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Systematic review and meta-analysis of community and facility-based HIV testing to address linkage to care gaps in sub-Saharan Africa

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HIV testing and counselling is the first crucial step for linkage to HIV treatment and prevention. However, despite high HIV burden in sub-Saharan Africa, testing coverage is low, particularly among young adults and men. Community-based HIV testing and counselling (testing outside of health facilities) has the potential to reduce coverage gaps, but the relative impact of different modalities is not well assessed. We conducted a systematic review of HIV testing modalities, characterizing community (home, mobile, index, key populations, campaign, workplace and self-testing) and facility approaches by population reached, HIV positivity, CD4 count at diagnosis and linkage. Of 2,520 abstracts screened, 126 met eligibility criteria. Community HIV testing and counselling had high coverage and uptake and identified HIV-positive people at higher CD4 counts than facility testing. Mobile HIV testing reached the highest proportion of men of all modalities examined (50%, 95% confidence interval (CI) = 47–54%) and home with self-testing reached the highest proportion of young adults (66%, 95% CI = 65–67%). Few studies evaluated HIV testing for key populations (commercial sex workers and men who have sex with men), but these interventions yielded high HIV positivity (38%, 95% CI = 19–62%) combined with the highest proportion of first-time testers (78%, 95% CI = 63–88%), indicating service gaps. Community testing with facilitated linkage (for example, counsellor follow-up to support linkage) achieved high linkage to care (95%, 95% CI = 87–98%) and antiretroviral initiation (75%, 95% CI = 68–82%). Expanding home and mobile testing, self-testing and outreach to key populations with facilitated linkage can increase the proportion of men, young adults and high-risk individuals linked to HIV treatment and prevention, and decrease HIV burden.

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Globally, there are around 2.3 million new HIV infections annually, 80% of which occur in sub-Saharan Africa[1]. Despite the high burden, only one-third of adults in sub-Saharan Africa have been tested for HIV in the past year and less than 50% of HIV-positive individuals know their status[2,3]. Knowledge of one's serostatus is vital for accessing lifesaving antiretroviral therapy (ART) and linking to HIV prevention. Conventional facility-based HIV testing and counselling (HTC) has not achieved high testing coverage in sub-Saharan Africa and will probably be insufficient to meet UNAIDS ambitious 90–90–90 targets — 90% of HIV-positive people knowing their status, 90% of HIV-positive people who are aware of their status on ART, and 90% of people on ART virally suppressed[4,5]. Barriers to facility testing include distance from clinic, long wait times, costs (transportation, lost wages and childcare), confidentiality concerns, low perceived risk and infrequent contact with the health-care system[6]. In addition, patients often present at facilities late in the course of their illness, increasing HIV morbidity, mortality and transmission[7]. Community-based HTC (conducted outside of a health facility) has the potential to overcome these barriers, achieve high coverage, and identify asymptomatic HIV-positive individuals at high CD4 counts[8,9]. In addition, community HTC may reach more men, young adults, and key populations than facility HTC. Community-based strategies also require minimal infrastructure allowing for easier scale up[10-12].

Community HTC modalities include: home, mobile, workplace, index partner/family members (sexual partners or family members of HIV-positive individuals) and as part of a campaign. Uptake and demographics of populations reached can vary widely by modality[9]. A large number of studies on HTC have been conducted in sub-Saharan Africa and a previous systematic review was completed in 2012, but facility testing was not included and uptake in men and young adults was not assessed. In addition, several large-scale interventions have been published since 2012 (refs 11, 13–15). Recently, the World Health Organization released guidelines that strongly recommend implementing community HTC[16]. As most countries have multiple and varying epidemics, UNAIDS recommends creating regional policies tailored to the macroepidemic rather than nationwide approaches[17]. Local policymakers will need to determine the optimal combination of community HTC interventions to increase testing in the context of their country's HIV epidemic.

To provide evidence for decision makers, we summarize the literature on community and facility-based HTC. We characterize each modality by population coverage, since high coverage is beneficial to both HIV-positive and -negative people. HTC can reduce risk behaviour in HIV-negative individuals, while providing a means to link them to primary prevention (including circumcision and pre-exposure prophylaxis (PrEP))[18-21]. We evaluate effectiveness in reaching men and young adults (both groups have low HIV testing and poorer clinical

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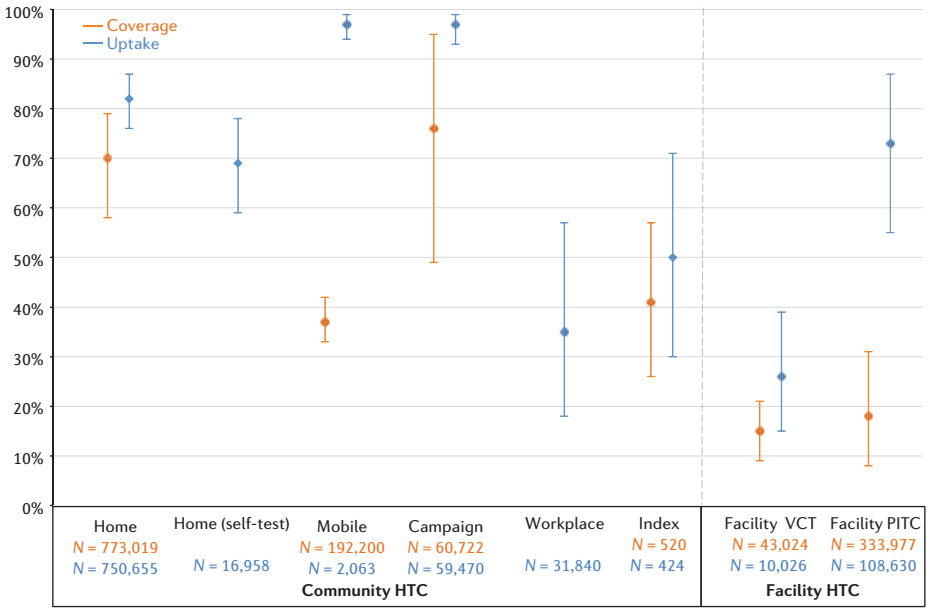

Figure 1 | Pooled coverage and uptake of HIV testing and counselling (HTC) modalities. Coverage is defined as total number of people tested/total number of people in the target population. Uptake is defined as total number of people tested/total number of people offered testing. Bars indicate 95% confidence intervals of random effects meta-analyses. *N*, sample size; PITC, provider-initiated testing and counselling; VCT, voluntary counselling and testing.

outcomes once infected[22-24]) and targeted HTC for key populations (men who have sex with men (MSM), commercial sex workers (CSWs) and people who inject drugs (PWID)) — groups that generally have very high HIV prevalence and low access to health care[25]. We assess HIV positivity to characterize yield and examine CD4 count at diagnosis to identify modalities that have the potential to link infected individuals to care earlier in their disease course. Estimates from our analysis can also be used as parameters in mathematical models to project the long-term impact of HTC interventions.

METHODS

Inclusion criteria. We conducted a systematic literature review following Cochrane and PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines[26]. Studies were eligible for inclusion if they reported data on at least one of the following outcomes: coverage (individuals who accepted HTC/eligible target population); uptake (individuals who accepted HTC/individuals offered HTC); proportion of young adults (either under 25 or under 30 years); proportion of men; proportion of first-time testers; HIV positivity (number positive/total tested); proportion with a CD4 count of 350 cells μl^{-1} or less; proportion linked to care (those who had visited a clinic, obtained a CD4 count or initiated ART); proportion retained in care (individuals retained/individuals who initiated ART); or cost per person tested. The target population was defined as the eligible population in the catchment area, either enumerated by the study (often the case for home HTC) or estimated (often the case for mobile and campaign HTC). For facility HTC, the target population was defined as people visiting the clinic, and for index partner or family members it was defined as all sexual partners or cohabitating family members listed by the index patient. With the exception of HTC targeted to key populations, we excluded HTC studies not related to general population screening, including case reports and studies limited to antenatal or paediatric settings, or to patients with specific diseases (for example, tuberculosis). Observational (cross-sectional and cohort) studies and randomized trials were eligible for inclusion. Studies were included in the analyses more than once if they had different arms or multiple study sites (for example, urban and rural settings or different countries). If more than one wave of a survey or intervention was completed, only the most recent was used.

Search strategy. Literature searches were conducted with the help of a librarian on 22 July 2014 and updated on 10 June, 2015. Briefly, we searched PubMed, EMBASE, Cochrane Library, Global Health Database, African Index Medicus, and conference abstracts (CROI, R4P, IAS) using MeSH terms for PubMed and comparable terms for other databases. Search terms included "HIV infections/diagnosis" AND "Africa South of the Sahara" AND ("mass screening" OR test OR tests OR testing OR screen* OR diagnosis OR "counseling"). Bibliographies of relevant papers were screened and authors were contacted for missing outcomes. Searches were limited to human studies published between 2000 and 2015. The full strategy is described in the Supplementary Information.

Definitions of HTC modalities. Community-based HTC was defined as testing conducted outside of health facilities. Facility-based HTC was conducted in health-care facilities (clinics, hospitals, fixed stand-alone voluntary counselling and testing sites). Facility HTC was divided into two categories: voluntary counselling and testing (VCT), which is patient-initiated testing and provider-initiated testing and counselling (PITC), which is routine; or opt-out HTC that is initiated by a provider. Community HTC modalities included home (offering HTC door-to-door to a catchment area), mobile (setting up a mobile van or container to provide HTC in a central area of a community), index partner or family member (offering HTC to individuals who may have been exposed to HIV by a sexual partner or who have an HIV-positive household member), campaign (short — generally 1 to 2 weeks — intensive community mobilization followed by mobile testing, often partnered with other health interventions), key populations (targeted to MSM, CSWs and PWID) and workplace (offered at a place of employment). We examined a subset of home and workplace HTC that used self-testing.

Data screening and extraction. M.S., R.Y. and R.V.B. screened abstracts for initial inclusion. Disagreements were adjudicated by reviewing the full text. M.S., R.V.B., R.Y. and G.T. reviewed papers for eligibility and used a standardized extraction form to characterize eligible studies (Supplementary Information 2). Study quality was rated low, moderate or high based on representativeness of underlying population, follow-up (present or absent), assessment of outcomes, and number of outcomes presented. Costs were inflated to 2012 US dollars by converting to local currency units, multiplying by the ratio of each country's gross domestic product deflator (2012 deflator divided by base year deflator) and converting back to US dollars[27].

Statistical analysis. Random effects meta-analysis of single proportions with binomial exact confidence intervals (CI) was used to summarize results. Proportions were stabilized using the Freeman–Tukey double arcsine transformation unless the number of events was less than ten, in which case a logit

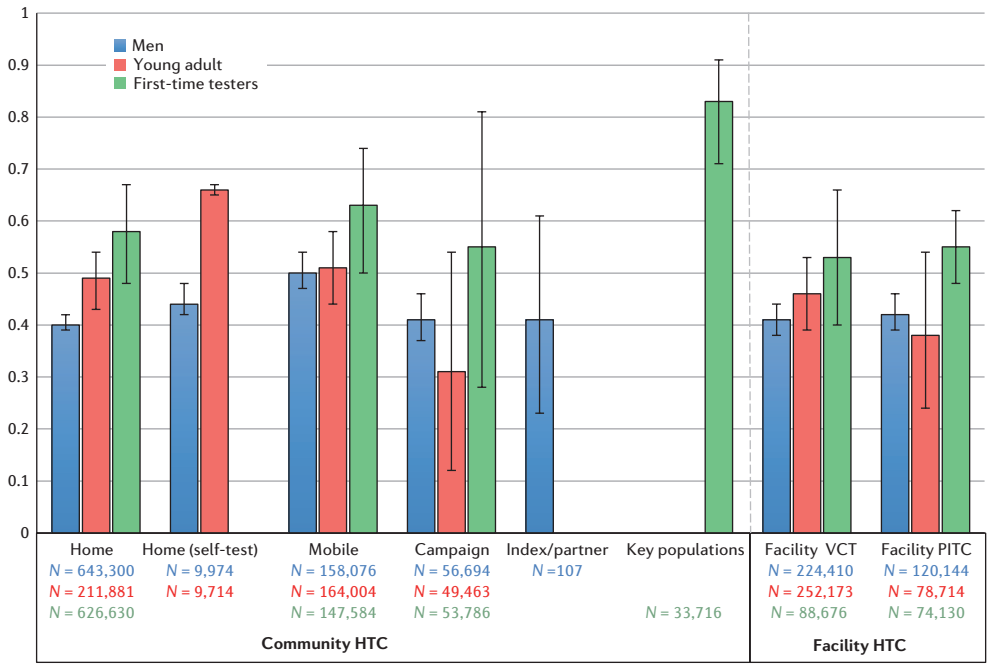

Figure 2 | Pooled percentage of men, young adults and first-time testers by HIV testing and counselling (HTC) modality. Bars indicate 95% confidence intervals of random effects meta-analyses. *N*, sample size. PITC, provider-initiated testing and counselling; VCT, voluntary counselling and testing.

transformation was used because of convergence issues. Heterogeneity was quantified using the I^2 statistic. For modalities with enough data (ten studies or more), trends were examined by year before 2005 (when the HIV rapid diagnostic test was introduced), country and facilitated linkage. Analyses were conducted in R software using the metaprop function in the meta package[28].

RESULTS

We identified 126 eligible studies out of 2,520 abstracts (Supplementary Figure S0.a). Overall, 64% of studies were rated moderate or high quality (Supplementary Information 2). Most studies included in our analysis evaluated facility and home HTC. We identified far fewer studies on other types of community HTC: home with self-testing (n = 2), workplace with self-testing (n = 2), index partner/family member (n = 5), key populations (n = 5), campaign (n = 5) and workplace (n = 4). Forest plots of each outcome by modality are provided in the Supplementary Information with pooled estimates presented here. I^2 values of pooled estimates varied from 90% to 100%, reflecting high heterogeneity in study designs and countries included (Supplementary Information). The countries represented varied by outcome with the greatest number of countries having data for home and facility HTC coverage, uptake and tester demographics. Far fewer studies reported CD4 count at diagnosis and linkage to care outcomes; studies containing these data were mainly conducted in South Africa, Kenya and Uganda. All home self-testing studies were conducted in Malawi and the most key population studies were conducted in Nigeria. Overall, the largest number of studies were conducted in South Africa.

Coverage and uptake

Coverage was reported in 19 home HTC studies[15,18,29–45], 1 mobile[13], 2 campaign[46,47], 3 index partner/family member[48–50], 5 facility VCT[51–55], and 5 facility PITC studies[56–61]. Overall, community HTC modalities achieved higher coverage than facility, with home (70%, 95% CI = 58–79) and campaign (76%, 95% CI = 49–95%) having the highest population coverage (Fig. 1). Home HTC consistently achieved high coverage across 19 studies, whereas campaign coverage was also high, but based on only two studies. Pooled coverage was 37% (95%, CI = 33–42%) for mobile HTC, from 1 study conducted in 3 countries (South Africa, Tanzania and Zimbabwe). Coverage of index HTC was heterogeneous depending on target group (family members or sexual partners) and type of contact tracing (active or passive referral). Figure 1 shows results for sexual partner tracing only (41%); full results are shown in Supplementary Figure S18. Facility VCT (15%, 95% CI = 9–21%) and PITC (18%, 95% CI = 18–31%) attained the lowest coverage.

Uptake was reported in 31 home HTC studies[5,14,15,18,27,29–38,40–45,53,62–74], 2 home with self-testing[11,75], 2 mobile[10,68], 3 index partner or family member[48–50], 4 campaign[46,47,76,77], 3 workplace[78–80], 3 facility VCT[54,56,81], and 11 facility PITC studies[56,57,59,60,81–87]. Overall, community modalities had high uptake (Fig. 1). Home HTC had a pooled uptake of 82% (95% CI = 76–87%) and home with self-testing had slightly lower uptake (69%, 95% CI = 59–78). Mobile and campaign had the highest uptake (both 97%). Index uptake was 89% (95% CI = 88–90%) for home testing of family members (Supplementary Figure S10) and 52% for sexual partners (95% CI = 30–71%; Fig. 1). Uptake for facility VCT was defined as number tested divided by number referred for VCT by provider, for facility PITC it was defined as number tested divided by number offered PITC. We found higher uptake for people given routine PITC (73%, 95% CI = 55–87%) compared with those referred to on site VCT (26%, 95% CI = 15–39%).

Demographics of testers

The percentage of men out of total persons tested was reported in 25 home HTC studies[5,14,18,29,31,32,37,38,41–45,63,64,66,68–72,88–90], 2 home with self-testing[11,75], 10 mobile[10,13,68,72,91–99], 3 index partner[47,49,88], 3 campaign[46,47,76], 2 workplace[100,101], 20 facility VCT[52,54,61,64,81,88,89,92,93,95,96,98,102–107], and 13 facility PITC[58,60,82–84,86,99,108–113] (Fig. 2). Mobile had the highest percentage of men (50%, 95% CI = 47–54%), whereas home had the lowest for general population HTC (40%, 95% CI = 39–41%). Index partner testing had 41% men (95% CI = 23–61%), but varied greatly by tracing strategy; active tracing had 50% men whereas passive clinic referral had only 15% (Supplementary Figure S18). Facility VCT and PITC both had 42% men.

Percentage of participants reporting testing for the first time was included in 20 home HTC studies[5,14,18,29,31,32,38,41–44,63,65,66,68–72,88], 11 mobile[10,12,68,93–95,97,103,114], 3 campaign[46,47,77], 3 key populations[25,115,116], 7 facility VCT[12,54,91,93,95,106], and 5 facility PITC[58,86,88,111,112]. Pooled percentages of first-time testers were higher for community than facility modalities (Fig. 2). Percentages varied by country, with South Africa consistently having the lowest percentage of first-time testers across modalities (Supplementary Figures S23–S27). Key population interventions had the highest proportion of first-time testers (83%, 95% CI = 71–91%), and mobile had the highest percentage among the general population (63%, 95% CI = 50–74%). Home HTC had 58% first-time testers (95% CI = 48–67%), and campaign had 55% (95% CI = 20–91%), but was highly variable depending on the setting (Supplementary Figure S25). Facility VCT had 53% (95% CI =

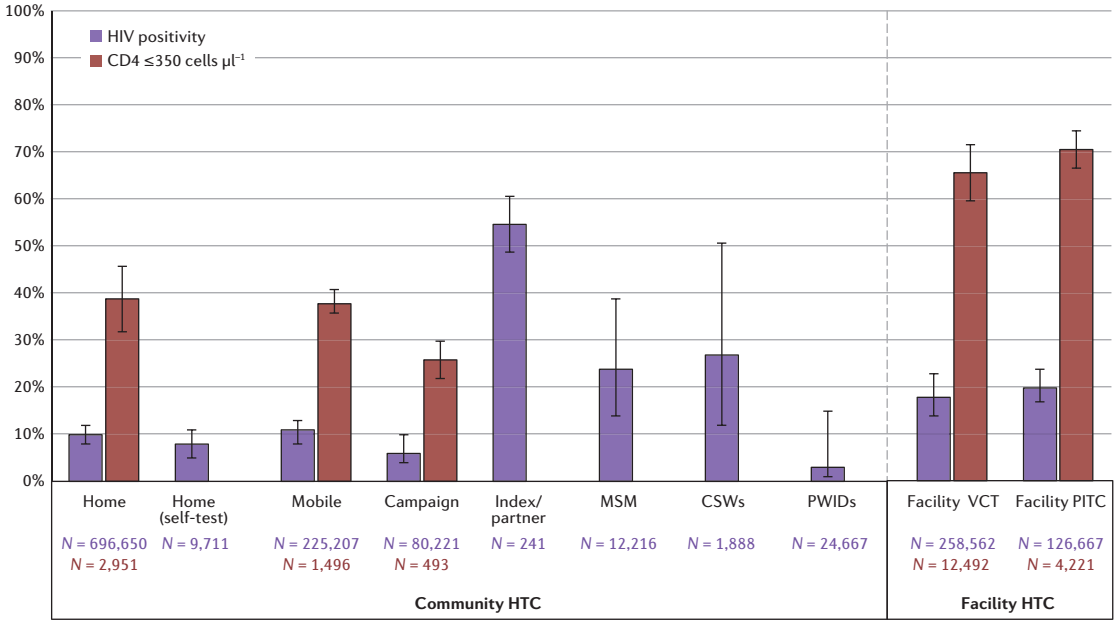

Figure 3 | Pooled HIV positivity and proportion of newly diagnosed HIV positivity with CD4 count of 350 cells μl^{-1} or less by HIV testing and counselling (HTC) modality. Bars indicate 95% confidence intervals of random effects meta-analyses. *N*, sample size. CSWs, commercial sex workers; MSM, men who have sex with men; PITC, provider-initiated testing and counselling; PWID, people who inject drugs; VCT, voluntary counselling and testing.

40–66%) and PITC had 55% (95% CI = 48–62%) first-time testers.

The percentage of young adults testers (either under 25 or 30 years) was reported in 17 home HTC studies[5,18,29–31,35,37,38,45,63,64,68–70,73,74,90,117], 1 home with self-testing[11], 13 mobile[10,12,13,68,91,93,95–97,103,107,114], 2 index partner[48,88], 2 campaign[47,77], 20 facility VCT[12,51,52,54,64,88,89,91–93,95,104–107,114,118–120], and 6 facility PITC[58,82,86,88,110,113]. Results varied considerably by study (Supplementary Figures S29–S35). Community HTC generally tested a higher proportion of young adults than facility modalities; home with self-testing had the largest percentage (66%, 95% CI = 65–67%), followed by mobile, and then home (Fig. 2). Campaign reported 31% of young adults, but varied from 20–50% depending on the study (Supplementary Figure S32). Facility VCT had 46% (95% CI = 39–53%) and PITC had 38% (95% CI = 39–53%).

HIV positivity and CD4 count ≤350 cells ml^{-1}

Yield of HIV-positive people (HIV positivity) was reported in 29 home studies[14,15,18,27,29–32,34,36,38,41–45,63,65,66,68,70–73,88,89], 1 home with self-testing[11], 12 mobile[10,13,68,72,92–95,97,98,103,107,114], 5 campaign[46,47,76,77,120], 3 workplace[79,80,121], 4 key population[12,115,116,122], 4 index partner[48–50,88], 27 facility VCT[54–56,64,81,84,88,91–93,95,98,102,104–107,114,118–120,123–127], and 17 facility PITC[56,57,59,60,81,83–88,99,110–113,126] studies. Community-based strategies for the general population had lower HIV positivity (6–11%) than facility HTC (18–20%), whereas targeted community HTC for key populations and sexual partners of index patients had the highest HIV yield (Fig. 3). HTC interventions targeting sexual partners of index cases had 55% positivity (95% CI = 49–61%), those for MSM had 24% (95% CI = 14–39%), for CSWs had 27% (95% CI = 12–51%), and interventions targeting PWIDs had the lowest positivity of 3% (95% CI = 1–15%). Index HTC for family members had similar HIV yield to home and mobile HTC (9%, 95% CI = 5–14%) (Supplementary Figure S42). Forest plots of HIV positivity for each modality stratified by country are shown in Supplementary Figures S36–S44). HIV positivity for community HTC in the general population largely mirrored prevalence of the country where the study was conducted, with the exception of four countries with the highest prevalence: Mozambique, Swaziland, Botswana and Lesotho. These countries have adult HIV prevalence ranging from 22 to 27% (ref. 128), but HIV yield from home, mobile and campaign HTC was 5–12%. HIV positivity for facility VCT and PITC was generally higher than prevalence in the general population.

The proportion of individuals with a CD4 count of 350 cells μl^{-1} or less at HIV diagnosis was reported in 7 home[14,38,42,43,65,72,73], 3 mobile[91,94,114], 3 campaign[46,47,76], 8 facility VCT[60,81,107,126,127,129–131] and 5 facility PITC studies[61,81,99,126,130]. Community-based strategies identified HIV-positive individuals at higher CD4 counts than facility HTC, with campaign having the lowest proportion with a CD4 count of 350 cells μl^{-1} or less (26%, 95% CI = 22–30%) (Fig. 3). Home (39%, 95% CI = 32–46%) and mobile (38%, 95% CI = 36–41%) had similar proportions of HIV-positive individuals with a CD4 count of 350 cells μl^{-1} or less, whereas facility VCT (66%, 95% CI = 60–72%) and PITC (71%, 95% CI = 67–75%) had the highest proportion.

Linkage and retention in care for HIV-positive people

Linkage to care was defined as visiting a clinic for community HTC and returning to the clinic to obtain CD4 count results (or enrolling in pre-ART care) for facility HTC. Linkage was reported for ten home[14,15,29,34,41–43,65,72,132], six mobile[72,91,92,94,133–135], two campaign[76,77], eight facility VCT[56,81,84,91,92,123,126,136] and five facility PITC studies[60,84,87,111,126]. Home and campaign interventions achieved a high proportion of individuals linked (95%, 95% CI = 87–98%) when paired with facilitated linkage to care strategies (for example, lay-counsellor follow-up to encourage clinic visit); interventions without facilitated linkage achieved lower proportions of HIV-positive individuals visiting a clinic (26%, 95% CI = 18–36%) (Fig. 4). Mobile HTC achieved linkage rates of 37% (95% CI = 24–51%); rates were highest in two interventions conducted in South Africa, one or which used incentivized monetary recruitment and another which used a call centre to encourage linkage after HTC[94,134]. Linkage to care from facility VCT was 61% (95% CI = 48–72%) and from PITC was 55% (95% CI = 39–71%) (Fig. 4). Time from HTC to linkage to care ascertainment varied by study (ranging from 1 to 12 months); the method of ascertainment (participant self-report or clinic record) also varied.

Four home HTC studies reported ART initiation among those eligible[14,41,43,65]. Similar to linkage to care, ART initiation was higher in home interventions with facilitated linkage (76%, 95% CI = 68–82%) compared with those without facilitated linkage (16%, 95% CI = 12–20%) (Fig. 5). ART initiation rates after home HTC with facilitated linkage were similar to those achieved through facility HTC. Initiation among those eligible was 64% (95% CI = 54–72%) in facility VCT and 70% (95% CI = 61–78%) in facility PITC, with 3 studies reporting initiation rates for VCT[61,126,130] and 4 for facility PITC[60,81,84,87,111]. Self-testing showed an ART initiation rate of 29% (95% CI = 17–45%), although this number is among all HIV-positive individuals and is not restricted to those who are ART eligible because point of care CD4 testing was not conducted[11] (Supplementary Figure S55).

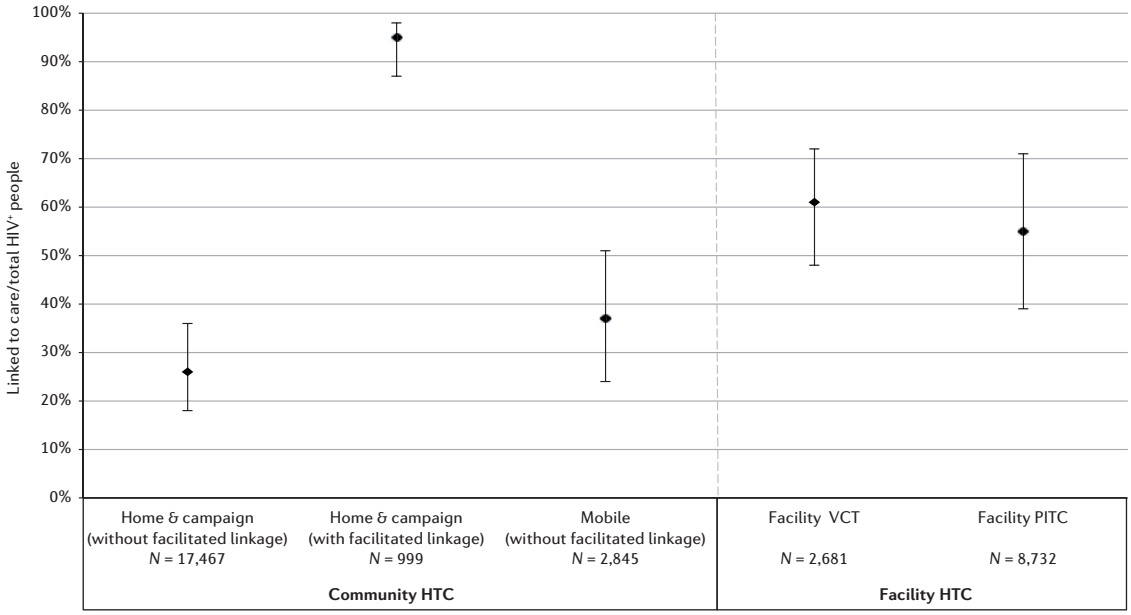

Figure 4 | Linkage to care after community and facility HIV testing and counselling (HTC). Bars indicate 95% confidence intervals of random effects meta-analyses. *N*, sample size. PITC, provider-initiated testing and counselling; VCT, voluntary counselling and testing.

One study reported retention in care at 12 months after ART initiation for home HTC[14] and two studies of both facility VCT and PITC reported retention — one at 6 months[60] and one at 12 months[130]. Not surprisingly, linkage rates were higher in the 6-month compared with the 12-month retention study (Supplementary Figure S59). Retention was highest for home HTC, although the sample size was small (93%, 95% CI = 83–97%) (Fig. 5). Facility VCT achieved 53% (95% CI = 32–71%) retention, and PITC retention achieved 64% (95% CI = 32–90%).

Cost per person tested

The average cost per person tested (2012 US dollars) for community HTC was $27.38 for mobile, $16.60 for index, $11.17 for campaign and $8.58 for home HTC[88,93,103,137–141] (Supplementary Table S2 and Figure S61). The cost per person tested was highest for stand-alone VCT ($36.78)[88,93,142]. Hospital and clinic HTC had similar costs ($12.56 and $12.32, respectively)[81,88,93,140,142–147] (Supplementary Table S3 and Figure S62). Costs were dependent on the country where the study was conducted, the costs that were included (start-up or ongoing only) and the intervention scale.

DISCUSSION

Across modalities, community HTC successfully reached target groups (men, young adults and first-time testers) with higher coverage than facility HTC (Table 1). High uptake of community HTC reflects acceptability of testing outside of health-care facilities. Community HTC identified HIV-positive individuals with higher CD4 counts who were likely to be earlier in their disease course. Combined with the potential of community HTC with facilitated linkage to achieve high linkage to treatment with similar retention rates as facility HTC, this suggests that scaling up community interventions could reduce the morbidity, mortality and transmission associated with late or non-initiation of ART. Although community interventions test a large number of HIV-negative individuals, HTC can reduce risky sexual behaviour[74] and provide a means to link uninfected persons to primary prevention. This is particularly crucial for young women, who have high HIV incidence and can benefit from PrEP[21]. Preventing HIV infections averts future treatment costs as well as morbidity. A recent modelling study found that ART scale up should be combined with primary prevention such as PrEP to achieve maximum HIV reduction[148]. High coverage of HTC can also reduce stigma around testing.

Each HTC modality reaches distinct subpopulations and a combination of strategies will probably be necessary to achieve high ART coverage. Mobile and campaign HTC had high uptake (97%), as individuals who present at a mobile van or during a campaign are probably seeking out testing, but home HTC also achieved high uptake among people who were offered testing (82%). Home HTC also attained high population coverage, probably because offering testing door-to-door removes substantial barriers, including eliminating the need to actively seek out HIV testing[149]. However, home HTC is less likely to reach men and young adults. A recent home HTC intervention in Botswana reached 85% of women in the target population compared with just 50% of men[150]. This may be because women are more likely to be home at times when the intervention is conducted.

Campaign HTC has the potential to attain high coverage in large catchment areas and identify HIV-positive individuals at high CD4 counts (one-third of newly diagnosed HIV-positive individuals had a CD4 count of 350 cells μl^{-1} or less compared with two-thirds or more for facility HTC). The multidisease focus of campaigns may reduce stigma of HIV testing interventions. Our results suggest that campaign HTC can be a successful strategy for countries seeking to increase overall testing coverage in a short time frame.

Home HTC with self-testing reached the greatest proportion of young adults of all modalities examined[11] and is a promising strategy with high uptake[151]. Young adults (age 15 to 24 years) represent 39% of new infections in those over 15 years old[23], but have lower access to HTC and HIV care and poorer clinical outcomes than other age groups[24]. Home HTC with self-testing had slightly lower coverage and reached fewer first-time testers than home HTC administered by counsellors. The World Health Organization recommends HIV self-testing as an option for individuals who are unable or unwilling to receive counsellor-administered HTC. However, supervision improves interpretation of results[151] and a reactive self-test should not be considered a definitive diagnosis, as standard testing is needed to confirm results. More studies evaluating linkage to care following a positive self-test are needed[16].

Mobile HTC is the most effective strategy for reaching men — a target group in sub-Saharan Africa. Men are more likely to be lost at each step of the HIV treatment cascade; they are less likely to undergo testing, more likely to start ART at an advanced disease stage and more likely to interrupt treatment — all of which leads to increased morbidity and mortality[22]. Qualitative studies highlight men's preference to test outside of facilities[152], so scale up of community interventions can meet this need. Future studies could investigate HTC at predominantly male workplaces, nightclubs or bars.

Index testing of sexual partners through active contact tracing is an efficient high-yield method that should be scaled up. HIV positivity was 55% in this group and the intervention attained a high coverage (41%). The HIV prevalence we

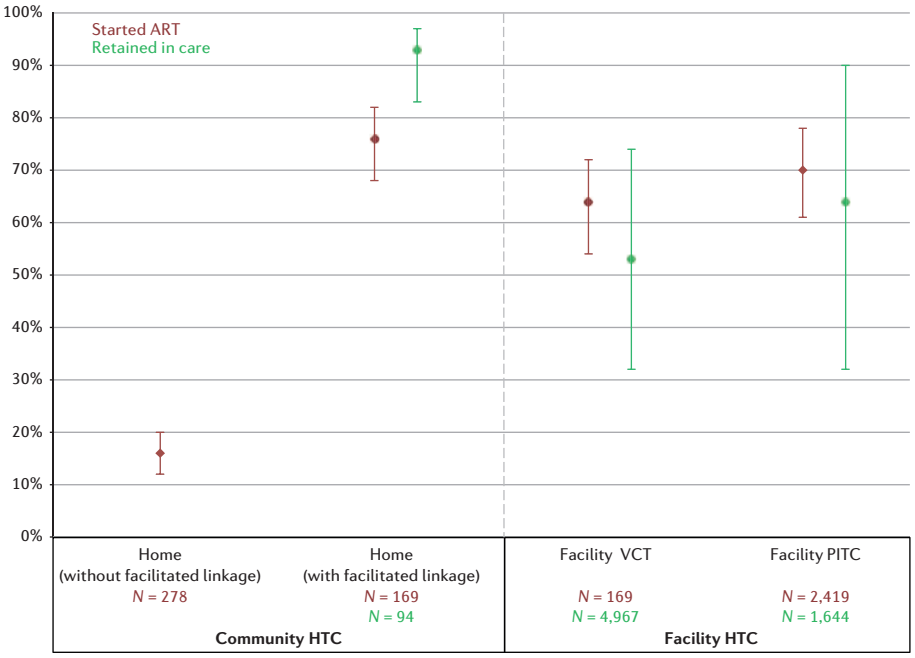

Figure 5 | Pooled percentage initiated antiretroviral therapy (ART) between those eligible and retained in care among those who initiated ART. Bars indicate 95% confidence intervals of random effects meta-analyses. *N*, sample size. PITC, provider-initiated testing and counselling; VCT, voluntary counselling and testing.

report is similar to that found in the literature — 45–50% in cohabitating partners of HIV-positive adults, most of whom are unaware of their status[48]. Interestingly, high coverage of males was achieved only through active contact tracing, whereas passive tracing identified more women (Supplementary Figure S18).

Facilitated linkage strategies are a key component of successful community-based HTC. Individuals testing at an HIV facility generally have higher rates of linking to care and initiating ART than those who test outside the health-care system. However, we found that high linkage rates (comparable with, or higher than, facility HTC) can be achieved with community HTC when individuals are followed-up to encourage linkage.

Although scaling up community HTC with facilitated linkage is important, the benefits of improving facility HTC coverage should not be overlooked. Consistent with previous studies, our analysis finds opt-out facility PITC had much greater uptake than referring patients to VCT[56]. However, coverage of PITC in health facilities is low, demonstrating missed opportunities to identify HIV-positive individuals and to link them to care. For example, a Ugandan hospital reported only 50% of inpatients with HIV-related diagnoses were tested for HIV before leaving the hospital[86]. PITC is an underused strategy in sub-Saharan Africa and scaling up testing would provide a safety net for those who do not independently seek HTC[61,112]. Because PITC identifies mainly symptomatic HIV-positive individuals with low CD4 counts as well as those with health-care access, it should be coupled with other modalities to maximize population coverage.

Our review identified gaps where additional evidence is needed. A large proportion of CD4-count and linkage data came from South Africa, with Uganda and Kenya also well represented. South Africa has the lowest percentage of first-time testers, reflecting the successful scale-up of HTC. There are fewer studies from other parts of sub-Saharan Africa, which may limit how much the pooled estimates can be generalized. Also, few studies followed patients longitudinally and measured linkage to care, ART initiation, retention and viral suppression. In addition, although many studies evaluated home HTC, more data are needed for other community modalities, including campaign and workplace.

Data were also limited for key populations. Despite having an HIV prevalence up to eight times higher than the general population, interventions for key populations are scarce and scale up is urgently needed[115,153]. Key population interventions can reduce the spread of HIV in the general population[154]. Currently, numerous policy barriers exist that restrict the availability and access of HIV-related services for MSM and CSWs, including police harassment and criminal laws[155]. Only three HTC interventions were targeted to MSM and only one was targeted to CSWs and PWIDs. Most key population HTC studies were from Nigeria; data are needed from other parts of sub-Saharan Africa. We report a high HIV positivity combined with a high proportion of first-time testers in MSM and CSW groups, highlighting the need for service expansion. We found a lower HIV prevalence in PWIDs compared with MSM and CSW groups, reflecting sexual transmission as the main mode of HIV spread in sub-Saharan Africa. Successful HTC programmes for key populations are community based (particularly mobile) as many high-risk groups are marginalized and do not have access to conventional health systems[122]. Community-based HTC for MSM and PWIDs have been shown to have higher acceptance and greater HIV yield than clinic referral for HTC[115]. In addition, self-testing is a potential strategy to reach key populations, as it demonstrates high acceptability and is considered convenient and private[156].

Costs of community-based and facility-based HTC vary by modality, country, scale of intervention, linkage strategy and costs included. Generally, community-based HTC and integrated facility HTC costs were comparable. However, stand-alone HTC had the highest cost per person tested, indicating that integrated HTC may be more cost-efficient than stand-alone services (Supplementary Table S3).

The limitations of our analysis included the heterogeneity across studies, which may not be accurately reflected in the pooled estimates. Differences in study design, geographical location (country, urban or rural area) and intervention year added to the heterogeneity. To address this, we used random effects meta-analysis and stratified on key variables (year <2005, country and facilitated linkage). In addition, large numbers of HIV-positive individuals were lost to follow-up in studies that reported linkage, so we considered these individuals unlinked in our analyses. If individuals linked at another clinic, our estimates may be conservative[157]. Furthermore, assessment of linkage to care differed by study (self-report or clinic records review), as did time to linkage assessment, which varied from 1 to 12 months after HTC. In addition, CD4 count at diagnosis and ART uptake among those with eligible CD4 counts could only be assessed in community HTC interventions employing point-of-care CD4, as studies that report CD4 only for those visiting a clinic would not provide accurate denominators. Only studies reporting linkage to care among those eligible for ART were included in our main analysis. Also, estimates of coverage vary in their precision because some studies conducted population enumeration and others used census estimates of the catchment area. Finally, proportion of first-time testers, men and young adults tested are crude measures of relative uptake. For example, for home HTC, it is not possible to discern whether the 40% of those tested being

Table 1 | Summary of HIV testing and counselling coverage and tester demographics.

Parameter	Home		Mobile		Self-testing (home)		Campaign		Index		Key populations		Facility VCT		Facility PITC	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Coverage (accepted/ target population)	70	58–79	37	33–42			76	49–95	41	26–57			15	9–21	18	8–31
Uptake (accepted/ offered)	82	76–87	97	94–99	69	59–78	97	93–99	50	31–71			26	15–39	73	55–87
Young adult (age <25 or 30)	49	43–54	51	44–58	66	65–67	31	12–54					46	39–53	38	24–54
Men	40	39–42	50	47–54	44	42–48	41	37–46	41	23–61			41	38–44	42	39–46
First-time testers	58	48–67	63	50–74			55	28–81			83	71–91	53	40–66	55	48–62
CD4 ≤350 cells μl^{-1}	39	32–46	38	36–41			26	22–30					66	60–72	71	67–75
HIV positivity	10	8–12	11	8–13	8	5–11	6	4–10	55	49–61	16	9–26	18	13–23	20	17–24

CI, confidence interval; PITC, provider-initiated testing counselling; VCT, voluntary counselling and testing

men reflects a lower coverage of men, or a greater coverage of women, or a combination of the two. Future studies reporting the number of men, first-time testers and young adults offered testing compared with those accepting testing would increase the accuracy of these measures. Our findings on uptake, HIV positivity and CD4 count at diagnosis are similar to a previously published meta-analysis[9].

This analysis characterizes linkage and populations reached by HTC modalities to inform policymakers who are charged with addressing gaps in testing. Facility HTC, although important, is unlikely to be sufficient to curb the HIV epidemic because many people in sub-Saharan Africa do not have regular access to health care. Scaling a combination of community HTC, mobile testing to reach men, self-testing to reach young adults and outreach to high-risk populations, as appropriate to the local epidemic setting, is crucial to achieve high knowledge of serostatus and linkage to HIV treatment and prevention in sub-Saharan Africa.

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SUPPLEMENTARY MATERIAL

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ADDITIONAL INFORMATION