Comment
https://doi.org/10.1016/S2352-3018(20)30235-6

*Contributed equally

†Dr Morales died in May, 2020

ICAP at Columbia University, New York, NY, USA (C Steiner MBBS, C Madevu-Matson MPH, J Justman MD); **Division of Global HIV and TB, National Center for Global Health, US Centers for Disease Control and Prevention, Atlanta, GA, USA** (D MacKellar DrPH, H J Cham MPH, S Pals PhD); **US Centers for Disease Control and Prevention, Dar es Salaam, Tanzania** (O E Rwabiyago MD, K Kazaura DDS); **ICAP at Columbia University, Maseru, Lesotho** (H Maruyama MPH, O Msumi MD, G Kundi BA, F Morales MD); **US Centers for Disease Control and Prevention, Harare, Zimbabwe** (R Weber PhD); **ICF International, Atlanta, GA, USA** (J Byrd MPH); **Ministry of Health, Community Development, Gender, Elderly and Children, Bukoba, Tanzania** (T Rutachunzibwa MD); **and National AIDS Control Program, Ministry of Health, Community Development, Gender, Elderly and Children, Dodoma, Tanzania** (A Rwebembera MMED)

Correspondence to:
Dr Claire Steiner, ICAP at Columbia University, New York, NY 10032, USA
cs3324@cumc.columbia.edu

Research in context

Evidence before this study

On Jan 15, 2019, we searched PubMed for studies that assessed the impact of universal HIV testing and antiretroviral therapy (ART; test and treat) on HIV incidence in sub-Saharan Africa. We used search terms "HIV" AND "incidence" AND "test and treat" AND "community randomized" AND "Africa" in English. We found four community randomised, test and treat trials conducted in Kenya and Uganda (SEARCH), South Africa (TasP), Zambia and South Africa (PopART), and Botswana (BCCP). All trials were conducted for approximately 3 years and included comprehensive repeat community-based HIV testing, referral and linkage services, and ART for all people living with HIV in intervention communities. To evaluate incidence, SEARCH studied 95 083 residents from 32 rural communities in Kenya and Uganda; TasP studied 14 223 residents in 22 communities in rural KwaZulu-Natal, South Africa; PopART studied 48 301 residents of 12 periurban communities in Zambia and nine communities in Western Cape Province, South Africa; and BCCP studied 8974 residents of 30 rural or periurban communities in Botswana. By the end of the study in intervention communities, more than 90% of all people with HIV had been diagnosed, 58–97% of those diagnosed were on ART, and 46–88% of all people with HIV had achieved viral load suppression. Compared with study control arms, HIV incidence was significantly lower by approximately 30% in two of five intervention arms of the four trials. Mixed results from the universal test and treat trials have been attributed to multiple factors including increased ART access in control communities and delay (or failure) in reaching ART coverage targets in intervention communities. Notably, only 48–65% and 63–73% of people with HIV linked to care within 6 and 12 months of diagnosis, respectively, in three of the four trials (TasP, PopART, and SEARCH), underscoring the need for new prevention interventions to optimise test and treat.

Added value of this study

Implemented during a period of expanding national ART policies, the Bukoba Combination Prevention Evaluation (BCPE) aimed to achieve more than 80% ART coverage of all residents with HIV aged 18–49 years in Bukoba Municipal Council, a mixed urban and rural council in Tanzania with approximately 150 000 residents. BCPE is the first study in Tanzania to assess the scale-up of a comprehensive package of services that included facility and community-based HIV testing, peer-delivered linkage case management, and defaulter tracing. We demonstrate that our combination prevention intervention helped to substantially reduce prevalence of undiagnosed HIV infection, and as national treatment guidelines expanded access to ART, helped to substantially increase ART coverage and reduce considerable sex and age-group ART disparities.

Implications of all the available evidence

BCPE testing, linkage, and defaulter tracing interventions are promising strategies that can help strengthen test and treat to achieve epidemic control. In 2017, BCPE facility-based testing and linkage case-management interventions were approved by the Tanzania Ministry of Health, Community Development, Gender, Elderly and Children as new service delivery models. In 2019, these interventions were implemented by four HIV prevention organisations and scaled up in all regions of Tanzania.

reduced to help achieve 81% (90%×90%) or greater ART coverage for all people living with HIV.[1,4]

Several experimental combination prevention trials in sub-Saharan Africa that aimed to achieve 81% or greater ART coverage among all people living with HIV have had mixed success.[7–11] Three of the four studies relied primarily on community-based testing, referral, and universal ART initiation without comprehensive linkage or defaulter tracing services.[7–10] No combination prevention studies in Tanzania or elsewhere have evaluated whether implementation of facility-based and community-based testing, combined with comprehensive linkage and defaulter tracing services can achieve 81% or greater ART coverage in a community under non-experimental conditions.

Implemented during a period of expanding national ART policies, the Bukoba Combination Prevention Evaluation (BCPE) aimed to achieve 90-90-90 among all residents living with HIV aged 18–49 years in Bukoba Municipal Council (Bukoba) through a community-wide HIV testing, linkage, and defaulter tracing combination prevention intervention. Here, we describe pre-intervention and post-intervention differences in population prevalence of undiagnosed HIV infection and ART coverage among all people living with HIV, diagnostic-associated and ART-associated sociodemographic disparities, particularly among men and young adults, and progress towards 90-90-90.

Methods

Study design and participants

We did population-based, cross-sectional surveys in Bukoba before and after our community-wide intervention to assess changes in prevalence of undiagnosed HIV infection and progress towards 90-90-90. As the capital of Kagera region on the western shore of Lake Victoria, Bukoba is a mixed urban-rural council with approximately 150 000 residents (figure 1). Excluding military and police facilities, all 11 government-supported health-care facilities in Bukoba participated in BCPE, including eight public facilities (one regional referral hospital, two health centres, five dispensaries), and three faith-based health centres (figure 1).

HIV testing, linkage, and defaulter-tracing interventions were implemented throughout Bukoba over 2·5 years (Oct 1, 2014–March 31, 2017) when national

guidelines for ART eligibility expanded from CD4 counts of less than 350 cells per µL (Oct 1, 2014–Dec 31, 2015) and 500 or less cells per µL (Jan 1, 2016–Sept 30, 2016) to any CD4 cell count (test and treat, Oct 1, 2016–March 31, 2017). Beginning Dec 1, 2015, eligible patients ready to begin treatment were initiated on ART at their first clinic visit (same-day ART). Beginning Nov 1, 2016, same-day ART was also offered to all people living with HIV at the point of diagnosis during community-based testing events.

Institutional review boards of the Government of Tanzania, National Institute for Medical Research, and Columbia University approved BCPE testing, linkage, and defaulter tracing interventions, and all survey methods and data collection activities. The study was also reviewed and approved in accordance with US Centers for Disease Control and Prevention (CDC) human participants research protection procedures. Research staff obtained written informed consent from pre-intervention and post-intervention survey participants. All identified people living with HIV who enrolled and remained in HIV care were provided ART when they became eligible, according to national guidelines.

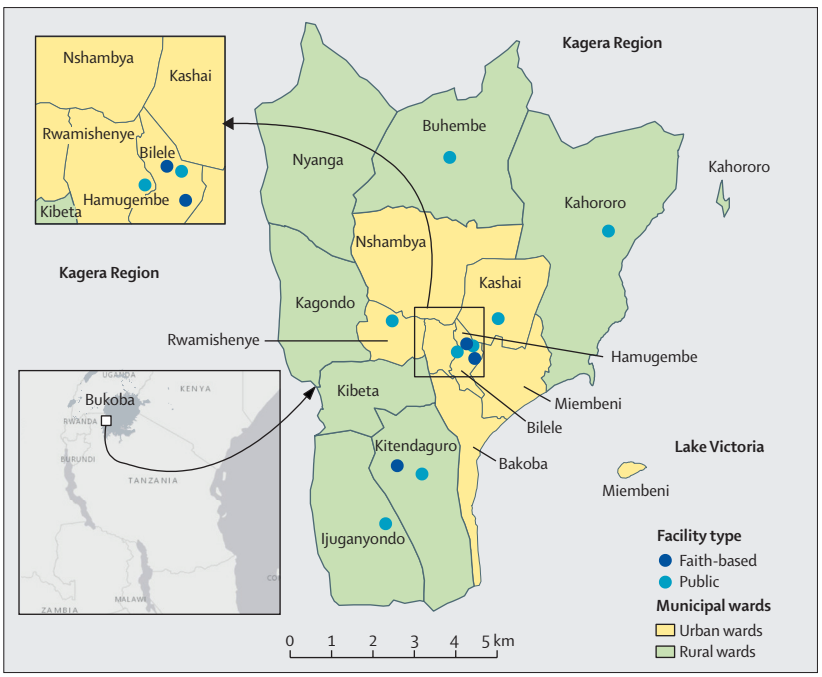

Figure 1: **Bukoba Municipal Council wards and participating health-care facilities**
Estimated population in 2017 approximately 150 000. Councils are designated by the Tanzania National Bureau of Statistics as districts, municipalities, or towns.

Procedures

Methods, outcomes, and costs of BCPE HIV testing and linkage interventions have been previously described in detail.[12,13] HIV testing was offered to all eligible patients attending outpatient department clinics in the 11 participating facilities. Testing was also offered at all occupied homes at least once and at 79 male-frequented venues throughout Bukoba.[12] Peer-delivered, linkage case management was routinely offered to all diagnosed people living with HIV who were referred to participating facilities.[13] As part of linkage case management, HIV-positive peer counsellors provided a comprehensive package of services recommended by the CDC and WHO for up to 90 days for all consenting people living with HIV.[3,13,14] Defaulter tracing was implemented July 1, 2016–May 31, 2017, for patients who had defaulted from care since Oct 1, 2014. Electronic medical records were queried quarterly to identify patients who had not received care within 90 days. Lay counsellors did defaulter tracing for up to 30 days via phone and home visits. Patients who were contacted and wished to return to care received treatment navigation, expedited care, and same-day ART services. Patients who were not contacted or refused services once were re-traced in a subsequent quarter to ensure all reasonable efforts were made to help patients restart care.

We did identical pre-intervention and post-intervention single-stage cluster sample surveys from Nov 4, 2013, to Jan 25, 2014, and from June 21, to Sept 20, 2017, respectively. Survey sample sizes were estimated based on Fisher's exact test for expected differences between two independent sample proportions. In Bukoba census enumeration areas randomly selected in proportion to ward population, all consenting household members aged 18–49 years were eligible to participate in a computer-assisted personal interview and test for HIV.

Staff did interviews in Kiswhali or English on socio-demographic characteristics, previous HIV testing and diagnosis, and use of ART. Nurse counsellors did HIV testing in accordance with national guidelines after the interview. Blood specimens from HIV-positive participants were sent to the national laboratory in Dar es Salaam, Tanzania, for viral quantification using the COBAS TaqMan HIV-1 test (Roche Molecular Systems, Branchburg, NJ, USA).

Outcomes

For the intervention, staff recorded testing, linkage, and defaulter tracing outcomes on standard forms. For linkage clients, enrolment in HIV care and ART initiation were measured during the 90-day case management period.[13] Staff compiled outcomes monthly, by sex and age group. For the evaluation, classification of previous HIV diagnosis and current ART use among HIV-positive survey participants was based on: interview self-report of these conditions, medical record confirmation, or having achieved viral load suppression (<1000 HIV RNA copies per mL). Undiagnosed HIV infection among HIV-positive participants was defined as not having received a previous diagnosis.

Statistical analysis

We compared characteristics of study participants in pre-intervention and post-intervention surveys using

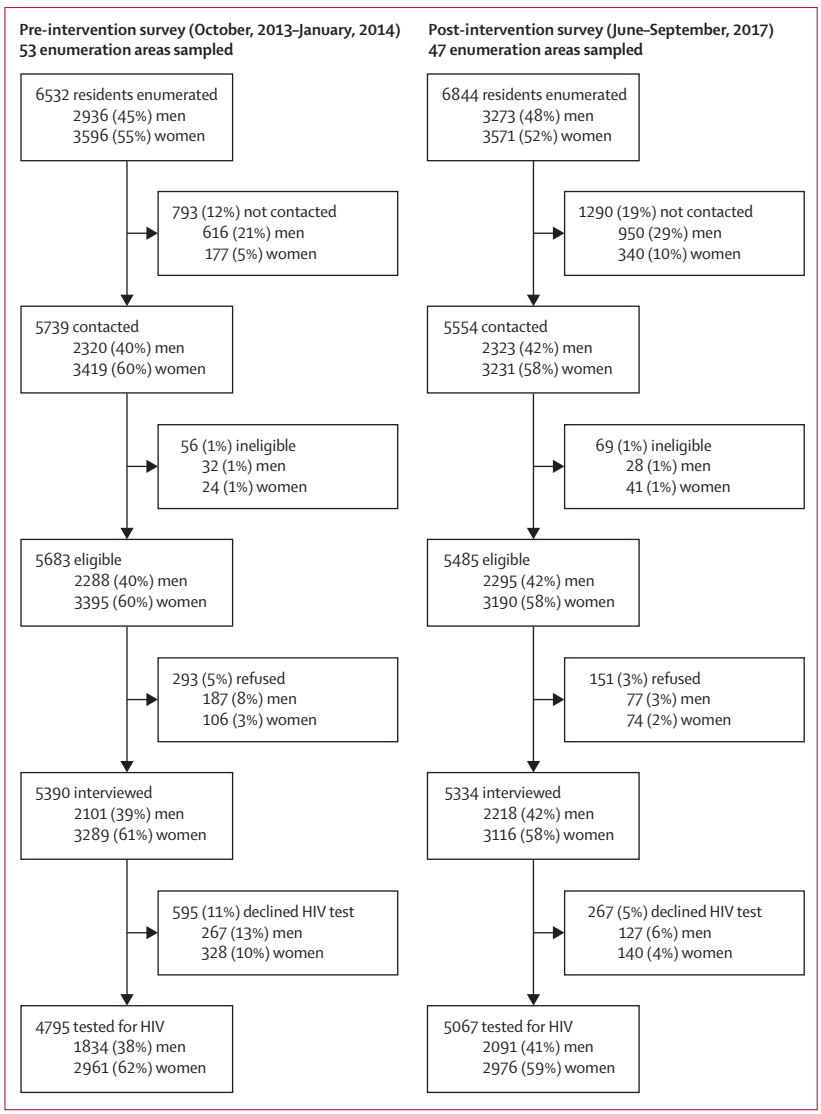

Figure 2: **Pre-intervention and post-intervention household survey participation cascades, 2014–17**

Rao-Scott χ^2 tests, incorporating survey weights and adjusting for clustering within enumeration areas. Population prevalence of undiagnosed HIV infection, previous HIV diagnosis, and ART use among people living with HIV before and after the intervention used Taylor series linearisation variance estimation to account for clustering within enumeration areas. Prevalence ratios (PRs) and adjusted prevalence ratios (APRs) were estimated using generalised estimating equations models with a log link and empirical sandwich standard errors to account for clustering within enumeration areas. For both surveys, we divided participants and census data into cells defined by four age groups, sex, and three geographical areas, and computed weights by dividing the percentage of census participants in each cell by the percentage of survey participants. We incorporated weights into all statistical tests and models to address under-coverage of the sample and survey non-response related to age, sex, and geographical area. SAS version 9.3 was used for all analyses; pre-intervention and post-intervention population prevalence of HIV infection, undiagnosed HIV infection, and current ART use was estimated with SURVEYFREQ, and intrasurvey and intersurvey PRs and APRs were estimated with GENMOD.

Role of the funding source

Authors from CDC contributed to the study design, selection of settings investigated, strategies assessed, conduct of the analyses, and interpretation of results. ICF supported the salary for JB and had no role in study design, data collection and analysis, or manuscript development. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Between Oct 1, 2014, and March 31, 2017, 133 695 HIV tests were done, 56 304 (42%) among men and 43 247 (32%) among young adults aged 15–24 years. Of 4732 people who had tested HIV-positive and were not in care (4143 newly diagnosed), 1822 (1583 newly diagnosed) were men, and 993 (881 newly diagnosed) were young adults aged 15–24 years. Of 4206 linkage clients who participated during CD4 counts of less than 350 cells per µL (n=2233), 500 or less cells per µL (n=1221), and test-and-treat (n=752) periods, 2018 (90%), 1168 (96%), and 732 (97%) enrolled in HIV care, of whom 1057 (52%), 815 (70%), and 649 (89%) initiated ART within 90 days of diagnosis, respectively. Excluding patients who upon tracing were found to have moved (n=504), transferred HIV care (n=300), or died (n=172), of 1650 patients who defaulted from care, 820 (50%) were contacted and received defaulter tracing services, of whom 604 (74%) returned to care and 573 (70%) initiated or re-initiated ART; the remaining 830 patients were lost to follow-up.

In pre-intervention and post-intervention surveys, 4795 (73%) of 6532 and 5067 (74%) of 6844 enumerated household residents aged 15–49 years were interviewed and tested for HIV, respectively. In both surveys, proportionally fewer men than women participated due to challenges contacting men for enrolment (figure 2). Proportionally more post-intervention than pre-intervention survey participants reported at least some secondary-level education, being employed, owning a mobile phone or television, difficulty meeting household food needs, never using alcohol, engaging in unprotected sexual intercourse in the last 6 months, and testing for HIV in the past 2 years (table 1).

Overall prevalence of HIV infection was similar between pre-intervention and post-intervention surveys (table 1). In both surveys, prevalence of HIV infection was higher among women than men, and residents aged 40–49 and 30–39 years than residents aged 18–29 years (figure 3).

	Pre-intervention survey (November, 2013–January, 2014)			Post-intervention survey (June, 2017–September, 2017)			p value*
	n	Unweighted %	Weighted† % (95% CI)	n	Unweighted %	Weighted† % (95% CI)	
Total	4795	100%	100%	5067	100%	100%	..
Sex							
Male	1834	38·25%	49·04% (47·02–51·07)	2091	41·27%	49·04% (47·27–50·81)	..
Female	2961	61·75%	50·96% (48·93–52·98)	2976	58·73%	50·96% (49·19–52·73)	..
Age group (years)							
18–29	2749	57·33%	54·39% (52·07–56·71)	2832	55·89%	54·39% (51·94–56·84)	..
30–39	1385	28·88%	30·40% (28·51–32·30)	1461	28·83%	30·41% (28·51–32·30)	..
40–49	661	13·79%	15·21% (13·79–16·62)	774	15·28%	15·20% (13·72–16·69)	..
Residence							
Urban	3791	79·06%	75·58% (61·66–89·50)	3724	73·50%	75·58% (60·83–90·33)	..
Rural	1004	20·94%	24·42% (10·50–38·34)	1343	26·50%	24·42% (9·67–39·17)	..
Duration of current home residence (years)	..	..	..	..	..	..	0·33
<1	1559	32·51%	31·34% (28·75–33·94)	1519	29·98%	29·66% (27·08–32·23)	..
1–2	1059	22·09%	22·14% (19·96–24·33)	1226	24·20%	24·43% (22·93–25·93)	..
>2	2177	45·40%	46·52% (42·74–50·29)	2322	45·83%	45·91% (42·86–48·97)	..
Highest level of education completed‡	..	..	..	..	..	..	0·0092
None or some primary	556	11·60%	11·92% (9·11–14·73)	532	10·50%	10·77% (9·10–12·46)	..
Completed primary	2596	54·17%	54·54% (51·66–57·42)	2546	50·27%	49·55% (46·50–52·59)	..
At least some secondary	1640	34·22%	33·54% (30·05–37·03)	1987	39·23%	39·68% (35·60–43·75)	..
Employed	..	..	..	..	..	..	0·021
No	983	20·50%	17·45% (15·05–19·84)	767	15·14%	14·08% (12·16–15·99)	..
Yes	3812	79·50%	82·55% (80·16–84·95)	4300	84·86%	85·92% (84·01–87·84)	..
Ownership of mobile phone or television	..	..	..	..	..	..	0·0002
No	364	7·59%	8·04% (5·49–10·59)	209	4·12%	4·42% (3·03–5·81)	..
Yes	4431	92·41%	91·96% (89·41–94·51)	4858	95·88%	95·58% (94·19–96·97)	..
Trouble satisfying household food needs	..	..	..	..	..	..	<0·0001
Never	2707	56·64%	56·01% (50·49–61·52)	2285	45·34%	45·93% (40·30–51·57)	..
Seldom	1822	38·13%	38·69% (33·35–44·02)	2118	42·02%	41·20% (36·25–45·15)	..
Sometimes, often, or always	250	5·23%	5·31% (4·12–6·49)	637	12·64%	12·86% (9·56–16·17)	..
Frequency of alcohol use§	..	..	..	..	..	..	0·0005
Never	2971	62·03%	58·97% (55·03–62·90)	3376	66·65%	65·14% (62·04–68·24)	..
Monthly	985	20·56%	20·78% (18·80–22·77)	1044	20·61%	20·93% (18·55–23·29)	..
Weekly or daily	834	17·41%	20·25% (17·25–23·26)	645	12·73%	13·93% (11·33–16·54)	..
Sexual behaviour in the past 6 months¶	..	..	..	..	..	..	0·040
Protected intercourse	1122	23·40%	22·85% (21·07–24·63)	1067	21·06%	20·83% (19·40–22·27)	..
Unprotected intercourse	3019	62·96%	63·76% (61·59–65·94)	3380	66·71%	67·25% (65·10–69·40)	..
No sexual partners	654	13·64%	13·39% (12·16–14·61)	620	12·24%	11·92% (10·24–13·60)	..
Last tested for HIV in past 2 years‖	..	..	..	..	..	..	<0·0001
No	1957	40·82%	41·89% (39·51–44·27)	1091	21·53%	21·46% (19·85–23·07)	..
Yes	2837	59·18%	58·11% (55·73–60·49)	3976	78·47%	78·54% (76·93–80·15)	..
HIV infected	..	..	..	..	..	..	0·48
No	4359	90·91%	91·07% (89·63–92·51)	4632	91·42%	91·63% (90·14–93·11)	..
Yes	436	9·09%	8·93% (7·49–10·37)	435	8·58%	8·37% (6·89–9·86)	..

*Rao-Scott χ^2 test for differences in pre-intervention and post-intervention prevalence estimates; not reported for variables used for census-based weights. †All estimates were census weighted by sex, age group, and residence, and adjusted for clustering within census enumeration areas. ‡Pre-intervention, 3 participants did not respond; post-intervention, 2 did not respond. §Pre-intervention, 5 participants did not respond; post-intervention, 2 did not respond. ¶Unprotected indicates condom use for <100% of sexual-intercourse acts; protected indicates condom use for 100% of sexual-intercourse acts. ‖Pre-intervention, 1 participant did not respond.

Table 1: **Pre-intervention and post-intervention household survey participant characteristics**

In 2017, post-intervention prevalence of previously diagnosed HIV infection across each demographic subgroup was greater than undiagnosed infection in each subgroup (figure 3).

By 2017, prevalence of undiagnosed HIV infection decreased by approximately half overall, and at least by

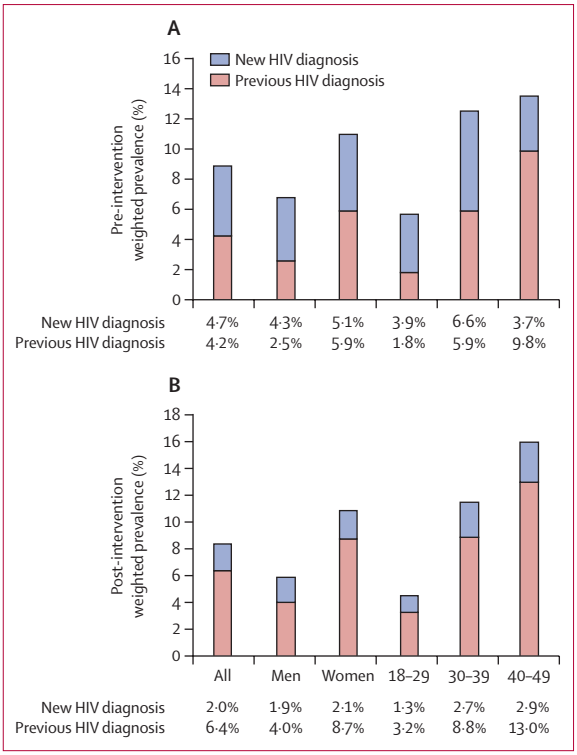

Figure 3: **Pre-intervention (A) and post-intervention (B) prevalence of HIV infection in Bukoba Municipal Council among residents aged 18–49 years, by sex and age group (years)**
Residents with HIV infection who had received a previous diagnosis of HIV infection (red) and residents who had not been diagnosed previously and were newly HIV diagnosed at the time of the survey (blue).

half among most subgroups including men and women, urban and rural residents, employed and unemployed, and those who engaged in unprotected sexual intercourse (table 2). Prevalence of undiagnosed infection decreased by approximately two-thirds among residents aged 18–29 years and those who had not completed a primary education.

In 2017, post-intervention prevalence of undiagnosed HIV infection was similar among men and women, and urban and rural residents (table 2). Compared with reference subgroups, prevalence of undiagnosed HIV infection was approximately two times higher among residents aged 30–39 and 40–49 years, approximately three times higher among residents with only a primary education, having difficulty meeting household food needs, or using alcohol at least weekly; and approximately five times higher among residents without a mobile phone or television (table 2).

By 2017, current ART use increased two times overall and among women; nearly three times among men; three times among people living with HIV who had a secondary-level education, or reported unprotected intercourse in the past 6 months; and nearly four times among young adults aged 18–29 years (table 3). By 2017, disparities in ART use were substantially reduced between men and women, and people living with HIV aged 30–39 and 40–49 years compared with those aged 18–29 years (table 3).

By 2017, diagnostic coverage among people living with HIV increased from 47·4% (95% CI 41·3–53·4) to 76·2% (71·8–80·6); ART use among diagnosed people living with HIV increased from 68·0% (60·9–75·2) to 93·1% (90·2–96·0), and viral load suppression among people living with HIV on ART increased from 88·7% (83·6–93·8) to 91·3% (88·6–94·1), with similar gains in most sex and age groups (figure 4). In 2017, diagnostic coverage among people living with HIV was lowest among men and residents aged 18–29 years, and highest among women and residents aged 40–49 years (figure 4).

Discussion

After implementation of a comprehensive combination prevention intervention during a 2·5 year period of expanding ART policy, ART coverage among people living with HIV in Bukoba increased two times overall, and nearly three times among men and four times among young adults—populations that consistently have low ART coverage.[5,6] In 2017, more than 90% of diagnosed people living with HIV in Bukoba were using ART and more than 90% of those on ART were virally suppressed, meeting the last two goals of 90-90-90 that are necessary to reduce HIV transmission.[1] Notably, BCPE was not an experimental test-and-treat community trial. ART was provided in accordance with national treatment guidelines, and only in the final 6 months of the intervention were all HIV-positive people eligible to receive ART. Our findings suggest that comprehensive facility-based and community-based HIV testing, combined with recommended linkage, defaulter tracing, and test-and-treat services can help reduce gender and age-group disparities and increase HIV diagnostic, ART, and viral load suppression coverage in urban and rural communities in a relatively short period.[12,13,17]

Although BCPE facility-based and community-based testing programmes newly diagnosed more than 4000 people living with HIV and helped to substantially increase HIV diagnostic coverage, the 90% coverage target was not met, contributing to higher prevalence of undiagnosed infection and lower ART coverage among people living with HIV in several sociodemographic groups. Prevalence of undiagnosed infection remained high among residents who had never completed primary education, frequently used alcohol, or were likely impoverished (suggested by not owning a mobile phone or difficulty meeting family food needs).

Although diagnostic coverage among people living with HIV in 2017 was substantially higher among women than men, post-intervention prevalence of undiagnosed HIV infection between women and men was similar. Similarly, although diagnostic coverage in 2017 was higher among people living with HIV aged 30–49 than

	Pre-intervention survey (November, 2013–January, 2014)					Post-intervention survey (June, 2017–September, 2017)					Intersurvey PR (95% CI)
	Total (n)	Prevalence of undiagnosed HIV infection*				Total (n)	Prevalence of undiagnosed HIV infection*				
		n	% (95% CI)	PR (95% CI)	APR† (95% CI)		n	% (95% CI)	PR (95% CI)	APR† (95% CI)	
Total	4795	222	4·70% (3·76–5·64)	..	..	5067	96	1·99% (1·37–2·61)	..	..	0·42 (0·31–0·57)
Sex											
Male	1834	72	4·28% (3·15–5·40)	1 (ref)	1 (ref)	2091	36	1·90% (1·13–2·67)	1 (ref)	1 (ref)	0·44 (0·29–0·69)
Female	2961	150	5·10% (4·04–6·17)	1·19 (0·94–1·51)	1·20 (0·95–1·52)	2976	60	2·08% (1·45–2·71)	1·10 (0·79–1·52)	1·14 (0·82–1·58)	0·41 (0·31–0·54)
Age group (years)											
18–29	2749	110	3·95% (3·01–4·88)	1 (ref)	1 (ref)	2832	39	1·35% (0·93–1·76)	1 (ref)	1 (ref)	0·34 (0·24–0·48)
30–39	1385	87	6·56% (4·92–8·21)	1·66 (1·36–2·04)	1·67 (1·37–2·05)	1461	37	2·67% (1·48–3·87)	1·99 (1·36–2·91)	2·00 (1·37–2·92)	0·41 (0·26–0·64)
40–49	661	25	3·66% (2·13–5·20)	0·93 (0·58–1·48)	0·94 (0·59–1·50)	774	20	2·94% (1·52–4·36)	2·18 (1·28–3·73)	2·20 (1·29–3·76)	0·80 (0·44–1·46)
Residence											
Urban	3791	170	4·54% (3·41–5·66)	1 (ref)	..	3724	70	1·93% (1·20–2·65)	1 (ref)	..	0·42 (0·30–0·59)
Rural	1004	52	5·20% (3·64–6·77)	1·15 (0·79–1·67)	..	1343	26	2·19% (1·02–3·37)	1·14 (0·61–2·14)	..	0·42 (0·23–0·76)
Duration of current home residence (years)											
≥2	2177	81	3·90% (2·81–4·99)	1 (ref)	1 (ref)	2322	40	1·89% (1·22–2·57)	1 (ref)	1 (ref)	0·49 (0·33–0·71)
1–2	1059	56	5·32% (3·73–6·90)	1·36 (0·98–1·91)	1·48 (1·05–2·10)	1226	19	1·45% (0·79–2·11)	0·76 (0·46–1·27)	0·95 (0·57–1·57)	0·27 (0·16–0·45)
<1	1559	85	5·45% (3·99–6·91)	1·40 (1·01–1·94)	1·65 (1·18–2·30)	1519	37	2·59% (1·55–3·63)	1·37 (0·95–1·98)	1·84 (1·25–2·69)	0·48 (0·31–0·72)
Highest level of education completed‡											
At least some secondary	1640	41	2·63% (1·75–3·51)	1 (ref)	1 (ref)	1987	16	0·81% (0·41–1·21)	1 (ref)	1 (ref)	0·31 (0·18–0·53)
Completed primary	2596	130	4·92% (3·81–6·03)	1·87 (1·27–2·76)	1·73 (1·16–2·57)	2546	63	2·68% (1·83–3·53)	3·33 (2·12–5·21)	2·88 (1·77–4·70)	0·55 (0·38–0·77)
None or some primary	556	51	9·53% (6·96–12·10)	3·62 (2·45–5·36)	3·42 (2·29–5·10)	532	17	3·19% (1·53–4·85)	3·95 (2·23–7·02)	3·52 (1·99–6·22)	0·33 (0·20–0·57)
Employed in past 12 months											
No	983	30	3·02% (1·75–4·29)	1 (ref)	1 (ref)	767	10	1·22% (0·49–1·95)	1 (ref)	1 (ref)	0·40 (0·20–0·80)
Yes	3812	192	5·05% (4·04–6·06)	1·67 (1·11–2·52)	1·65 (1·06–2·56)	4300	86	2·12% (1·42–2·82)	1·74 (0·92–3·29)	1·40 (0·73–2·68)	0·42 (0·30–0·58)
Ownership of television or mobile phone											
Yes	4431	186	4·23% (3·47–4·99)	1 (ref)	1 (ref)	4858	78	1·66% (1·14–2·19)	1 (ref)	1 (ref)	0·39 (0·29–0·53)
No	364	36	10·08% (6·28–13·88)	2·38 (1·70–3·34)	2·41 (1·72–3·39)	209	18	9·05% (5·54–12·57)	5·44 (3·52–8·40)	5·05 (3·16–8·07)	0·90 (0·53–1·51)
Trouble satisfying food needs in past 12 months§											
Never	2707	97	3·68% (2·79–4·57)	1 (ref)	1 (ref)	2285	27	1·24% (0·80–1·69)	1 (ref)	1 (ref)	0·34 (0·22–0·52)
Seldom	1822	102	5·65% (4·36–6·95)	1·54 (1·22–1·93)	1·48 (1·17–1·88)	2118	45	2·25% (1·26–3·24)	1·81 (1·01–3·25)	1·70 (0·94–3·08)	0·40 (0·27–0·59)
Sometimes, often, or always	250	22	8·46% (5·42–11·50)	2·30 (1·63–3·23)	2·25 (1·60–3·16)	637	24	3·91% (2·13–5·68)	3·14 (1·74–5·65)	2·72 (1·44–5·11)	0·46 (0·27–0·80)
Frequency of alcohol use in past 6 months¶											
Never	2971	105	3·54% (2·70–4·37)	1 (ref)	1 (ref)	3376	47	1·36% (0·94–1·78)	1 (ref)	1 (ref)	0·38 (0·27–0·54)
Less than monthly or monthly	985	49	4·85% (3·11–6·58)	1·37 (0·98–1·92)	1·31 (0·93–1·86)	1044	23	2·39% (0·95–3·83)	1·76 (0·95–3·25)	1·62 (0·86–3·07)	0·49 (0·26–0·95)
Weekly or daily	834	68	7·95% (6·13–9·78)	2·25 (1·69–2·99)	2·31 (1·66–3·23)	645	26	4·35% (2·14–6·55)	3·20 (1·93–5·28)	2·98 (1·71–5·17)	0·55 (0·34–0·89)
Sexual behaviour in past 6 months‖											
Protected intercourse	1122	32	3·01% (1·93–4·08)	1 (ref)	1 (ref)	1067	20	1·94% (0·68–3·20)	1 (ref)	1 (ref)	0·65 (0·35–1·20)
Unprotected intercourse	3019	153	5·12% (3·99–6·25)	1·70 (1·22–2·37)	1·52 (1·07–2·17)	3380	65	2·01% (1·32–2·69)	1·03 (0·53–2·01)	..	0·39 (0·27–0·56)
No sexual partners	654	37	5·60% (3·48–7·72)	1·86 (1·15–3·01)	1·83 (1·14–2·93)	620	11	1·99% (0·75–3·23)	1·02 (0·48–2·20)	..	0·36 (0·18–0·72)

PR=prevalence ratio. APR=adjusted prevalence ratio. *Weighted by sex, age group, and geographical area of the Bukoba Municipal Council census, and adjusted for clustering within census enumeration areas. All PRs and APRs with 95% CIs that exclude 1·0 are statistically significant (p<0·05). †Variables noted with .. were not included in the multivariate model. ‡Pre-intervention, 3 participants did not respond; post-intervention, 2 did not respond. §Pre-intervention, 16 participants did not respond. ¶Pre-intervention, 5 participants did not respond; post-intervention, 2 did not respond. ||Unprotected indicates condom use for <100% of sexual-intercourse acts; protected indicates condom use for 100% of sexual-intercourse acts.

Table 2: **Pre-intervention and post-intervention population prevalence of undiagnosed HIV infection among residents aged 18–49 years, and intrasurvey and intersurvey undiagnosed infection PRs**

	Pre-intervention HIV survey (November, 2013–January, 2014)					Post-intervention HIV survey (June, 2017–September, 2017)					Intersurvey PR (95% CI)
	People living with HIV (n)	Prevalence of current ART use*				People living with HIV (n)	Prevalence of current ART use*				
		n	% (95% CI)	PR (95% CI)	APR† (95% CI)		n	% (95% CI)	PR (95% CI)	APR† (95% CI)	
Total	436	147	32·23% (26·36–38·10)	..	..	435	315	70·94% (65·52–76·37)	..	..	2·20 (1·82–2·66)
Sex											
Male	113	25	23·01% (14·80–31·22)	1 (ref)	1 (ref)	112	69	62·06% (53·55–70·57)	1 (ref)	1 (ref)	2·70 (1·84–3·96)
Female	323	122	37·68% (31·15–44·20)	1·64 (1·15–2·32)	1·52 (1·14–2·04)	323	246	75·60% (70·51–80·69)	1·22 (1·07–1·38)	1·15 (1·04–1·27)	2·01 (1·69–2·38)
Age group (years)											
18–29	163	30	16·65% (9·63–23·67)	1 (ref)	1 (ref)	136	89	64·39% (56·31–72·46)	1 (ref)	1 (ref)	3·87 (2·54–5·89)
30–39	180	60	29·81% (23·26–36·35)	1·79 (1·17–2·73)	1·95 (1·30–2·93)	172	124	70·56% (62·77–78·35)	1·10 (0·95–1·26)	1·18 (1·05–1·34)	2·37 (1·85–3·03)
40–49	93	57	60·38% (47·85–73·91)	3·63 (2·44–5·38)	3·24 (2·20–4·79)	127	102	78·19% (68·85–87·53)	1·21 (1·01–1·46)	1·26 (1·08–1·47)	1·29 (1·04–1·62)
Residence											
Urban	344	123	34·00% (27·66–40·34)	1 (ref)	..	313	227	71·11% (64·12–78·10)	1 (ref)	..	2·09 (1·72–2·55)
Rural	92	24	26·85% (14·33–39·38)	0·79 (0·49–1·28)	..	122	88	70·49% (64·00–76·99)	0·99 (0·87–1·13)	..	2·63 (1·66–4·16)
Duration of current home residence (years)											
<1	137	32	22·46% (16·51–28·40)	1 (ref)	1 (ref)	142	95	65·24% (56·50–73·99)	1 (ref)	1 (ref)	2·91 (2·17–3·89)
1–2	99	29	28·82% (17·27–40·36)	1·28 (0·88–1·87)	1·10 (0·71–1·70)	89	63	70·90% (60·99–80·80)	1·09 (0·91–1·29)	1·01 (0·86–1·18)	2·46 (1·63–3·70)
>2	200	86	40·19% (31·56–48·82)	1·79 (1·31–2·45)	1·38 (1·03–1·84)	204	157	74·92% (67·98–81·87)	1·15 (1·01–1·31)	1·03 (0·93–1·14)	1·86 (1·49–2·33)
Highest level of education completed											
At least some secondary	65	17	23·88% (13·45–34·31)	1 (ref)	1 (ref)	76	56	72·03% (61·10–82·95)	1 (ref)	..	3·02 (1·96–4·64)
Completed primary	279	103	35·52% (27·48–43·56)	1·49 (0·95–2·33)	1·15 (0·85–1·56)	276	198	69·82% (63·83–75·82)	0·97 (0·84–1·12)	..	1·97 (1·56–2·47)
None or some primary	92	27	28·22% (19·48–36·96)	1·18 (0·69–2·01)	1·07 (0·66–1·73)	83	61	73·59% (63·76–83·41)	1·02 (0·83–1·26)	..	2·61 (1·86–3·65)
Employed in past 12 months											
No	56	21	38·18% (22·97–53·39)	1 (ref)	..	56	43	75·80% (65·14–86·46)	1 (ref)	..	1·99 (1·32–2·98)
Yes	380	126	31·48% (25·56–37·40)	0·82 (0·55–1·23)	..	379	272	70·31% (64·66–75·97)	0·93 (0·80–1·07)	..	2·23 (1·83–2·72)
Ownership of mobile phone or television											
No	68	19	26·62% (16·92–36·31)	1 (ref)	1 (ref)	44	24	54·94% (39·61–70·26)	1 (ref)	1 (ref)	2·06 (1·31–3·25)
Yes	368	128	33·33% (27·07–39·60)	1·25 (0·87–1·80)	1·06 (0·81–1·39)	391	291	73·06% (67·68–78·44)	1·33 (1·01–1·76)	1·22 (0·94–1·58)	2·19 (1·81–2·66)
Trouble satisfying household food needs‡											
Never	193	68	33·02% (25·02–41·02)	1 (ref)	..	120	85	69·04% (61·37–76·71)	1 (ref)	..	2·09 (1·62–2·71)
Seldom	196	63	31·38% (23·90–38·86)	0·95 (0·71–1·27)	..	206	148	70·68% (63·39–77·98)	1·02 (0·88–1·20)	..	2·25 (1·73–2·93)
Sometimes, often, or always	46	16	33·14% (19·35–46·92)	1·00 (0·66–1·54)	..	108	81	73·32% (63·18–83·47)	1·06 (0·90–1·25)	..	2·21 (1·47–3·32)
Frequency of alcohol use in past 6 months§											
Weekly or daily	93	14	14·95% (6·54–23·35)	1 (ref)	1 (ref)	67	39	54·98% (41·93–68·03)	1 (ref)	1 (ref)	3·68 (1·96–6·90)
Less than monthly or monthly	106	34	32·21% (22·44–41·98)	2·16 (1·20–3·89)	1·77 (0·99–3·17)	114	84	72·86% (62·81–82·92)	1·33 (1·03–1·71)	1·16 (0·93–1·45)	2·26 (1·65–3·11)
Never	237	99	40·36% (32·74–47·97)	2·70 (1·58–4·63)	2·36 (1·45–3·85)	253	191	74·90% (69·35–80·45)	1·36 (1·08–1·72)	1·21 (1·00–1·45)	1·86 (1·53–2·26)

(Table 3 continues on next page)

	Pre-intervention HIV survey (November, 2013–January, 2014)					Post-intervention HIV survey (June, 2017–September, 2017)					Intersurvey PR (95% CI)
	People living with HIV (n)	Prevalence of current ART use*				People living with HIV (n)	Prevalence of current ART use*				
		n	% (95% CI)	PR (95% CI)	APR† (95% CI)		n	% (95% CI)	PR (95% CI)	APR† (95% CI)	
(Continued from previous page)											
Sexual behaviour in the past 6 months¶											
Unprotected intercourse	234	50	19·99% (14·54–25·44)	1 (ref)	..	192	117	60·19% (52·68–67·70)	1 (ref)	1 (ref)	3·01 (2·27–4·00)
Protected intercourse	106	51	47·27% (36·08–58·46)	2·37 (1·71–3·27)	..	151	122	80·05% (73·16–86·94)	1·33 (1·15–1·54)	1·25 (1·09–1·43)	1·69 (1·33–2·15)
No sexual partners	96	46	46·50% (34·23–58·77)	2·33 (1·72–3·15)	..	92	76	80·54% (70·41–90·67)	1·34 (1·15–1·55)	1·20 (1·05–1·38)	1·73 (1·29–2·33)

ART=antiretroviral therapy. PR=prevalence ratio. APR=adjusted prevalence ratio. *Weighted by sex, age group, and geographical area of the Bukoba Municipal Council census, and adjusted for clustering within census enumeration areas. All PRs and APRs with 95% CI that exclude 1·0 are statistically significant (p<0·05). Current ART use included people living with HIV who either: reported ART use as part of the standard survey interview, were confirmed by medical record to be on ART, or had achieved viral load suppression (HIV-1 RNA concentration <1000 per µL on a viral load assay). ART use included viral load suppression because of low sensitivity (77%) of self-reported ART use[15] and that only 1% of people living with HIV achieve durable viral load suppression in the absence of ART adherence.[16] †Variables noted with ·· were not included in the multivariate model. ‡Pre-intervention, 1 participant did not respond; post-intervention, 1 did not respond §Post-intervention, 1 participant did not respond. ¶Unprotected indicates condom use for <100% of sexual-intercourse acts; protected indicates condom use for 100% of sexual-intercourse acts.

Table 3: **Pre-intervention and post-intervention population prevalence of ART use among people living with HIV aged 18–49 years, and intrasurvey and intersurvey ART use PRs**

18–29 years, residents aged 30–49 years had twice the prevalence of undiagnosed infection than residents aged 18–29 years. Applying our estimated prevalence of undiagnosed infection to the census of Bukoba residents aged 18–49 years suggests that 660 (34 724×0·0190) and 750 (36 078×0·0208) men and women living with HIV, and 520 (38 510×0·0135) and 891 (32 292×0·0276) people living with HIV aged 18–29 and 30–49 years, respectively, remained unaware of their HIV infection and needed diagnosis in 2017.[18]

Although considerable emphasis has been placed on increasing diagnostic coverage among younger people and men (due to lower diagnostic coverage among people living with HIV in these subgroups), as noted in our study and elsewhere, total undiagnosed infections might remain higher in older people and women due to higher prevalence of HIV infection.[6] In Bukoba, our findings suggest testing programmes should equally target men and women and similar if not greater efforts should be made to reach and test high-risk people aged 30–49 years. Because prevalence of undiagnosed HIV infection remained substantially higher in lower socioeconomic and alcohol-using groups, our findings underscore the importance of other testing strategies needed to reach those who might not frequent health-care facilities to achieve more than 90% diagnostic coverage.

Over the 2·5 year intervention, we did 27 407 home-based and 17 475 venue-based tests (34% of all tests) to reach people living with HIV who might not regularly access health-care services.[12] Lower socioeconomic neighbourhoods were not specifically targeted for home-based testing and the 79 community venues were mostly high-volume market, street locations, or community events.[12] Our findings suggest that community-based testing strategies targeting impoverished neighbourhoods, the homeless, and bars and clubs might be important to achieve diagnostic coverage in low socio-economic and alcohol-using groups.[19] Also, while we diagnosed new HIV infections in 25% of 691 sexual partners and family members of linkage clients who were HIV tested, we had limited success in reaching most sexual partners.[13] Safe and appropriate index client testing services might also be effective in reducing undiagnosed infections among residents of all ages, including those aged 30 years or older.[20–23]

Of the four community-randomised, combination prevention test-and-treat trials, three had similarly low ART coverage as BCPE at baseline and offer useful comparisons.[7–11] Of these, only the SEARCH trial[8] in Kenya and Uganda reached 90-90-90, achieving 89% ART coverage among all stable-resident people living with HIV.[8] In KwaZulu-Natal, South Africa, TasP trial[9] made modest progress towards 90-90-90, achieving 48% ART coverage among all people living with HIV aged 16 years or older.[9] Over an intervention of 2 or more years, all identified people living with HIV in these experimental test-and-treat trials were informed they would be initiated on

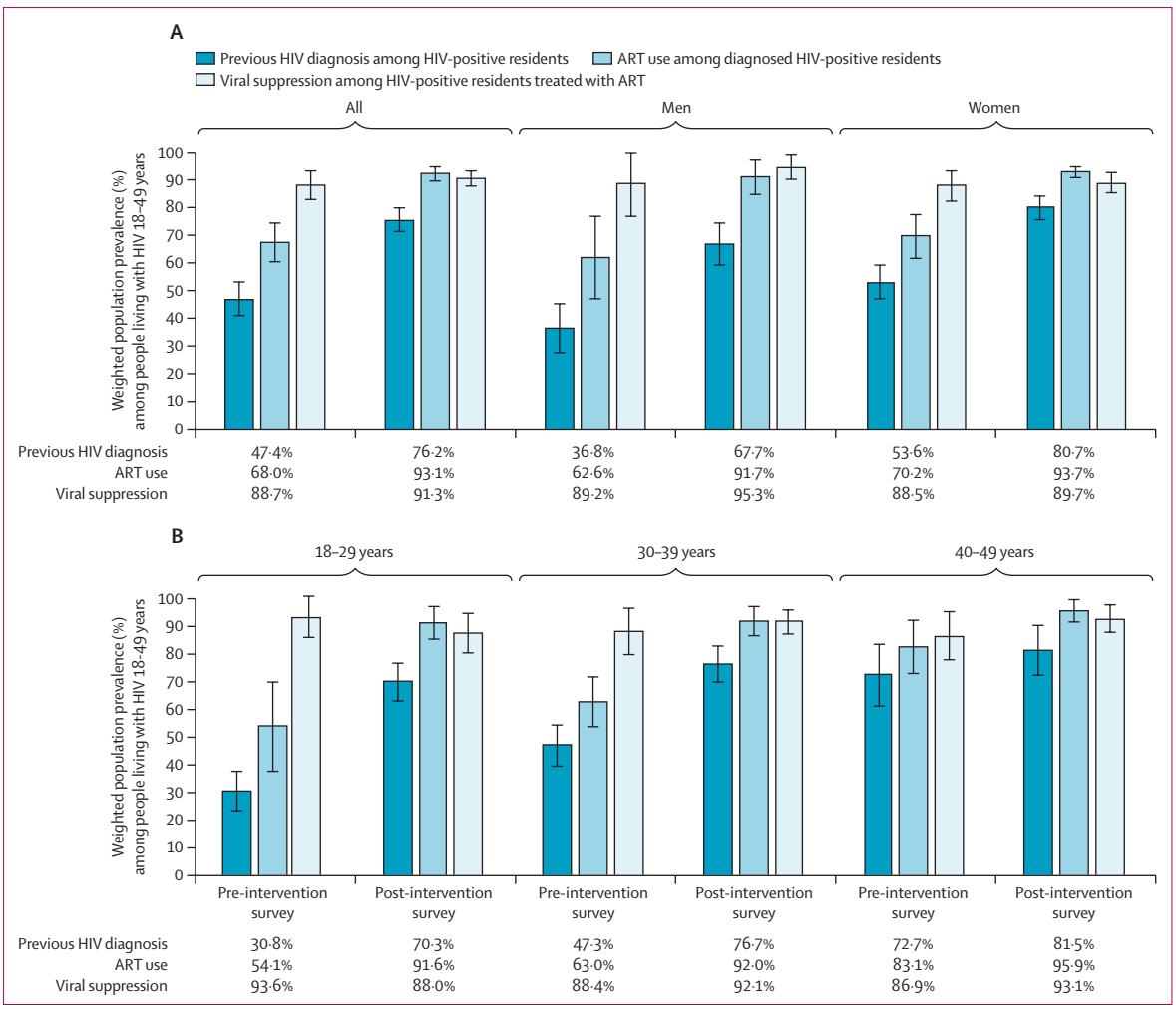

Figure 4: **Conditional population prevalence of previous HIV diagnosis, current ART use, and viral load suppression among people living with HIV aged 18–49 years, by sex (A) and age group (B), pre-intervention and post-intervention household surveys**

Error bars show 95% CIs. Previous HIV diagnosis and current ART use included people living with HIV who either: reported these conditions as part of the standard survey interview, were confirmed by medical record to have these conditions, or had achieved viral load suppression (HIV-1 RNA concentration <1000 per µL on a viral load assay). Conditions included viral load suppression because of low sensitivity (77%) of self-reported ART use[15] and that only 1% of people living with HIV achieve durable viral load suppression in the absence of ART adherence.[16] Pre-intervention (October, 2013–January, 2014) and post-intervention (June, 2017–September, 2017) prevalence estimates and 95% CI for previous HIV diagnosis, ART use, and viral load suppression among people living with HIV were weighted by sex, age group, and geographical area of the Bukoba Municipal Council census and adjusted for clustering within census enumeration areas. ART=antiretroviral therapy.

ART regardless of CD4 cell count.[7–10] In 16 small rural communities of approximately 5000 residents each, SEARCH relied primarily on home-based and community-based testing campaigns to achieve 90-90-90, a strategy that might not be as effective in larger urban communities.[8] Notably, only 48–65% of people living with HIV in these trials linked to care within 6 months of diagnosis and 63–73% did so within 12 months.[7–9] Linkage services in these trials, at least at first, relied primarily on point-of-diagnosis counselling and referral, with home-visit follow-up for clients who failed to enrol in care.[7–9] By contrast, during the 6-month test-and-treat period, BCPE's linkage case management intervention, combined with community-based and facility-based same-day ART services, enrolled in HIV care 97% of all clients within 3 months of diagnosis.[13] Our peer-delivered, linkage case management intervention provided a comprehensive package of CDC and WHO recommended linkage services to consenting clients from the point of diagnosis for up to 90 days.[13] HIV-positive, peer counsellors served as linkage champions for their clients, sharing their own personal experiences of living with HIV to help clients overcome the shock of diagnosis, escorted and facilitated their enrolment in care, ensured they understood how to navigate care, and helped mitigate real or perceived barriers to care (eg, stigmatisation, perceived wellness, denial, concerns about partner response or loss, etc). These proactive, peer-delivered services might have been particularly helpful to younger people and men who are more likely to delay enrolment in care.[5,6,13,19] Our linkage-

to-care findings are similar to those reported by a peer-delivered linkage case management programme in eSwatini, and is consistent with other studies in sub-Saharan Africa that report the benefits of integrated testing and linkage support for early ART initiation.[6,19,24–27] Not a major component of the test-and-treat experimental trials, BCPE defaulter tracing services also contributed to improving ART coverage in Bukoba by initiating or re-initiating ART on over 500 patients who had stopped care. As experienced throughout sub-Saharan Africa, many pre-ART patients in Bukoba defaulted from HIV care, and defaulter tracing services were implemented after the first ART-eligibility expansion in 2016 as an effort to help former patients receive ART.[28,29] Because of low retention in pre-ART care, more patients might have been retained in care and higher ART coverage achieved in Bukoba if both test-and-treat and defaulter tracing services were provided from the beginning of our intervention.[28,29] Many patients were traced 1–2 years after defaulting from pre-ART care and were lost to follow-up. Findings from our defaulter tracing programme underscores both the value of test and treat and same-day ART to avert early drop-out, and need for more immediate initiation of defaulter tracing services to prevent patients from becoming lost to follow-up.[29]

Our findings are subject to at least five limitations. First, because our research design did not include control communities, BCPE intervention effects on population-level coverage of previous HIV diagnosis and ART could not be estimated. Although BCPE provided a large majority of testing services during the intervention, some residents were diagnosed and linked to ART as hospital inpatients, and pre-natal and post-natal care, tuberculosis, and voluntary medical male circumcision outpatients. Nonetheless, we believe a large intervention effect is likely. As reported elsewhere, BCPE testing and linkage interventions diagnosed and enrolled in HIV care 3488 people living with HIV aged 15–49 years during the intervention period, representing nearly 100% of the estimated 3493 people living with HIV residents aged 18–49 years who were not in HIV care in 2014.[12,13,17] Second, contributing to uncertainty in estimating BCPE intervention effects, residence of clients who received BCPE testing and linkage services was not collected and is unknown. Some BCPE participants who were diagnosed and linked to HIV care in Bukoba facilities might not have been residents of Bukoba, which is home to the regional referral hospital and two health centres known to provide medical services to some residents of other districts. Third, although prevalence estimates were weighted to the census population, residual bias might reduce the validity of estimates for men who were underrepresented in both surveys. Fourth, although we used a combination of self-report, medical record review, and viral load suppression to define previous HIV diagnosis and ART use, these outcomes might remain underestimated given the low sensitivity of self-report among people living with HIV and likelihood that medical record reviews did not capture all survey participants who were currently in HIV care.[15] Finally, the scalability of our combined interventions might be limited to well resourced HIV prevention and treatment programmes. However, to help enable adoption, all our interventions were developed to be reasonably low cost, relying primarily on peer lay counsellors to deliver services. For example, estimated peer-delivered costs per HIV test (US$, 2017) for BCPE facility-based, home-based, and venue-based strategies were $3·06, $4·81, and $5·45, respectively, similar with other reported HIV-test costs.[12] Estimated per client cost for peer-delivered linkage case management was $18·00 for a facility-based model.[13]

Interventions modelled on BCPE when implemented under a test-and-treat programme are promising strategies that might help countries achieve 90-90-90 goals. In 2017, BCPE facility-based testing and linkage case management interventions were approved by the Ministry of Health, Community Development, Gender, Elderly and Children as new service delivery models. In 2019, these interventions were implemented by four HIV prevention organisations and scaled up in all regions of Tanzania.[30] The United States President's Emergency Plan for AIDS Relief recommends optimised testing in facilities and peer-delivered linkage case management as possible solutions for country programmes striving to achieve 90-90-90.[31]

Contributors

CS and DMK conceived and wrote the first draft of the manuscript. DMK, RW, KK, FM, and JJ acquired funding for the study. CS, DMK, HJC, OER, HM, OM, RW, GK, JB, KK, and CM-M contributed to study investigation, methodology, and validation of the study data. CS, DMK, HJC, OER, HM, OM, RW, GK, JB, KK, CM-M, FM, and JJ administered the project and resources, and supervised the study. SP did the statistical analysis. SP, JJ, and TR contributed to the study methodology. SP and TR and contributed to the study investigation. All authors reviewed and edited the final version of the manuscript.

Declaration of interests

We declare no competing interests.

Data sharing

Study protocol, statistical analysis plan, and analytical code will be made available upon request to the corresponding author.

Acknowledgments

In memory of our dear colleague and friend Dr Fernando Morales who sadly passed away before publication of this Article. He was a loving father, inspiring leader, and dedicated mentor who humbly dedicated his career trying to improve the health of those less fortunate throughout sub-Saharan Africa. In memory of Dr Subilaga Kaganda, a public health practitioner determined to address the HIV/AIDS epidemic in Tanzania, who sadly passed away before the project was completed. We are thankful for the support of the Tanzania's Ministry of Health, Community Development, Gender, Elderly and Children, National AIDS Control Program, Tanzania Commission for AIDS, Bukoba Municipal Council and Kagera region leadership, and staff at the 11 health-care facilities. We are also grateful to the residents of Bukoba Municipal Council for embracing the study. We acknowledge the invaluable contributions of the lay counsellors, health-care workers, and data clerks without whom these achievements would not be possible. This research was supported by the United States' President's Emergency Plan for AIDS Relief through the US Centers for Disease Control and Prevention under the terms of cooperative agreement 5UGPS001998-05.
The findings and conclusions in this Article are those of the authors and do not necessarily represent the official position of the funding agencies.

Editorial note: the *Lancet* Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

References

1 UNAIDS. 90-90-90: an ambitious treatment target to help end the AIDS epidemic. Geneva: Joint United Nations Programme on HIV/AIDS, 2014. https://www.unaids.org/sites/default/files/media_asset/90-90-90_en.pdf (accessed July 8, 2019).

2 WHO. Guidelines for managing advanced HIV disease and rapid initiation of antiretroviral therapy. Geneva: World Health Organization, 2017. https://apps.who.int/iris/bitstream/handle/10665/255884/9789241550062-eng.pdf?sequence=1 (accessed July 8, 2019).

3 WHO. Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV Infection. Recommendations for a public health approach, 2nd edn. France: World Health Organization Press, 2016. https://apps.who.int/iris/bitstream/handle/10665/208825/9789241549684_eng.df;jsessionid=5E126DA7B4BA1E450E5EA61E80E3BF40?sequence=1 (accessed July 8, 2019).

4 Tanzania Commission for AIDS ZACZ. Tanzania HIV Impact Survey (THIS) 2016–2017: final report. Dar es Salaam, 2018. http://www.nbs.go.tz/nbs/takwimu/this2016–17/THIS_2016–2017_Final_Report.zip (accessed July 8, 2019).

5 Maheu-Giroux M, Tanser F, Boily M-C, Pillay D, Joseph SA, Bärnighausen T. Determinants of time from HIV infection to linkage-to-care in rural KwaZulu-Natal, South Africa. *AIDS* 2017; **31:** 1017–24.

6 Auld AF, Shiraishi RW, Oboho I, et al. Trends in prevalence of advanced HIV disease at antiretroviral therapy enrollment—10 countries, 2004–2015. *MMWR Morb Mortal Wkly Rep* 2017; **66:** 558–63.

7 Hayes R, Floyd S, Schaap A, et al. A universal testing and treatment intervention to improve HIV control: one-year results from intervention communities in Zambia in the HPTN 071 (PopART) cluster-randomised trial. *PLoS Med* 2017; **14:** e1002292.

8 Petersen M, Balzer L, Kwarsiima D, et al. Association of implementation of a universal testing and treatment intervention with HIV diagnosis, receipt of antiretroviral therapy, and viral suppression in east Africa. *JAMA* 2017; **317:** 2196–206.

9 Iwuji CC, Orne-Gliemann J, Larmarange J, et al. Uptake of home-based HIV testing, linkage to care, and community attitudes about ART in rural KwaZulu-Natal, South Africa: descriptive results from the first phase of the ANRS 12249 TasP cluster-randomised trial. *PLoS Med* 2016; **13:** e1002107.

10 Floyd S, Ayles H, Schaap A, et al. Towards 90-90: findings after two years of the HPTN 071 (PopART) cluster-randomized trial of a universal testing-and-treatment intervention in Zambia. *PLoS One* 2018; **13:** e0197904.

11 Makhema J, Wirth KE, Pretorius Holme M, et al. Universal testing, expanded treatment, and incidence of HIV infection in Botswana. *N Engl J Med* 2019; **381:** 230–42.

12 Cham HJ, MacKellar D, Maruyama H, et al. Methods, outcomes, and costs of a 2·5 year comprehensive facility- and community-based HIV testing intervention in Bukoba Municipal Council, Tanzania, 2014–2017. *PLoS One* 2019; **14:** e0215654.

13 MacKellar D, Maruyama H, Rwabiyago OE, et al. Implementing the package of CDC and WHO recommended linkage services: methods, outcomes, and costs of the Bukoba Tanzania Combination Prevention Evaluation peer-delivered, linkage case management program, 2014–2017. *PLoS One* 2018; **13:** e0208919.

14 Centers for Disease Control and Prevention HRaSA, National Institutes of Health, American Academy of HIV Medicine, et al. Recommendations for HIV prevention with adults and adolescents with HIV in the United States. 2014. https://stacks.cdc.gov/view/cdc/44064 (accessed April 29, 2020).

15 Grabowski MK, Reynolds SJ, Kagaayi J, et al. The validity of self-reported antiretroviral use in persons living with HIV: a population-based study. *AIDS* 2018; **32:** 363–69.

16 Olson AD, Meyer L, Prins M, et al. An evaluation of HIV elite controller definitions within a large seroconverter cohort collaboration. *PLos One* 2014; **9:** 86719.

17 MacKellar D, Steiner C, Rwabiyago OE, et al. Threefold increases in population HIV viral load suppression among men and young adults—Bukoba Municipal Council, Tanzania, 2014–2017. *MMWR Morb Mortal Wkly Rep* 2019; **68:** 658–63.

18 Tanzania Bureau of Statistics. Bukoba Municipal Council census update 2017. 2017. https://www.nbs.go.tz/index.php/en/ (accessed Jan 6, 2019).

19 Sharma M, Ying R, Tarr G, Barnabas R. Systematic review and meta-analysis of community and facility-based HIV testing to address linkage to care gaps in sub-Saharan Africa. *Nature* 2015; **528:** S77–85.

20 WHO. Guidelines on HIV self-testing and partner notification. Supplement to consolidated guidelines on HIV testing services. Geneva: World Health Organization, 2016. https://apps.who.int/iris/bitstream/handle/10665/251655/9789241549868-eng.pdf?sequence=1 (accessed July 8, 2019).

21 Henley C, Forgwei G, Welty T, et al. Scale-up and case-finding effectiveness of an HIV partner services program in Cameroon: an innovative HIV prevention intervention for developing countries. *Sex Transm Dis* 2013; **40:** 909–14.

22 Cherutich P, Golden MR, Wamuti B, et al. Assisted partner services for HIV in Kenya: a cluster randomised controlled trial. *Lancet HIV* 2017; **4:** e74–82.

23 Kahabuka C, Plotkin M, Christensen A, et al. Addressing the first 90: a highly effective partner notification approach reaches previously undiagnosed sexual partners in Tanzania. *AIDS Behav* 2017; **21:** 2551–60.

24 Reddy EA, Agala CB, Maro VP, et al. Test site predicts HIV care linkage and antiretroviral therapy initiation: a prospective 3.5 year cohort study of HIV-positive testers in northern Tanzania. *BMC Infect Dis* 2016; **16:** 497.

25 MacKellar DA, Williams D, Storer N, et al. Enrollment in HIV care two years after HIV diagnosis in the Kingdom of Swaziland: an evaluation of a national program of new linkage procedures. *PLoS One* 2016; **11:** e0150086.

26 MacKellar D, Williams D, Bhembe B, et al. Peer-delivered linkage case management and same-day ART initiation for men and young persons with HIV infection—Eswatini, 2015–2017. *MMWR Morb Mortal Wkly Rep* 2018; **67:** 663–67.

27 Mavegam BO Jr, Pharr JR, Cruz P, Ezeanolue EE. Effective interventions to improve young adults' linkage to HIV care in sub-Saharan Africa: a systematic review. *AIDS Care* 2017; **29:** 1198–204.

28 Plazy M, Orne-Gliemann J, Dabis F, Dray-Spira R. Retention in care prior to antiretroviral treatment eligibility in sub-Saharan Africa: a systematic review of the literature. *BMJ Open* 2015; **5:** e006927.

29 Keane J, Pharr JR, Buttner MP, Ezeanolue EE. Interventions to reduce loss to follow-up during all stages of the HIV care continuum in sub-Saharan Africa: a systematic review. *AIDS Behav* 2017; **21:** 1745–54.

30 Ministry of Health, Community Development, Gender, Elderly and Children. HIV service delivery models. Mapping HIV service delivery strategies in Tanzania. Dar-es-Salam: Ministry of Health, Community Development, Gender, Elderly and Children, 2017. https://www.go2itech.org/wp-content/uploads/2017/07/SDM_Tanzania_Mapping-Report_FINAL_June2017_-with-Signature.pdf (accessed July 8, 2019).

31 PEPFAR Solutions Team. Bukoba Combination Prevention Evaluation: effective approaches to linking people living with HIV to care and treatment services in Tanzania. Washington, DC: US Presidents' Emergency Plan for AIDS Relief; 2018. https://www.pepfarsolutions.org/solutions/2018/1/15/bukoba-combination-prevention-evaluation-effective-approaches-to-linking-plhiv-to-care-and-treatment-services-in-tanzania-sp3la (accessed July 8, 2019).