

The 4 youth by youth (4YBY) crowdsourced HIV prevention intervention: A stepped-wedge longitudinal trial on HIV self-testing uptake among adolescents and young people in Nigeria

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ABSTRACT

Adolescents and young adults (AYAs) participatory approaches for HIV control have increased across LMICs, but there are few trials to evaluate effectiveness. We assessed a crowdsourced HIV self-testing (HIVST) intervention among a cohort of AYA in Nigeria.

Methods: We conducted a pragmatic stepped-wedge cluster randomized control trial recruiting participants (aged 14–24 years) from 32 local government areas across four geo-political zones in Nigeria. Eligible AYA were HIV negative or unknown HIV status, residing in study sites, spoke English, and consented. Areas were randomly assigned to one of four steps and AYA were followed for 24 months. AYA research facilitators implemented a 4YBY crowdsourced HIV prevention bundle. The primary outcome was self-reported HIVST uptake. We compared the probability of HIVST between the control and intervention periods using a generalized linear mixed model. We examined the fixed cost and per capita cost of the intervention. The protocol was registered with Clinical [Trials.gov](https://www.clinicaltrials.gov) on January 15, 2021, under registration NCT04710784.

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Results: 2652 AYA were screened, and 1500 were enrolled in the study (March 10, 2021– August 31, 2023). 1333/1500 (89 %) were followed up at 24 months. The mean age of AYA was 20 ± 2.65 years old, most were students (1155/1500, 77 %), and unemployed (915/1500, 61 %). The intervention led to a 9.96-fold increase in HIV self-testing uptake compared to the control period (95 % CI: 8.36–11.85, $p < 0.0001$). The annual fixed cost of the intervention was estimated at US\$42,237, with a per capita testing cost of US\$14.8. No significant adverse events were reported.

Conclusion: A crowdsourced HIV prevention intervention increased HIVST uptake among Nigerian AYA. Greater participation of AYA in the design and implementation of clinical trials is needed to achieve UNAIDS targets.

1. Background

Achieving the first global target of diagnosing 95 % of people living with HIV, particularly adolescents and young people (AYAs) aged 14–24, there is a critical need for innovative, decentralized HIV testing strategy in community settings [1–3]. Traditional HIV prevention programs have been developed without meaningful participation from AYA, which has led to poor uptake of clinic-based services, including HIV testing [4–6]. In Nigeria, AYA face significant HIV prevention gap, with only 1 in 5 are being tested for HIV, despite being at high risk [7–9]. Barriers exist at multiple levels, including individual (fear and low perceived risk), social (insufficient social support), and structural (poor access to testing) [9].

Although participatory approaches to HIV prevention have gained traction, it remains unclear which strategies are most effective in increasing HIV testing. The relative absence of AYA-friendly HIV prevention programs in Nigeria underscores this gap [8,9]. HIV self-testing (HIVST) offers a promising solution by decentralizing HIV testing, decreasing stigma, and facilitating access to prevention services for those who test negative, while linking those who test positive to treatment and care and those testing positive to treatment and care [10]. HIVST allows individuals to collect their specimens in privacy and interpret their results. Recognizing the expanding evidence supporting HIVST, the World Health Organization [10] and Nigerian National AIDS Control Agency recommend scaling up HIVST [11].

AYA-focused participatory research has begun to increase AYA participation by increasing AYA agency in the research process [6,12]. This approach recognizes youth as experts and knowledge producers in their own experiences, uniquely positioned to understand and successfully navigate barriers to the uptake of interventions designed for them [9,12]. Nonetheless, despite the need for youth-friendly HIV prevention services that actively engage youth, few interventions have been designed and implemented with the youth themselves as the best experts to guide these efforts.

We conducted a pragmatic stepped-wedge cluster randomized control trial to test the hypothesis that a multi-faceted, crowdsourced campaign designed for youth by youth (4YBY) to promote the uptake of HIVST and other essential HIV prevention services, including linkage to sexually transmitted infections (STI) testing, linkage to treatment, and pre-exposure prophylaxis (PrEP) leads to increased HIV testing and testing for other STIs [9]. Crowdsourcing involves having a group (i.e. young people) develop solutions to a problem and disseminate these solutions to a broader public [13]. From 2018 to 2019, we conducted a series of crowdsourcing and other co-creation activities with youth input to design and pilot a 4YBY bundle of HIV prevention services [8,14–17]. We report here on the use of a stepped-wedge cluster randomized control trial to evaluate whether the crowdsourced intervention increases the uptake of HIVST among Nigerian youth [9]. We used a stepped-wedge design to facilitate a gradual and naturalistic implementation, investigate how the intervention's impact develops over time once it is introduced into a cluster, and avoid contamination between clusters [18]. We also examined the cost of the multifaceted campaign. We hypothesized that a crowdsourced HIV self-testing campaign tailored to AYAs' needs would be cost-effective. Findings provide critical information for scaling and sustaining HIVST programs for young people in the

context of high rates of new HIV infection among AYA in Nigeria.

2. Methods

This study was conducted and reported in accordance with the CONSORT extension for Stepped-Wedge Cluster Randomized Trials (SW-CRTs) to ensure transparency, completeness, and methodological rigor [18]. The CONSORT extension provides specific guidelines for reporting SW-CRTs, including the justification for the use of the stepped-wedge design, details of the cluster randomization process, sequence generation, and allocation concealment. (See Supplementary File 1 for the CONSORT checklist).

2.1. Design and setting overview

The 4YBY project was a crowdsourced HIV prevention intervention designed with AYA to increase the uptake of HIVST [9]. A stepped-wedge cluster randomized controlled trial of the crowdsourced intervention was implemented in 32 local government areas in Nigeria. The overall goal was to explore whether a youth-friendly and youth-driven intervention would increase the uptake of HIV self-testing among Nigerian youth aged 14–24 [9]. In this study, each LGA had a pre-implementation phase to prepare for the intervention's implementation, a three-month period of implementation, and a post-implementation phase that lasted for 24 months. Methodological details are described in a published study protocol and briefly described below [9].

2.2. Participants' inclusion and exclusion criteria

Nigerian youth aged 14–24 years were included in the trial. Additionally, participants who self-reported as HIV negative or unknown HIV status, those currently or planning to reside in one of the 30 areas during the next 24 months, and those able to complete the survey in the English language, the official language in Nigeria, and those who agreed to informed consent [9]. To ensure adequate follow-up rates, participants were required to provide their mobile cell phone numbers. Participants younger than 14 and older than 24 were excluded from the study. Also, participants without mobile phones for follow-up and retention, those who did not provide informed consent or follow study protocol, and those who presented with illness, cognitive impairment, or threatening behavior with acute risk to self and others were excluded from the study [9].

2.3. Recruitment

2.3.1. Randomization and follow-up assessment

According to the stepped-wedge protocol, the 32 LGAs were stratified per geo-political zones in Nigeria (Northeast, Southeast, South-South, and Southwest). Each LGA within each zone was then randomized in groups of four steps and assigned randomly to either the first, second, third, or fourth step, indicating when they would start the pre-implementation, implementation, and post-implementation activities for the 4YBY intervention. A study statistician randomized each of the 32 local government areas to one of four steps in the stepped-wedge

design using a computer-generated algorithm. The steps lasted three months, with a 1-month transition between each step. Following randomization, all sites began recruiting participants assessed at baseline, 3-, 6-, 12-, and 24-month follow-up after intervention implementation. Recruitment began in April 2021 and ended in August 2021. The 24-month follow-up ended in August 2023. The youth research facilitators conducted all baseline and follow-up interviews [9].

2.3.2. Intervention period

The 4YBY intervention included a packaged of bundled services crowdsourced by young Nigerians to increase HIVST uptake [9]. The HIVST bundle contained AYA-friendly assets such as information about HIVST, with instructions on photo verification of test results, male and female condoms, male or female hygiene products, linkage to AYA-friendly clinics for confirmatory HIV testing, STI testing and PrEP referrals and peer support for repeat HIV testing [9]. Two AYA research assistants were recruited from all the local government areas ($n = 64$) to implement the 4YBY package and provide peer support in promoting HIVST uptake. The AYA research assistants received training and supervision that included: 1) participatory learning communities, which consisted of monthly virtual meetings to support change and improve the quality of the 4YBY implementation; 2) sessions on peer support provision and technical assistance with intervention implementation from 4YBY AYA ambassadors who also worked as peers to the research assistants, checking in via one-on-one support or group conversations to support ongoing implementation activities; and 3) on-site supervision, guidance, monitoring and feedback to the AYA research facilitators, led by supervisors and research coordinators within the Nigerian Institute of Medical Research ($n = 34$) [9].

2.3.3. Control period

All the LGAs started as the control period, where baseline data was collected and standard health education about healthy living without any specific implementation program to foster HIVST. Each of the 32 local government areas served as its control condition before they were transitioned to the intervention per the randomization schedule.

2.3.4. Outcomes

We report here only on the primary outcome (HIVST uptake from baseline to 24 months) as well as secondary outcome measure of cost-effectiveness (i.e., the cost per client of HIV prevention services delivered; cost per HIV infection and STIs averted). The primary outcome was ascertained by self-report because of the inadequacy of digital tools (mobile phone application, USSD) to accurately determine test uptake in low-bandwidth settings, such as informal settlements.

2.4. Statistical analysis

We compared the uptake of HIV testing (specifically HIVST) from the baseline period (pre-implementation phase) with the implementation and post-implementation periods. Individual-level baseline data taken from eligible participants were analyzed against data collected at baseline, 3-month, 6-month, 12-month, 18-month, and 24-month follow-ups. Descriptive analysis was used to summarize the characteristics and behaviors of the participants at baseline and follow-up surveys. We examined the hypothesis comparing the superiority of the intervention with pre-intervention periods using the stepped-wedge cluster randomized control design. This analysis was accomplished with generalized linear mixed models to account for the within-person factor – time (baseline, 3-month, 6 months, 12 months, 18 months, and 24 months) and one primary between-person factor. Given that the calendar time may be associated with both the intervention exposure and outcomes, we included time in the analysis as a potential confounder. Also, the length of the time that each cluster has been exposed to the intervention was analyzed as a possible effect modifier. The three-level model is structured as observations nested within

subjects that are nested within local government areas. Analytic software SAS version 9.4 (PROC GLIMMIX) with logit as link function was used to compute full information maximum likelihood (FIML) estimates of the model parameters. The model included the intervention status and time as fixed effects and site (local government areas) and individuals as random effects and the interaction between site and (time - s) where s is the number of months at which the intervention starts. The estimated intervention effects were reported using odds ratios with 95 % CIs and p values. The generalized linear mixed models proposed for the primary and secondary analyses also incorporate an assumption of data that are missing at random (MAR). Using sensitivity analyses, we assessed the impact of different assumptions about the missing data mechanism and explored the robustness of trial results to these different assumptions. A full description of statistical analysis is described in the study protocol [9].

2.5. Cost-effectiveness component

We evaluated costs associated with intervention preparation and implementation using a micro-costing approach and reported costs in US \$ (2022). Based on the cost survey, we collected data on staff numbers, salary scales, quantities and unit prices of laboratory equipment and other supplies, and training and promotional costs to calculate the fixed costs of the intervention. We excluded research-related costs. We assumed a 5-year life expectancy for equipment and used a 3 % discount rate for annuity calculations. We also collected unit prices for the components of the HIVST bundle to calculate the variable cost of the intervention, which is the cost of testing per person. The analysis was conducted from the health-care provider's perspective. We reported the fixed cost of the intervention per year as well as the cost of testing per person.

2.6. AYA engagement

AYA were engaged following UNICEF's guidelines for meaningful participation across four areas. Space was created through open calls, participatory judging, and learning communities [19]. Influence was established by involving AYA in intervention design, implementation, and as co-authors on publications. Voices were amplified via WhatsApp inclusion in the AHISA conference and the 4YBY Instagram page. The Audience was specifically tailored for Nigerian AYA, enhancing relevance and ownership.

2.7. Ethical considerations

The protocol was registered with Clinical [Trials.gov](https://www.clinicaltrials.gov) on January 15, 2021, under registration NCT04710784. The trial was approved by Saint Louis University approved this trial, the Nigerian HREC and the Nigerian Institute of Medical Research Institutional Ethical Review Boards.

3. Results

2652 participants were recruited, and 1500 were enrolled and divided into four groups, each receiving intervention at different steps within three months (See [Fig. 1](#)). Based on the randomization schedule, 398 participants were assigned to the first step (Group 1), 346 participants to the second step (Group 2), 398 participants to the third step (Group 3), and 345 participants to the fourth step (Group 4). Over three months, Groups 1 through 4 received the intervention at different times (steps), with each group receiving the intervention once.

3.1. Descriptive characteristics

[Table 1](#) highlights the sociodemographic characteristics among 1500 participants, with an average age of 19.83 years. Most participants (68.6 %) had completed secondary education. Students comprised 77 %

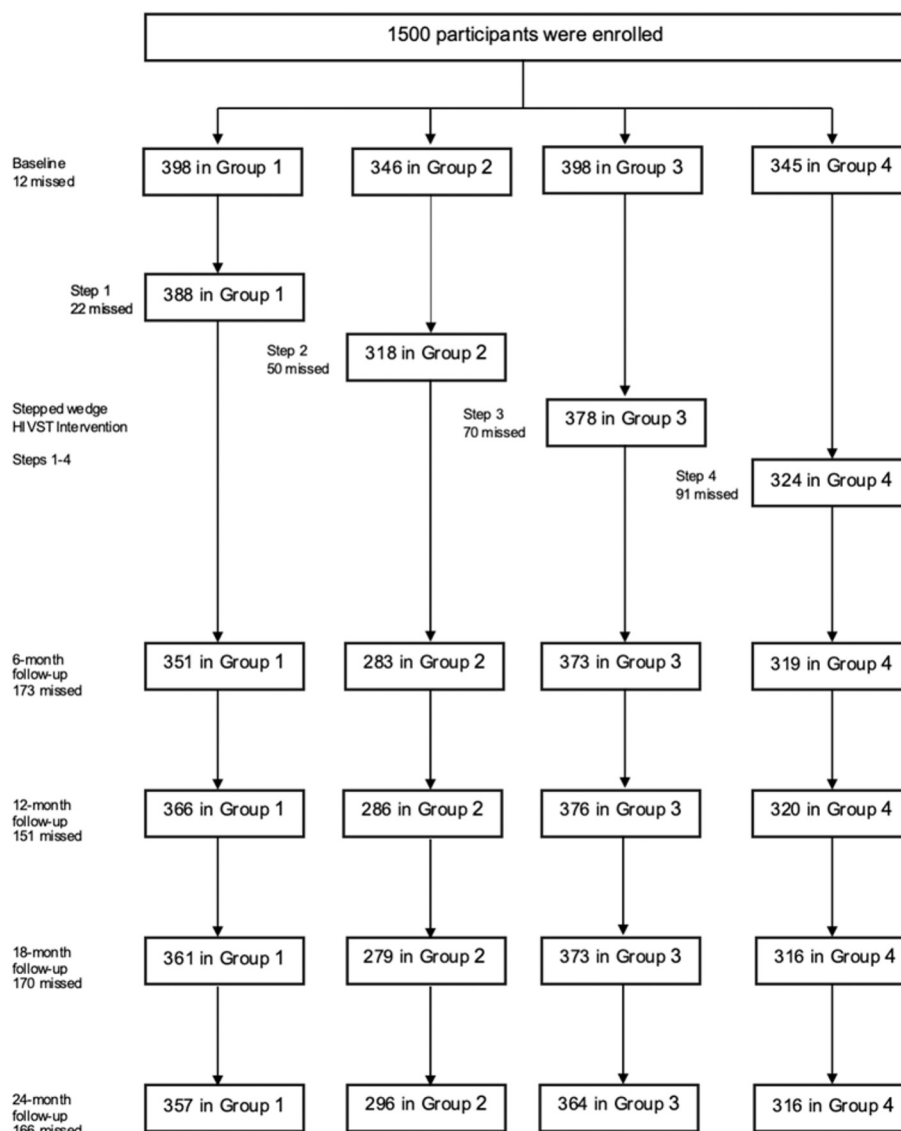


Fig. 1. Trial Profile. The intervention was implemented in a closed cohort stepped wedge design.

of the sample. Ethnicity was diverse, with a similar distribution across the sample. Employment status varied significantly ($p = 0.006$): self-employment was common (57.67 %), while a portion of the participants reported being unemployed (52.58 %). Monthly income differences were not statistically significant ($p = 0.07$), although a few participants reported earning over 100,000 Naira.

Regarding marital status, 76.47 % of those who were cohabiting as unmarried couples were reported. Sexual activity was reported by 44.24 % of the participants, with a subset indicating experience with paid sexual activity ($p < 0.0001$). Alcohol use in the past 30 days showed notable prevalence, with drug use remaining low but statistically significant ($p < 0.0001$).

3.2. Proportion of participants who tested for HIV

Table 2 presents the HIVST proportion within three months for each group, measured at baseline and four steps. In Group 1, the baseline HIVST proportion was 3.77 % (15/398). After the intervention in Step 1, the proportion increased to 67.78 % (263/388). This indicates that the intervention at Step 1 led to a substantial increase in HIV self-test uptake. Group 2's baseline proportion was 9.54 % (33/346). However, after the intervention in Step 2, the proportion increased to 61.01 %

(194/318). The intervention in Step 2 resulted in a significant increase in uptake. Group 3's baseline proportion was 7.29 % (29/398). After the intervention in Step 3, the proportion increased markedly to 76.46 % (289/378). This indicates that the intervention at Step 3 led to a marked increase in uptake. Group 4 had a baseline proportion of 6.67 % (23/345). However, after the intervention in Step 4, the proportion increased significantly to 95.37 % (309/324). This group saw the highest increase in uptake among all groups, indicating that the intervention at Step 4 was the most effective.

3.3. Cumulative HIV testing uptake

Table 2 also presents the HIVST proportion during the follow-up periods of 6, 12, 18, and 24 months. In Group 1, the HIV testing proportions were 86.04 % (302/351) at six months, 81.97 % (300/366) at 12 months, 73.41 % (265/361) at 18 months, and 77.59 % (277/357) at 24 months. For Group 2, the proportions were 87.28 % (247/283) at six months, 83.92 % (240/286) at 12 months, 86.38 % (241/279) at 18 months, and 85.47 % (253/296) at 24 months. In Group 3, the proportions were 82.57 % (308/373) at six months, 79.79 % (300/376) at 12 months, 90.35 % (337/373) at 18 months, and 87.09 % (317/364) at 24 months. Group 4 had the highest proportions, with 90.60 % (289/

Table 1
Sociodemographic factors distribution.

| Measures | Overall | Male | Female | P-value |
|--|---------------------|--------------|--------------|---------|
| | N = 1500 | 753 (50.2 %) | 747 (49.8 %) | |
| Sociodemographic factors | | | | |
| Age, mean (SD; range), years | 19.83 (2.65, 14–24) | 20.19 | 19.48 | <0.0001 |
| Highest Level of Education (%) | | | | 0.61 |
| Primary or less | 178 (11.9) | 87 (48.68) | 91 (51.12) | |
| Secondary | 1027 (68.6) | 520 (50.63) | 507 (49.37) | |
| Tertiary (+ Postgraduate) | 285 (19.0) | 138 (48.42) | 147 (51.58) | |
| Other | 7 (0.45) | 5 (71.43) | 2 (28.57) | |
| Ethnicity (%) | | | | 0.49 |
| Yoruba | 445 (29.73) | 233 (52.36) | 212 (47.64) | |
| Igbo | 544 (36.34) | 264 (48.53) | 280 (51.47) | |
| Other | 551 (33.93) | 254 (50.00) | 254 (50.00) | |
| Student status (%) | | | | 0.08 |
| Yes | 1154 (77.09) | 565 (48.96) | 589 (51.04) | |
| No | 343 (22.91) | 188 (54.81) | 155 (45.19) | |
| Employment status | | | | 0.006 |
| Employed full time | 77 (5.16) | 39 (50.65) | 38 (49.35) | |
| Employed part time | 117 (7.84) | 66 (56.41) | 51 (43.59) | |
| Self employed | 326 (21.84) | 188 (57.67) | 138 (42.33) | |
| Unemployed | 911 (61.02) | 432 (47.42) | 479 (52.58) | |
| Others | 62 (4.15) | 25 (40.32) | 37 (59.68) | |
| Monthly Income (Naira) (%) | | | | 0.07 |
| Less than 18,000 | 636 (42.89) | 309 (48.58) | 327 (51.42) | |
| 18,000- to 35,000 | 245 (16.52) | 128 (52.24) | 117 (47.76) | |
| 36,000 to 50,000 | 62 (4.18) | 35 (56.45) | 27 (43.55) | |
| 51,000 to 70,000 | 28 (1.89) | 20 (71.43) | 8 (28.57) | |
| 71,000 to 100,000 | 14 (0.94) | 8 (57.14) | 6 (42.86) | |
| Over 100,000 | 4 (0.27) | 4 (100.00) | 0 (0.00) | |
| Do not want to answer | 494 (33.31) | 240 (48.58) | 254 (51.42) | |
| Marital Status (%) | | | | 0.03 |
| Never married or single | 1466 (97.99) | 736 (50.20) | 730 (49.80) | |
| Unmarried couple living together | 17 (1.14) | 13 (76.47) | 4 (23.53) | |
| Married | 9 (0.60) | 2 (22.22) | 7 (77.78) | |
| Divorced or separated or widowed | 4 (0.27) | 1 (25.00) | 3 (75.00) | |
| Sexual and other Behavior factors | | | | |
| PrEP eligible | | | | 0.23 |
| Yes | 447 (0.30) | 235 (52.57) | 212 (47.43) | |
| No | 1053 (0.70) | 518 (49.19) | 535 (50.81) | |
| Ever had sex (%) | | | | <0.0001 |
| Yes | 661 (44.24) | 385 (58.25) | 276 (41.75) | |
| No | 833 (55.76) | 364 (43.70) | 469 (56.30) | |
| Paid for sex (%) | | | | <0.0001 |
| Yes | 65 (9.83) | 58 (89.23) | 7 (10.77) | |

Table 1 (continued)

| Measures | Overall | Male | Female | P-value |
|-------------------------------|--------------|--------------|--------------|---------|
| | N = 1500 | 753 (50.2 %) | 747 (49.8 %) | |
| No | 596 (90.17) | 327 (54.87) | 269 (45.13) | |
| Received money for sex (%) | | | | 0.22 |
| Yes | 61 (9.52) | 40 (65.57) | 21 (34.43) | |
| No | 580 (90.48) | 333 (57.41) | 247 (42.59) | |
| Alcohol use, last 30 days (%) | | | | <0.0001 |
| None | 1029 (68.97) | 444 (43.15) | 585 (56.85) | |
| Rarely | 171 (11.46) | 100 (58.48) | 71 (41.52) | |
| Sometimes | 213 (14.28) | 143 (67.14) | 70 (32.86) | |
| Frequently | 54 (3.62) | 42 (77.78) | 12 (22.22) | |
| Often | 25 (1.68) | 18 (72.00) | 7 (28.00) | |
| Drug Use (%) | | | | <0.0001 |
| Marijuana | 44 (2.96) | 36 (81.82) | 8 (18.18) | |
| Tramadol | 20 (1.34) | 14 (70.00) | 6 (30.00) | |
| Codeine | 18 (1.21) | 15 (83.33) | 3 (16.67) | |
| Others | 15 (1.00) | 12 (80.00) | 3 (20.00) | |
| None | 1392 (93.49) | 671 (48.20) | 721 (51.80) | |

319) at six months, 90.94 % (291/320) at 12 months, 91.46 % (289/316) at 18 months, and 93.04 % (294/316) at 24 months. The follow-up data indicates that the intervention had a lasting impact, with high testing proportions maintained over 24 months, particularly in Groups 3 and 4. Table 3 shows that HIVST intervention significantly increased HIVST uptake over time in both males and females. There were no significant differences in HIVST uptake between males and females at most time points, except at the 12-month follow-up, where a statistically significant difference was observed, with females having slightly lower uptake.

3.4. Sensitivity analyses

We utilized a generalized linear mixed model (GLMM) with LGAs as random effects to evaluate the impact of an intervention on HIV self-test uptake and its effectiveness. The outcome measured was whether participants took an HIV self-test (yes/no), with the primary exposure variable being the intervention. Various covariates were included in the models to control for potential confounding factors.

3.5. Model 1: baseline model

The baseline model included the month and intervention variables. The intervention significantly increased HIV self-test uptake, with the rate of uptake during the intervention period being 9.96 times the rate during the control period (RR = 9.96, 95 % CI: 8.36–11.85, $p < 0.0001$). The month variable also significantly affected HIV self-test uptake ($p < 0.0001$). This baseline model indicates a strong and highly significant effect of the intervention on HIV self-test uptake, suggesting that the intervention was very effective in increasing the testing rate.

3.6. Model 2: interaction with PrEP eligibility

The second model incorporated the variables from the baseline model and added PrEP eligibility and the interaction between PrEP eligibility and the intervention. The intervention remained highly significant ($p < 0.0001$). Being eligible for PrEP had a significant effect on HIV self-test uptake ($p = 0.0062$). The interaction between PrEP

Table 2
HIVST rates at baseline, steps, and follow-ups.

| Group | Enrollment, n | HIV testing proportion in the past three months, percent (participants tested/total participants) | | | | | | | | |
|---------|---------------|---|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | | Baseline | Step 1 | Step 2 | Step 3 | Step 4 | 6-month | 12-month | 18-month | 24-month |
| Group 1 | 398 | 3.77 (15/398) | 67.78 (263/388) | 67.78 (263/388) | 67.78 (263/388) | 67.78 (263/388) | 86.04 (302/351) | 81.97 (300/366) | 73.41 (265/361) | 77.59 (277/357) |
| Group 2 | 346 | 9.54 (33/346) | 9.54 (33/346) | 61.01 (194/318) | 61.01 (194/318) | 61.01 (194/318) | 87.28 (247/283) | 83.92 (240/286) | 86.38 (241/279) | 85.47 (253/296) |
| Group 3 | 398 | 7.29 (29/398) | 7.29 (29/398) | 7.29 (29/398) | 76.46 (289/378) | 76.46 (289/378) | 82.57 (308/373) | 79.79 (300/376) | 90.35 (337/373) | 87.09 (317/364) |
| Group 4 | 346 | 6.67 (23/345) | 6.67 (23/345) | 6.67 (23/345) | 6.67 (23/345) | 95.37 (309/324) | 90.60 (289/319) | 90.94 (291/320) | 91.46 (289/316) | 93.04 (294/316) |

Table 3
HIVST Uptake at baseline, 3-month, 6-month, 12-month, 18-month, and 24-month Stratified by sex.

| Measures | Overall N = 1500 | Male 753 (50.2 %) | Female 747 (49.8 %) | P-value |
|---------------------|---------------------|----------------------|------------------------|---------|
| Baseline (%) | | | | 0.11 |
| Yes | 100 (6.72) | 58 (58.00) | 42 (42.00) | |
| No | 1388 (93.28) | 690 (49.71) | 698 (50.29) | |
| 3-month (%) | | | | 0.70 |
| Yes | 1056 (74.95) | 527 (49.91) | 529 (50.09) | |
| No | 353 (25.05) | 172 (48.73) | 181 (51.27) | |
| 6-month (%) | | | | 0.37 |
| Yes | 1147 (86.44) | 583 (50.83) | 564 (49.17) | |
| No | 180 (13.56) | 85 (47.22) | 95 (52.78) | |
| 12-month (%) | | | | 0.036 |
| Yes | 1132 (83.91) | 573 (50.62) | 559 (49.38) | |
| No | 217 (16.09) | 93 (42.86) | 124 (57.14) | |
| 18-month (%) | | | | 0.62 |
| Yes | 1133 (85.19) | 562 (49.60) | 571 (50.40) | |
| No | 197 (14.81) | 94 (47.72) | 103 (52.28) | |
| 24-month (%) | | | | 0.21 |
| Yes | 1142 (85.61) | 563 (49.30) | 579 (50.70) | |
| No | 192 (14.39) | 104 (54.17) | 88 (45.83) | |

eligibility and the intervention was also significant ($p = 0.0056$), indicating that the intervention effect varied between those eligible for PrEP and those not eligible. For PrEP-eligible participants, the rate of HIV self-test uptake during the intervention was 7.85 times the rate during the control period (RR = 7.85, 95 % CI: 6.21–9.93). For non-PrEP-eligible participants, the rate was 11.26 times higher (RR = 11.26, 95 % CI: 9.23–13.75). This model shows that the intervention was effective for both PrEP-eligible and non-PrEP-eligible participants, but the effect was stronger among those not eligible for PrEP.

3.7. Model 3: full model with additional covariates

The full model included the variables from the second model and added education, ethnicity, marital status, age, gender, employment status, and income. The intervention remained highly significant ($p < 0.0001$). The effect of PrEP eligibility remained significant ($p = 0.0115$), and the interaction between PrEP eligibility and the intervention continued to be significant ($p = 0.0086$). The additional covariates (education, ethnicity, marital status, age, gender, employment status, and income) did not significantly affect HIV self-test uptake, indicating that these factors did not confound the main effects of the intervention and PrEP eligibility. For PrEP-eligible participants, the rate of HIV self-test uptake during the intervention was 7.73 times the rate during the control period (RR = 7.73, 95 % CI: 6.11–9.78). For non-PrEP-eligible participants, the rate was 10.89 times higher (RR = 10.89, 95 % CI: 8.92–13.29). This full model confirms the robustness of the intervention effect on increasing HIV self-test uptake, regardless of PrEP eligibility, and shows that other demographic factors did not significantly influence the results. The intervention was particularly effective for non-PrEP-

eligible participants.

3.8. Cost of intervention

The annual fixed cost of implementing the AYA-led crowdsourced intervention to promote the uptake of HIV self-testing and other essential HIV prevention services was estimated at US\$42,237. The per-person testing cost (i.e., the cost of each 4YBY HIVST bundle) was calculated to be US\$14.8.

4. Discussion

This study expands the literature by exceptional AYA engagement, examining crowdsourcing in an African context. Our study population comprises a critical demographic that is disproportionately vulnerable to HIV and often overlooked in HIV testing services [20–22]. Prior research highlights how AYAs face significant barriers to accessing traditional HIV testing modalities, including stigma, confidentiality concerns, and limited access to healthcare services [20–22]. A unique feature of this study, in the African context, is the assessment of an HIV intervention developed for youth by youth, which contrasts with most available HIV prevention interventions that are expert-driven and pushed onto youth populations regardless of fit [9]. Our use of crowdsourcing and other co-creation activities helped to facilitate youth participation and community engagement by involving a large group of AYAs who developed solutions for HIVST that resonated with their lived experiences and needs [13,23–25]. Such an approach echoes the need for meaningful engagement of AYA in research about them while respecting and promoting their RIGHTS (resourced, impactful, genuine, harmless, teen-friendly, and skills-building) to evidence-based interventions [12].

Our key findings are, first, a crowdsourced intervention designed for youth and implemented by young people themselves effectively promoted HIV testing uptake from baseline to 24 months. During the intervention period, there was a remarkable increase in HIVST rates compared to the baseline figures, with rates surging from 3.77 % to 67.78 % in group 1, 9.54 % to 61.01 % in group 2, 7.29 % to 76.46 % in group 3, and 6.67 % to 95.37 % in group 4. These findings are consistent with existing research, which has demonstrated the positive impact of crowdsourced campaigns in driving the uptake of HIV testing services [26–28]. In addition, cumulative HIV testing uptake was high over time, with rates over 70 % across all groups throughout the follow-up period. Finally, our results indicated the intervention significantly increased HIV self-test uptake, with the rate of uptake during the intervention period being 9.96 times the rate during the control period (RR = 9.96, 95 % CI: 8.36–11.85, $p < 0.0001$). The rate of HIV self-test uptake during the intervention was also 7.73 times the rate during the control period for those eligible for PrEP and 10.89 times higher for non-PrEP-eligible participants.

The AYA engagement in this study was distinctive in its alignment with UNICEF's meaningful participation framework, setting it apart from traditional youth engagement approaches. Unlike many studies

where youth input is limited to focus groups or token advisory roles, AYAs in this study were involved across the entire intervention process, from design to implementation, and as co-authors on publications, thus establishing a foundation for genuine influence and ownership [19]. The intervention's development through open calls and participatory judging allowed AYAs not only to shape content but also to critically assess its components, creating a collaborative environment that reinforced their expertise and agency in HIV prevention strategies. Digital platforms such as WhatsApp and Instagram further broadened AYA engagement by enabling continuous, interactive communication and fostering a youth-centered online community [8]. This multifaceted engagement approach contrasts with conventional top-down health interventions, where youth are often passive recipients rather than active contributors [17]. By embedding youth voices at every level, the study demonstrates that interventions authentically shaped by AYAs are more likely to resonate with their target audience and achieve sustained impact [12].

For policymakers, the affordability of healthcare investments may pose a significant barrier to the widespread implementation of innovative HIV prevention interventions [29]. Our findings indicated that the cost of the HIVST bundle is relatively high, suggesting that the 4YBY intervention may require substantial healthcare investment. A previous study conducted in Malawi reported an average cost of US\$8.78 per person for HIVST interventions [30]. In contrast, the per-person cost of the crowdsourced HIVST bundle in the 4YBY project is US\$14.8. This significant cost difference can be attributed to the inclusion of additional components in the HIVST bundle, designed to facilitate the uptake of other essential HIV prevention services [16].

In recent years, a growing number of governments, international organizations, multilateral partnerships, and non-governmental organizations have employed market-shaping strategies to reduce the prices of essential healthcare products, enabling more individuals in developing countries to benefit within the constraints of limited healthcare budgets [29,31]. Stakeholders may further reduce the prices of HIVST products through market-shaping strategies [29]. Shared financing between governments and individuals could also be considered to transition towards domestic country budgets. With declining costs of HIVST bundles, the intervention may yield a return on investment, as changes in HIV-related health states from the intervention can have a lasting impact on HIV transmission and reduce HIV-related testing and treatment expenses [32].

Strengths of our study include a pragmatic, real-world design that leverages the creativity and resourcefulness of AYA in intervention design. Randomization was robust, with participants recruited from local government areas of four out of six geopolitical zones in Nigeria, improving the generalizability of our findings. Access to peer youth research facilitators and site supervisors ensured complete capture of test results, minimizing detection bias. Our intervention was also based on a successful crowdsourcing approach that leverages young people's internal and external assets, including their unique perspectives, lived experiences, health-seeking behaviors in community and clinical settings, and social networks to develop culturally relevant, youth-friendly HIVST that resonate with their needs and preferences [13]. These attributes help to reduce complex barriers that often deter AYAs from accessing traditional HIV testing services, such as stigma and fear [22]. Although none of our participants were HIV-positive, to our knowledge, this randomized trial is the first to show improvements in HIV testing uptake among a status-neutral AYA population in need of other prevention services, retention in such services, and adherence in such services with repeat testing to monitor HIV acquisition using an intervention designed by young people [33–35]. A weakness of our study was the limited use of photo-verification tools to report the results of HIVST [36–38]. Overall, engagement with the USSD system was inconsistent across the follow-up periods, with 86 % of participants initially engaging with the system and 33 % subsequently engaging with USSD over time despite having access to it. This may be partly explained by the peer support the youth implementers provide monthly, face-to-

face interactions, HIVST testing support, and linkage to prevention services, which the participants highly value. This was also a pragmatic trial likely representing real-world technology use among the youth population where uptake is initially high, with a voltage drop resulting in limited use of these technologies over time. Nonetheless, we were able to compare patterns of HIVST uptake among youth who used the USSD code versus all youth. We observed similar patterns of HIVST uptake among those who used the USSD, as the rate of HIVST testing in the intervention period was 11.85 times the rate in the control period. These findings, however, merit further research in settings like Nigeria, which is limited by resources for sustained technological innovation use.

Overall, our findings provide evidence that targeted, crowdsourced HIV prevention designed by AYAs themselves achieves high HIVST uptake. AYA-designed HIV prevention interventions with streamlined resources and assets, such as peer support for repeat testing in community settings, are feasible and effective compared with traditional approaches to HIV testing. These findings address a crucial gap in the evidence-based HIV prevention interventions that are not expert-driven, lending strong evidence supporting guideline recommendations for youth participation in the design of health interventions targeting their needs and priorities [39]. Findings also justify renewed efforts to identify not only barriers but also developmental assets such as access to youth-friendly health services and peer support that are essential for repeat HIV testing over time [4,9,40]. Our work builds on previous work showing that advancing the global goal of zero new HIV infections will require that all status-neutral AYA receive the entire continuum of prevention services not as a one-time event but rather ongoing engagement and retention in the prevention process to achieve the goals for an AIDS-free generation [33–35]. Otherwise, hope that an end to the epidemic of HIV among AYAs will be out of sight [35].

CRediT authorship contribution statement

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cct.2025.107919>.

Data availability

Data will be made available on request.

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