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Title: Effectiveness of a digital, school-based, intervention in adolescent family planning and reproductive health in Rwanda: a cluster randomized implementation trial

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Abstract

We conducted a cluster randomized hybrid Effectiveness-Implementation study of *CyberRwanda*, a digital family planning and reproductive health intervention for Rwandan adolescents. Sixty schools were randomized 1:1:1 to control or to one of two implementation models: self-service (self-guided access on tablets) or facilitated (peer-led clubs plus tablet access) with no masking. Eligible participants were aged 12–19 years, in secondary school levels 1 or 2, and willing to provide consent or assent/parental consent and contact information for follow-up. In 2021, 6,078 randomly selected adolescents were enrolled. At 24 months, 91.3% of participants were retained and included in the primary intention-to-treat analyses (control: n=1,845; self-service: n=1,849; facilitated: n=1,858). There were no adverse events related to the study. CyberRwanda did not affect the primary outcomes of modern contraceptive use (prevalence ratio [PR]: 1.04; 95% confidence interval [CI]: 0.76, 1.42), childbearing (PR: 1.33; 95% CI: 0.71, 2.50), and HIV testing (PR: 1.00; 95% CI: 0.91, 1.11) in the full sample. Significantly higher modern contraceptive use observed in the CyberRwanda facilitated arm in a pre-specified analysis of sexually active participants suggests that longer-term evaluation is needed to examine effects as more of the study population becomes sexually active and has increased demand for contraception. **ClinicalTrials.gov registration:** NCT04198272.

Main text

Introduction

Digital health interventions are a promising approach for improving adolescent family planning and reproductive health (FP/RH) outcomes in low-resource settings. By increasing access to accurate health information and comprehensive health products and services through direct-to-consumer channels, digital health interventions have potential to mitigate health misinformation and extend quality healthcare coverage. Several studies in sub-Saharan Africa (SSA) have found that digital FP/RH interventions can improve FP/RH knowledge[1–4], increase contraceptive use[2,5], and reduce adolescent pregnancy.[1] Consequently, the United Nations promotes access to equitable, rights-based digital health technologies to reduce information disparities and increase sexual health literacy to meet the Sustainable Development Goals.[6,7]

Digital health interventions may be particularly well-suited for many adolescents, given their preference for private information channels and early technology adoption. In SSA, a paucity of youth-friendly FP/RH information and services contributes to low knowledge and use of contraception,[8,9] high rates of unintended pregnancy, and persistently high HIV incidence among young people who account for ~30% of all new HIV infections,[10] despite significant progress towards global HIV goals in the general population.[11] These detrimental FP/RH outcomes are bidirectionally linked to school dropout, which is pervasive in SSA.[12–15] Together with harmful gender norms and lack of access to quality FP/RH information, services, and products, these obstacles prevent many young people from completing school HIV-free and avoiding unintended pregnancy.[16–18] However, to date, few rigorous impact evaluations have examined the effectiveness of digital FP/RH interventions designed for adolescents or compared the effectiveness of different implementation models developed using community-led approaches.

CyberRwanda is an innovative digital FP/RH intervention that was developed using a multi-year, participatory, human-centered design (HCD) process to address gaps in FP/RH care in Rwanda.[19] It was designed as an online platform with three main features (Fig. 1): **STORIES**, webcomics on navigating relationships and sex, including sexual consent, contraceptive use, adolescent pregnancy, and HIV/sexually transmitted infections; **LEARN**, informational guides, videos, audio-recordings, and frequently asked questions focused on menstruation, puberty,

gender equality, relationships, consent, education, careers, money, and goal setting; and **SHOP**, a direct-to-consumer online store for discreet ordering of health products (e.g., condoms, emergency contraception, oral contraception, pads, paracetamol) from nearby pharmacies, health posts, and health facilities trained in youth-friendly services. Products at health posts and facilities were available for free, while products at pharmacies were offered at market rate with periodic promotional discounts to motivate SHOP use. The platform also included a facility finder to assist adolescents in finding nearby health facilities.

CyberRwanda was implemented in schools and youth centers; however, the present study evaluated school-based implementation only. Schools received one of two implementation models: self-service (self-guided access to the CyberRwanda platform on tablets provided to schools, school computers, or personal devices) or facilitated (self-guided and group access to the CyberRwanda platform along with peer-led weekly clubs to reinforce its content). In both models, CyberRwanda was accessible in Kinyarwanda and English with its content updated regularly based on student feedback and Google Analytics data on usage. A mixed-methods pilot study conducted in secondary schools revealed the acceptability and feasibility of both implementation models and the high demand and enthusiasm for the intervention among adolescents.[20]

Following the pilot, we initiated a 24-month Hybrid Effectiveness-Implementation trial in 60 secondary schools across eight districts of Rwanda. The aim of our study was to evaluate the effectiveness of the CyberRwanda intervention on individual-level FP/RH outcomes, including modern contraceptive use, childbearing, and HIV testing, and to compare the relative effectiveness of each implementation model to understand whether there are additional benefits from pairing digital interventions with in-person activities and how different implementation models translate into impact. We also assessed student engagement with each implementation model and secondary outcomes related to FP/RH knowledge, attitudes and beliefs, self-efficacy, and behavior.

Results

Participant characteristics

All sixty schools approached about the study agreed to participate. Of 10,107 students in study schools who were screened for enrollment and determined to be preliminarily eligible, 7,425 were randomly invited to participate and 6,078 enrolled between February 20 and May 29, 2021. School and participant characteristics were balanced across study arms at baseline (Table 1). At enrollment, participants were 15 years old on average, and 51.5% were female. Overall, 49.4% of study participants had access to a tablet or computer and 4.8% had their own smartphone.

Of 6,078 participants enrolled at baseline, 5,552 (91.3%) completed endline surveys at 24 months (Fig. 2). Participants who were lost to follow-up at 24 months were more likely to be older, male, have a parent with lower levels of education, and have a lower wealth index than participants who completed endline surveys (Supplementary Table S1). The endline sample (mean age: 18 years) included 29.2% who had transferred schools and 12.8% who had dropped out of school. Among female participants who reported having initiated childbearing (n=69), 85.5% had dropped out of school.

At endline, 26.6% of participants reported that they had ever had sexual intercourse (34.7% of males, 19.0% of females), with only 11.1% reporting sexual intercourse in the past year. Most sexually active participants reported having sexual intercourse less than three times in their lifetime (81.7%).

Implementation fidelity and engagement

Most indicators of school-level fidelity to and individual-level engagement with the CyberRwanda intervention were similar across models but modestly higher in the facilitated arm compared to the self-service arm (Table 2). At the school level, an average of 98.4% of participants per intervention school had heard of CyberRwanda. Among participants who had tried to access CyberRwanda, participants rated the ease of accessing CyberRwanda as a 4 out of 5 on average. Limited tablet availability and/or internet connectivity challenges were reported by an average of 39.2% of participants per school.

At the individual level, 75.9% of participants in CyberRwanda schools reported ever using the platform, and participants in CyberRwanda schools had used the platform once in the past month on average. Most CyberRwanda users had accessed CyberRwanda in schools (99.0%);

few reported accessing CyberRwanda outside of school (3.6%). Tablets were the main device used to access the platform (reported by 99.2% of users), while smartphones were rarely used (1.9%). Most users (85.2%) reported that they shared a tablet with others at last use.

STORIES was the most used CyberRwanda feature (used by 65.7% of all participants in CyberRwanda schools overall and 86.5% of participants who had ever used the platform), followed by LEARN (39.7% overall, 52.3% of users) and SHOP (30.1% overall, 39.6% of users). Most users (78.7%) reported that STORIES was the most useful feature on the platform, with 90.9% of users agreeing that the content was relevant to their life, needs, and interests. Many users agreed that the LEARN feature provided helpful information (91.8%) and that the SHOP feature made it easier for them to purchase health products (62.3%). Nonetheless, few participants (12.9%) had ever placed an online order using the SHOP feature, and 37.6% of users said they did not want to use the SHOP. The most common reason for not using the SHOP was not needing or wanting any of the products offered (70.8%).

Primary outcomes

Among all female participants, 10.6% reported using a modern method of contraception overall (intraclass correlation coefficient [ICC] = 0.02). Current modern contraceptive use did not differ by study arm (CyberRwanda combined vs. control: 10.7% vs. 10.6%, prevalence ratio [PR]: 1.04, 95% confidence interval [CI]: 0.76–1.42) (Table 3). Few female participants (2.4%) reported a previous pregnancy (ICC = 0.02). There were no differences in childbearing by study arm (CyberRwanda combined vs. control: 2.6% vs. 2.0%, PR: 1.33, 95% CI: 0.71–2.50). Half of all participants (51.6%) reported ever HIV testing (ICC = 0.12), with no differences by study arm (CyberRwanda combined vs. control: 51.6% vs. 51.4%, PR: 1.00, 95% CI: 0.91–1.11).

Secondary outcomes

Knowledge

Knowledge of the fertile window in a woman's menstrual cycle and HIV-related knowledge (among all participants) and knowledge of menstrual tracking tools (among females only) did not differ between study arms (Table 3, Extended Data Fig. 1). Participants in both the facilitated arm (57.5%) and the self-service arm (54.2%) had significantly higher knowledge of when

emergency contraception can be taken after unprotected sex to prevent a pregnancy compared to control (CyberRwanda combined vs. control: 55.9% vs. 49.2%, PR: 1.14, 95% CI: 1.04–1.24).

Attitudes and beliefs

Views on FP/RH service utilization were similar across study arms. Participants in the combined CyberRwanda arm and the facilitated arm were significantly more likely to have favorable beliefs about condom use compared to control (facilitated vs. control: 78.6% vs. 75.1%, PR: 1.06, 95% CI: 1.01–1.12).

Self-efficacy

There were no differences in self-efficacy for giving sexual consent or obtaining HIV testing across study arms. Participants in both the facilitated arm (94.5%) and the self-service arm (94.7%) were significantly more confident that they could get a partner to use contraceptives or condoms if desired compared to control (CyberRwanda combined vs. control: 94.6% vs. 92.7%, PR: 1.02, 95% CI: 1.00–1.03). Confidence in the ability to access and use contraceptive services among female participants was significantly higher in the facilitated arm compared to control (97.6% vs. 95.5%, PR: 1.02, 95% CI: 1.00–1.04).

Behavior

There were no differences in participants' reporting of previous sexual activity or receipt of FP counseling or HIV testing in the past 12 months by study arm. In addition to the primary outcome of current use of modern contraceptive methods among females, we also examined current modern contraceptive method use among male participants. Modern method use was significantly higher among male participants in the combined CyberRwanda arm and the facilitated arm compared to control (facilitated vs. control: 22.6% vs. 17.5%, PR: 1.31, 95% CI: 1.04–1.65).

Past condom use and partner contraceptive discussions were assessed among sexually active participants only. Sexually active participants in facilitated schools were significantly more likely to report having used a condom (*ever* condom use) compared to those in control (61.9% vs. 53.3%, PR: 1.19, 95% CI: 1.05–1.35). Sexually active participants in the combined

CyberRwanda arm and the facilitated arm were also significantly more likely to report discussing contraception with their most recent sexual partner (facilitated vs. control: 59.5% vs. 52.9%, PR: 1.15, 95% CI: 1.03–1.30).

Safety

There were seven participant deaths (unrelated to the study) over the study period. There were no adverse events related to the CyberRwanda intervention or impact evaluation reported.

Sensitivity analyses

Sensitivity analyses were conducted to compare outcomes in the full sample with the sexually active subgroup and by sex among sexually active participants only. Among sexually active participants overall (n=1,477), current modern contraceptive use was significantly higher in the combined CyberRwanda arm and the facilitated arm compared to control (facilitated vs. control: 63.0% vs. 52.7%, PR: 1.24, 95% CI: 1.12–1.38) (Fig. 3, Supplementary Table S2). This association was in part driven by higher *current* condom use among sexually active male participants in the facilitated arm (facilitated vs. control: 62.6% vs. 49.7%, PR: 1.28, 95% CI: 1.11–1.48).

There were no significant differences in *current* condom use among sexually active female participants in the facilitated arm compared to control (51.1% vs. 45.8%). However, sexually active female participants in both the facilitated arm (13.6%) and the self-service arm (15.1%) were more likely to report *current* use of modern contraceptive methods *other than* male condoms compared to control (CyberRwanda combined vs. control: 14.4% vs. 7.8%, PR: 2.06, 95% CI: 1.18–3.60).

The observed increases in *ever* condom use and contraceptive discussions among sexually active CyberRwanda participants were also driven by male participants; *ever* condom use was higher among sexually active males in the facilitated arm compared to control (64.8% vs. 53.0%, PR: 1.24, 95% CI: 1.08–1.41) (Fig. 3), and contraceptive discussions were higher among sexually active males in both arms compared to control (59.8% vs. 49.3%, PR: 1.23, 95% CI: 1.07–1.40) (Supplementary Table S2).

There were no differences in initiation of childbearing by study arm when limiting analyses to sexually active female participants; HIV testing was also similar across study arms among sexually active participants overall and of either sex (Supplementary Table S2).

Discussion

This manuscript presents results from a 24-month, Type 2 Hybrid Effectiveness-Implementation study in 60 schools evaluating CyberRwanda, a digital, school-based intervention designed by and for adolescents using an HCD approach to improve FP/RH outcomes. CyberRwanda was perceived favorably and widely accessed by students in participating schools. However, the majority of the study population reported that they were not yet sexually active, and we did not find significant impacts of CyberRwanda on the primary outcomes of modern contraceptive use and childbearing among all female adolescents and HIV testing in the full sample. Among all *sexually active* adolescents, CyberRwanda significantly increased modern contraceptive use among participants in intervention schools compared to those in control schools. Hypothesis-generating analyses revealed that this finding was driven by increased condom use among sexually active male participants (CyberRwanda combined arms and facilitated arm) and increased use of modern contraceptive method(s) other than male condoms among sexually active female participants (CyberRwanda combined, facilitated, and self-service arms) compared to the control arm.

CyberRwanda was also associated with positive shifts in other secondary, intermediate outcomes, including increased emergency contraceptive knowledge (combined, facilitated, and self-service arms), more favorable condom beliefs (combined and facilitated arms), greater confidence in getting a partner to use contraception (combined, facilitated, and self-service arms), greater confidence in accessing/using contraceptive services (facilitated arm), and increased partner contraceptive discussions (combined and facilitated arms) compared to control. Although some of these effect sizes were modest in magnitude, the intermediate impacts we observed align with the changes anticipated in the hypothesized impact pathway[19] and are consistent with the increased contraceptive use observed among sexually active participants.

This study contributes to a small but growing evidence base of studies evaluating digital FP/RH interventions delivered to adolescents in SSA, which have demonstrated improvements in

FP/RH and HIV outcomes.[1–4,21] Our findings add to this evidence and suggest that CyberRwanda has potential to achieve its intended FP/RH impacts and reinforce efforts and progress made by the Rwandan government to improve adolescent FP/RH. An innovative aspect of this study is our examination of the relative effectiveness of two CyberRwanda implementation models: a self-guided, digital-only delivery model (self-service) and a more resource-intensive delivery model with complementary in-person, peer-led group activities (facilitated). The facilitated implementation model demonstrated stronger benefits on FP/RH-related attitudes and behaviors among adolescents compared to the self-service model, although in most cases the width of the confidence intervals could not rule out that the two models performed similarly. We hypothesize that the in-person element and group setting of the facilitated model (i.e., peer-led club sessions which reached large numbers of students) may be important to foster deeper engagement with the digital content, increase exposure to sexual health education, and ultimately influence FP/RH behavior. Still, it remains uncertain as to whether these potential benefits are strong enough to warrant the added complexity and costs of the facilitated model compared to self-service. The effectiveness of peer-led education in reinforcing positive reproductive health beliefs and practices is supported by implementation research and adolescent neuro-developmental studies.[22–24] While implementation fidelity was high across both models, adolescents in facilitated schools had slightly higher engagement when comparing metrics related to use of the platform, lending some support to this hypothesis. However, we lacked sufficient quantitative metrics to adequately measure engagement with the in-person component of the facilitated model (i.e., weekly club meetings), a limitation of our evaluation.

A unique component of CyberRwanda is the direct-to-consumer SHOP feature through which adolescents can discreetly order FP/RH products from nearby youth-friendly pharmacies, health posts, and health facilities. Despite nearly two-thirds of participants reporting that the SHOP made it easier for them to purchase health products, SHOP orders were unexpectedly infrequent. While supply-side challenges may have deterred SHOP use, the most common explanation provided by participants was that they did not need or want any products. This lower-than-expected demand for contraceptives may relate to the low prevalence and frequency of sexual activity among the cohort; only one quarter of participants reported previous sexual activity at endline (mean age: 18 years), with only 11% reporting sex in the past year, suggesting that “sexually active” participants were not engaging in intercourse frequently. Longer-term follow up with study participants would provide us with more statistical power to

examine CyberRwanda's impact on these outcomes in the overall sample as more participants become sexually active and have increased need for FP/RH products. Nevertheless, the positive impacts we observed on contraceptive use among sexually active participants and on intermediate outcomes in the full sample suggest that CyberRwanda is working as intended, and we anticipate that early exposure to the platform's youth-friendly, age-appropriate FP/RH information for adolescents who are not yet sexually active may improve outcomes when they engage in sexual behavior in the future.

This study has notable strengths as well as some limitations. With a sample of >6,000 adolescents across 60 schools in eight districts of Rwanda, this is among the few trials of this size and scope conducted in SSA and, to our knowledge, the first in Rwanda to examine the effectiveness of a large-scale digital health intervention on youth sexual health outcomes. The results advance knowledge on youth sexual behavior and the utility of digital tools with and without in-person facilitation to improve knowledge, attitudes, self-efficacy, and behavior during a critical and sensitive development stage of adolescence. Through rigorous follow-up procedures, we successfully retained 91% of the enrolled study population at 24 months, including 29% of endline participants who had transferred schools and 13% who had dropped out of school yet remained in the study. Despite these efforts, there remains the possibility that participants who were lost to follow-up were unreachable due to pregnancy-related drop out from school and/or were less likely to use a contraceptive method than their in-school peers; thus, we cannot rule out the potential for selection bias in our analytic sample. In addition, while the survey was designed to maximize privacy and data quality for highly sensitive questions related to sexual behavior, there may have been social desirability bias for self-reported outcomes which, if similar across study arms, is likely to bias effect estimates towards the null.[25,26] While it is possible that such response bias was differential by study arm (e.g., if participants exposed to CyberRwanda were more or less likely to disclose and/or overreport certain FP/RH outcomes), participants were equally as likely to report past sexual activity across study arms, which mitigates concerns of differential reporting for sensitive questions about sexual behavior. Lastly, we enrolled adolescents attending secondary schools at baseline; therefore, our results may have limited generalizability for out-of-school youth who may be more likely to engage in higher-risk sexual behaviors.

We identified opportunities for improving intervention implementation, including increasing the amount of school time allocated to accessing CyberRwanda, addressing the high student-tablet

ratio, and mitigating technological challenges, which likely impeded access and engagement in both implementation models. Frequent tablet sharing may have been especially limiting for the SHOP feature, as some students may not have been able to access it privately. Other studies highlight internet connectivity as a common issue in the delivery of digital interventions[27] and recommend offline content as an alternative to improve access and engagement with digital tools, particularly in low-resource settings. CyberRwanda's STORIES and LEARN features could be accessed offline via the app during the study, and since study completion, the platform has incorporated USSD ordering of products via feature phones to support offline access to the SHOP feature. Taken together, this suggests that small investments in more tablets, offline access to the platform, and ongoing technological support in schools could further strengthen the benefits of CyberRwanda observed in this study.

In conclusion, the CyberRwanda intervention did not significantly impact the primary outcomes of modern contraceptive method use and initiation of childbearing among females and HIV testing overall. Despite this, we found significantly higher modern method use among sexually active CyberRwanda participants compared to the control arm. The intervention was implemented with high fidelity across 40 schools in Rwanda; had strong participant acceptability and engagement; and was also associated with positive shifts in some intermediate, secondary outcomes on the hypothesized impact pathway including FP/RH-related knowledge, attitudes, and behaviors among adolescents. The stronger shifts in intermediate outcomes observed in the facilitated model suggest that digital interventions may benefit from in-person education to reinforce digital content. Further research is warranted to compare the relative cost-effectiveness of the two implementation models and to examine CyberRwanda's longer-term effectiveness as more of the study population becomes sexually active and has increased demand for contraception.

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Author Contributions Statement

RH(1), LP, SB(2), RH(2), and SM conceptualized the study. RH(1), EG, LH, LP, FS, MM, SB(2), RH(2), and SM designed the study's methodology. EG, LK, and NI performed data collection. RH(1) and LH conducted data analyses. RH(1), LH, and SM drafted the manuscript. RH(1), EG, LK, LH, LP, NI, DC, DCL, PG, SB(1), FS, MM, SB(2), RH(2), and SM contributed to data interpretation and revised and approved the submitted manuscript.

Competing Interests Statement

The authors have no conflicts of interest to declare.

Tables

Table 1. Baseline characteristics of schools and participants enrolled in the CyberRwanda impact study by arm, 2021.

Schools	Control (n=20)	CR facilitated (n=20)	CR self-service (n=20)	Overall (n=60)
Number of students	1503.2 ± 544.7	1756.4 ± 718.7	1627.3 ± 767.9	1628.9 ± 681.2
Number of teachers	44.6 ± 9.0	41.3 ± 14.3	38.7 ± 14.8	41.6 ± 12.9
Student-teacher ratio	34.4 ± 12.1	41.4 ± 7.5	41.4 ± 11.0	39.0 ± 10.7
Has computers	12 (60.0%)	16 (80.0%)	15 (75.0%)	43 (71.7%)
Has internet	14 (70.0%)	13 (65.0%)	11 (55.0%)	38 (63.3%)
Has SRH curriculum	16 (80.0%)	19 (95.0%)	20 (100.0%)	55 (91.7%)
Participants	Control (n=2037)	CR facilitated (n=2025)	CR self-service (n=2016)	Overall (n=6078)
Age in years	15.4 ± 1.5	15.3 ± 1.5	15.4 ± 1.5	15.4 ± 1.5
Sex				
Female	1050 (51.5%)	1031 (50.9%)	1049 (52.0%)	3130 (51.5%)
Male	987 (48.5%)	994 (49.1%)	967 (48.0%)	2948 (48.5%)
School level				
Secondary 1	1174 (57.6%)	1134 (56.0%)	1147 (56.9%)	3455 (56.8%)
Secondary 2	863 (42.4%)	891 (44.0%)	869 (43.1%)	2623 (43.2%)
Partnered	402 (19.7%)	408 (20.1%)	373 (18.5%)	1183 (19.5%)
Parent completed primary school or higher	1187 (58.3%)	1232 (60.8%)	1209 (60.0%)	3628 (59.7%)
Wealth index (quartiles)*				
1 – lowest	521 (25.6%)	542 (26.8%)	458 (22.7%)	1521 (25.0%)
2	491 (24.1%)	524 (25.9%)	502 (24.9%)	1517 (25.0%)
3	535 (26.3%)	490 (24.2%)	494 (24.5%)	1519 (25.0%)
4 – highest	489 (24.0%)	469 (23.2%)	561 (27.8%)	1519 (25.0%)
Religion				
Protestant	995 (48.8%)	889 (43.9%)	960 (47.6%)	2844 (46.8%)
Catholic	633 (31.1%)	779 (38.5%)	715 (35.5%)	2127 (35.0%)
Adventist	249 (12.2%)	202 (10.0%)	188 (9.3%)	639 (10.5%)
Other	159 (7.8%)	155 (7.7%)	151 (7.5%)	465 (7.7%)

CR: CyberRwanda, SRH: sexual and reproductive health.
*Calculated using principal components analysis of the participant's household dwelling materials and assets with the first factor categorized into quartiles.
Data reported as mean ± standard deviation for continuous variables or n (column %) for categorical variables.
Missing responses: number of students (n=2), number of teachers (n=1), student-teacher ratio (n=3), computers (n=2), SRH curriculum (n=1), partnered (n=5), parental education (n=755), wealth index (n=2), religion (n=3).

Table 2. School-level fidelity and individual-level engagement with the CyberRwanda intervention, overall and by CyberRwanda implementation model.

School-level fidelity*	CR combined (n=40)	CR facilitated (n=20)	CR self-service (n=20)
Heard of CR	98.4% ± 2.2%	98.5% ± 1.4%	98.2% ± 2.8%
Ease of access score (range: 0–5)	4.0 ± 0.3	4.0 ± 0.4	3.9 ± 0.3
No tablet/internet challenges**	60.8% ± 9.0%	61.6% ± 7.9%	60.0% ± 10.1%
No issues with tablet access	61.7% ± 10.2%	63.9% ± 8.4%	59.6% ± 11.5%
Individual-level engagement	CR combined (n=3707)	CR facilitated (n=1858)	CR self-service (n=1849)
Ever used CR	2815 (75.9%)	1435 (77.2%)	1380 (74.6%)
Used CR “many times”	1175 (31.7%)	618 (33.3%)	557 (30.1%)
Times used CR in past month	1.0 ± 3.3	1.1 ± 2.8	0.9 ± 3.7
Number of STORIES seasons read	1.3 ± 1.2	1.3 ± 1.2	1.3 ± 1.2
Times used SHOP	0.8 ± 2.2	0.8 ± 2.4	0.8 ± 2.0
Ever placed SHOP order	479 (12.9%)	247 (13.3%)	232 (12.5%)

CR: CyberRwanda.
Data reported as mean ± standard deviation for continuous variables or n (column %) for categorical variables.
*School-level proportions or means among endline participants (n=3707 CR combined), excluding participants who had never heard of (n=34) or tried to access (n=520) CR.
**Challenges include restricted tablet access, too few tablets available, broken tablets, internet connection issues, and/or not enough time with tablet.
Missing responses: n=33 times used CR, n=183 STORIES seasons, n=20 times used SHOP, n=28 SHOP order.

Table 3. Effects of CyberRwanda on primary outcomes and secondary outcomes of knowledge, attitudes and beliefs, self-efficacy, and behavior at 24 months.

	Control (n=1845)	CR combined (n=3707)	PR (95% CI), CR combined vs. control	CR facilitated (n=1858)	PR (95% CI), CR facilitated vs. control	CR self-service (n=1849)	PR (95% CI), CR self-service vs. control
Primary outcomes†							
Current modern contraceptive use by self or partner (females)*	101 (10.6%)	205 (10.7%)	1.04 (0.76, 1.42)	106 (11.2%)	1.10 (0.76, 1.58)	99 (10.2%)	0.98 (0.68, 1.41)
Ever pregnancy (females)*	19 (2.0%)	50 (2.6%)	1.33 (0.71, 2.50)	20 (2.1%)	1.03 (0.49, 2.16)	30 (3.1%)	1.65 (0.82, 3.29)
Ever HIV testing	949 (51.4%)	1914 (51.6%)	1.00 (0.91, 1.11)	981 (52.8%)	1.05 (0.94, 1.17)	933 (50.5%)	0.96 (0.86, 1.07)
Secondary outcomes							
Knowledge							
Fertility knowledge	184 (10.0%)	385 (10.4%)	1.06 (0.83, 1.34)	205 (11.0%)	1.12 (0.86, 1.47)	180 (9.7%)	0.99 (0.75, 1.30)
EC knowledge	908 (49.2%)	2071 (55.9%)	**1.14 (1.04, 1.24)**	1069 (57.5%)	**1.17 (1.06, 1.28)**	1002 (54.2%)	**1.10 (1.00, 1.21)**
HIV knowledge	1332 (72.2%)	2660 (71.8%)	0.99 (0.94, 1.04)	1344 (72.3%)	0.99 (0.93, 1.05)	1316 (71.2%)	0.98 (0.93, 1.04)
Knowledge of menstrual tracking tool(s) (females)*	857 (89.9%)	1757 (91.4%)	1.02 (0.99, 1.05)	862 (90.7%)	1.01 (0.98, 1.04)	895 (92.1%)	1.03 (1.00, 1.06)
Attitudes and beliefs							
Favorable views on FP/RH service utilization	1184 (64.2%)	2297 (62.0%)	0.97 (0.90, 1.04)	1172 (63.1%)	0.98 (0.90, 1.06)	1125 (60.8%)	0.95 (0.87, 1.04)
Beliefs conducive to condom use	1385 (75.1%)	2892 (78.0%)	**1.05 (1.01, 1.09)**	1461 (78.6%)	**1.06 (1.01, 1.12)**	1431 (77.4%)	1.03 (0.98, 1.09)
Self-efficacy							
Confidence in ability to give consent	1529 (82.9%)	3141 (84.7%)	1.02 (0.99, 1.05)	1574 (84.7%)	1.02 (0.99, 1.05)	1567 (84.7%)	1.02 (0.99, 1.06)
Confidence in ability to get partner to use contraceptives	1710 (92.7%)	3507 (94.6%)	**1.02 (1.00, 1.03)**	1756 (94.5%)	**1.02 (1.00, 1.03)**	1751 (94.7%)	**1.02 (1.00, 1.04)**
Confidence in ability to access/use contraceptive services (females)*	910 (95.5%)	1867 (97.1%)	1.02 (1.00, 1.03)	927 (97.6%)	**1.02 (1.00, 1.04)**	940 (96.7%)	1.01 (0.99, 1.03)

	Control (n=1845)	CR combined (n=3707)	PR (95% CI), CR combined vs. control	CR facilitated (n=1858)	PR (95% CI), CR facilitated vs. control	CR self-service (n=1849)	PR (95% CI), CR self-service vs. control
Confidence in ability to obtain HIV test	1807 (97.9%)	3647 (98.4%)	1.00 (1.00, 1.01)	1830 (98.5%)	1.01 (1.00, 1.02)	1817 (98.3%)	1.00 (0.99, 1.01)
Behaviors							
Ever sexually active	488 (26.4%)	989 (26.7%)	1.00 (0.86, 1.16)	494 (26.6%)	1.00 (0.84, 1.18)	495 (26.8%)	1.00 (0.85, 1.18)
Current modern contraceptive use by self or partner (males)**	156 (17.5%)	394 (22.1%)	**1.25 (1.03, 1.53)**	205 (22.6%)	**1.31 (1.04, 1.65)**	189 (21.6%)	1.20 (0.95, 1.51)
Ever condom use***	260 (53.3%)	591 (59.8%)	1.13 (1.00, 1.27)	306 (61.9%)	**1.19 (1.05, 1.35)**	285 (57.6%)	1.07 (0.92, 1.24)
Received FP counseling in past 12 months	226 (12.2%)	498 (13.4%)	1.09 (0.90, 1.34)	244 (13.1%)	1.07 (0.85, 1.35)	254 (13.7%)	1.12 (0.89, 1.40)
Discussed contraception with most recent sexual partner***	258 (52.9%)	583 (58.9%)	**1.13 (1.02, 1.26)**	294 (59.5%)	**1.15 (1.03, 1.30)**	289 (58.4%)	1.11 (0.99, 1.25)
HIV testing in past 12 months	588 (31.9%)	1213 (32.7%)	1.02 (0.89, 1.18)	616 (33.2%)	1.06 (0.91, 1.24)	597 (32.3%)	0.99 (0.84, 1.15)

CR: CyberRwanda; PR: prevalence ratio estimated via generalized linear mixed model adjusted for district with school-level random intercepts; CI: confidence interval; EC: emergency contraception; FP/RH: family planning/reproductive health.
Bold values indicate p<.05 based on two-sided Wald test.
†Pre-specified primary outcomes; regression estimates inverse probability of censoring weighted to account for attrition.
*Among female participants only (control n=953, CR combined n=1922, CR facilitated n=950, CR self-service n=972).
**Among male participants only (control n=892, CR combined n=1785, CR facilitated n=908, CR self-service n=877).
***Among sexually active participants only (control n=488, CR combined n=989, CR facilitated n=494, CR self-service n=495).
Missing responses: current contraceptive use (females) n=17, ever pregnancy n=5, ever HIV testing n=1, fertility knowledge n=3, EC knowledge n=2, knowledge of menstrual tracking n=10, FP/RH attitudes n=17, condom beliefs n=113, consent self-efficacy n=16, partner contraceptive self-efficacy n=11, contraceptive service self-efficacy n=1, sexually active n=2, current modern contraceptive use (males) n=9, ever condom use n=30, 12-month FP counseling n=7, partner contraceptive discussion n=15, 12-month HIV testing n=32.

Figure Legends/Captions (for main text figures)

Fig 1. Features of the CyberRwanda intervention.

Fig 2. Trial profile for the CyberRwanda impact study, 2021–2023.

Fig 3. Effects of CyberRwanda on contraceptive use in sensitivity analyses among participants who reported past sexual intercourse at 24 months.

CR: CyberRwanda, PR: prevalence ratio estimated via generalized linear mixed model adjusted for district with school-level random intercepts, CI: confidence interval. *p<.05 based on two-sided Wald test.

Data are presented as prevalence ratios with error bars denoting 95% confidence intervals. Panel A presents estimates among n=547 sexually active female participants. Panel B presents estimates among n=930 sexually active male participants.

Detailed results are presented in Supplementary Table S2.

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Methods

Study design and participant selection

We conducted a three-arm, parallel-group cluster randomized, Type 2 Hybrid Effectiveness-Implementation trial in eight Rwandan districts.[1] The study design and analysis plan were pre-registered (clinicaltrials.gov NCT04198272),[2] and the study is reported per CONSORT guidelines.[3,4] Secondary schools located within 4.5 kilometers of a pharmacy, ≥1.5 kilometers from another secondary school, and with ≥150 students were eligible. Boarding schools were excluded. Within participating schools, students ages 12–19 years, in school levels S1 and S2 (the first two years of high school), and who were willing to provide contact information and informed consent (participants 18–19 years) or assent and parental consent (participants <18 years) were eligible to enroll. There were no exclusion criteria for participants.

Of 383 secondary schools in these districts, 61 met eligibility criteria; 60 were randomly selected to participate. Headteachers provided informed consent for their schools' participation. We generated a list of all S1–S2 students who had returned signed parental consent forms (distributed to students <18 years) and/or were ages 18–19 years based on school registers. We used sex-stratified random selection to reach our target enrollment of 100 students per school (50 males, 50 females), inviting an average of 124 students per school to participate, including randomly selected replacements for students who were no longer attending the school or did not enroll. Selected students were invited by teachers to attend weekend data collection events at their school.

Study arms

Schools assigned to both CyberRwanda implementation models and the control arm received Comprehensive Sexuality Education as part of the Competence-based Curriculum implemented by the Rwanda Education Board.[5]

In addition, CyberRwanda schools received one of two implementation models: self-service or facilitated (Fig 1). The self-service model offered self-guided access to the CyberRwanda platform and included tablets with instructional set-up guides (8 tablets per school), internet connection via hotspots, and marketing materials. Trained student ambassadors promoted

CyberRwanda in schools and supported peers in using the platform as needed. The facilitated model included all components of the self-service model, with the addition of peer facilitators (in lieu of student ambassadors) who guided interactive sessions at in-person weekly CyberRwanda clubs using an activity booklet with learning modules corresponding to the CyberRwanda content offered on the digital platform. The club sessions (1–2 hours in duration, 50–150 students per week) were voluntary and included group tablet access and activities such as skits, role-plays, and group discussions. The intervention was available to all students in CyberRwanda schools throughout the 24-month study period.

Student ambassadors (self-service model), peer facilitators (facilitated model), and lead teachers (both models) participated in a 1.5-day training on how to use CyberRwanda. Peer facilitators participated in an additional one-day training on facilitating clubs and using the activity booklet.

Theoretical framework and hypothesized impact pathway

The study design was guided by the Theory of Planned Behavior, which states that attitudes, beliefs, and perceived behavioral control are intermediate steps that can shift subjective norms and influence intentions, leading to behavior change.[6,7] CyberRwanda is hypothesized to create an impact by engaging adolescents with interactive sexual health edutainment content through the STORIES and LEARN features to improve knowledge, beliefs, attitudes, and self-efficacy related to reproductive empowerment and autonomy, and through increasing access to contraception and FP/RH information via the youth-friendly online SHOP with the overall goal of increasing contraceptive use and HIV testing and delaying initiation of childbearing among adolescents. The 12-month midline data demonstrated significant shifts in intermediate outcomes on the impact pathway (e.g., knowledge, beliefs, self-efficacy) among CyberRwanda participants.[8] The present analysis of endline data will determine whether these shifts were sustained and whether the intervention had any effect on the primary outcomes at 24 months.

Randomization

Randomization was conducted at the school (cluster) level, stratified by district, using a participatory two-stage approach. To ensure that global balance was achieved across all districts (i.e., 20 schools per arm), the study team randomly allocated the number of schools per

study arm in a 1:1:1 ratio within each district using Stata.[9] In cases when the number of schools in a district was not a multiple of three, "misfit" schools were grouped into a new stratum and randomly allocated across study arms.[10] Schools were then randomly assigned to study arms during community participatory randomization events held in each district. At each event, school representatives who consented to participate in the study were selected in a random order to choose colored balls (corresponding to their district's predetermined study arm assignments) from an opaque bag. After all balls were selected, the colors corresponding to each study arm were announced to the participating schools. This transparent, participatory approach was viewed favorably by participants and perceived to facilitate trust among stakeholders.[11] Due to the nature of the intervention, participants and research assistants who collected outcomes data were not blinded. The investigators were also not blinded to allocation during the intervention and outcome assessment.

Procedures

Enrollment and baseline data collection were conducted from February–May 2021. Midline and endline data collection took place 12 months (February–August 2022) and 24 months (March–August 2023) after baseline, respectively. After confirming students' eligibility and obtaining informed consent or assent plus parental consent, surveys (~45 minutes in length) were administered by trained research assistants in Kinyarwanda on tablets using Qualtrics software.[12] Participant sex was determined by research assistants based on the sex listed for each student in their school register and their gender presentation. Participants were offered 3,000 Rwandan francs (~$2.40) for transport reimbursement.

Sociodemographic and school characteristics were measured at baseline. The endline survey included questions on CyberRwanda exposure; FP/RH knowledge, attitudes and beliefs, and self-efficacy; sexual behavior; contraceptive use; pregnancy history; and HIV testing.

Outcomes

The study had three pre-specified primary outcomes: 1) uptake of a modern contraceptive method among females, defined as the proportion of all female participants who reported that they or their partner were currently using a modern contraceptive method (i.e., male or female condoms, oral contraceptive pills, injectable contraception, emergency contraceptive pills,

intrauterine devices [IUD], implants, diaphragms, spermicidal foam or jelly, male or female sterilization, lactational amenorrhea method [LAM], and Standard Days Method[13,14]); 2) initiation of childbearing among females, defined as the proportion of all female participants who reported ever having been pregnant regardless of the outcome; and 3) HIV testing among youth, defined as the proportion of all participants who reported ever having an HIV test.

Secondary outcomes were categorized in four domains: 1) knowledge related to fertility, emergency contraception, HIV, and menstrual tracking tools; 2) attitudes and beliefs related to FP/RH service utilization and condom use; 3) FP/RH self-efficacy, namely confidence in one's ability to give sexual consent, get a partner to use contraception, access and use contraceptive services, and obtain an HIV test; and 4) FP/RH behaviors including past sexual activity, current modern contraceptive use among males, current use of specific contraceptive methods (i.e., condoms vs. other modern methods), ever use of condoms, recent HIV testing, recent receipt of FP counseling, and discussion of contraception with one's most recent sexual partner. All secondary outcomes were pre-specified in a pre-registered analysis plan with the exception of four outcomes (HIV knowledge, self-efficacy for giving sexual consent, recent receipt of FP counseling, and partner contraceptive discussion), which were included to examine consistency with previously reported 12-month findings.[8]

All primary and secondary outcomes were examined at the individual level. Details on their operationalization can be found in Table S3.

Power and sample size

Power calculations were conducted using a simulation-based approach based on the primary outcome of modern contraceptive use among female participants.[15] The simulations assumed that the CyberRwanda intervention would not impact the rate at which participants become sexually active. Schools were also assumed to be independent. Simulated data included number of clusters (schools) and numbers of female participants per school, with a distribution of contraceptive uptake by school to account for variability at the school-level. School-level contraceptive uptake was based on the proportion of sexually active Rwandan youth currently using modern contraception reported in the 2014–15 Rwanda Demographic and Health Survey.[16] The simulated data (2000 datasets) demonstrated that the study was powered at 80% to detect an effect on modern contraceptive use when the facilitated model has an odds ratio,

approximating a relative risk, of ≥2.5 compared to control (i.e., an increase in modern contraceptive use from 2%[16] to 5%) with a target sample of 50 female participants per school (n=3,000). We recruited an equal number of male participants per school for a total of 6,000 participants overall. Sample size calculations accounted for 10% attrition over the study period.

Statistical Analyses

Analyses were conducted in R version 4.3.1[17] and Stata version 17.[9] We generated descriptive statistics to assess baseline balance of school and participant characteristics by study arm and to qualitatively compare endline indicators of school-level implementation fidelity and individual-level CyberRwanda engagement by intervention model. The intraclass correlation coefficient (ICC) was calculated for the primary outcomes using one-way analysis of variance (ANOVA).

For all outcomes, we constructed generalized linear mixed models with either a three-level explanatory variable for study arm (each CyberRwanda arm vs. control) or a two-level variable (combined CyberRwanda arms vs. control). Prevalence ratios (PRs) and two-sided 95% confidence intervals (CIs) were estimated using log-binomial regression or (when non-convergent) log-Poisson regression with robust standard errors.[18] All models were adjusted for district with random intercepts to account for clustering by school.

A joint test of no difference was conducted for each primary outcome to determine whether at least one of the CyberRwanda arms was significantly different than the control arm; likelihood ratio tests compared null models to models with the three-level explanatory variable for study arm. The study was designed as a non-inferiority trial. However, the likelihood ratio tests did not show evidence of an intervention effect ($p \geq .05$), therefore we did not proceed with non-inferiority testing.

Inverse probability of censoring weighting (IPCW) was used to account for loss to follow-up over the study period in the modified intention-to-treat analyses for the primary outcomes. The weighted analyses were compared to unweighted (complete case) models; models adjusted for sociodemographic and school characteristics; and an instrumental variable analysis modeling the intervention's impacts under conditions of high school-level implementation fidelity (model specifications are detailed in Table S4). As the conclusions were unchanged, we present only the primary analyses.

Complete case models were used to assess CyberRwanda's effects on the secondary outcomes and to conduct pre-specified sensitivity analyses limited to participants who reported past sexual intercourse at 24 months (both overall and stratified by sex).

Ethics and inclusion statement

The CyberRwanda intervention was developed using HCD with more than 1,000 Rwandan adolescents, parents, teachers, and healthcare providers to create a digital FP/RH intervention that was well-suited for the Rwandan context, accessible to adolescents at all literacy levels, and that addressed the most critical gaps in adolescent FP/RH in Rwanda. The impact evaluation was designed and implemented in collaboration with Rwanda-based researchers and government stakeholders. Best practices were used to ensure that all sensitive questions in survey instruments minimize risks to participants and maximize privacy and confidentiality. Ethical approval for this study was obtained from the Committee for Protection of Human Subjects at UC Berkeley and the Rwanda National Ethics Committee.

Data Availability

De-identified participant data used in these analyses will be available on the Open Science Framework (https://osf.io/hdc6g/) by September 2024. Approval to access or use the de-identified data is not required; however, please contact the corresponding author prior to using the data to inform the study team of the analyses to be performed.

Code Availability

R and Stata code files used in these analyses will be available on the Open Science Framework (https://osf.io/hdc6g/) by September 2024.

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WHAT IS CYBERRWANDA?

Intervention derived using human-centered design providing education on family planning and reproductive health, employment, and goal setting

Features

STORIES: Edutainment webcomics

LEARN: Educational videos and frequently asked questions

SHOP: Direct-to-consumer online store linked to youth-friendly pharmacies

IMPACT EVALUATION

60 schools
Cluster randomized 1:1:1

ARM 1
20 SCHOOLS

ARM 2
20 SCHOOLS

ARM 3
20 SCHOOLS

IMPLEMENTATION

Comparing two models

Self-service

- Self-guided access
- Tablets, hotspots
- School ambassadors

Facilitated

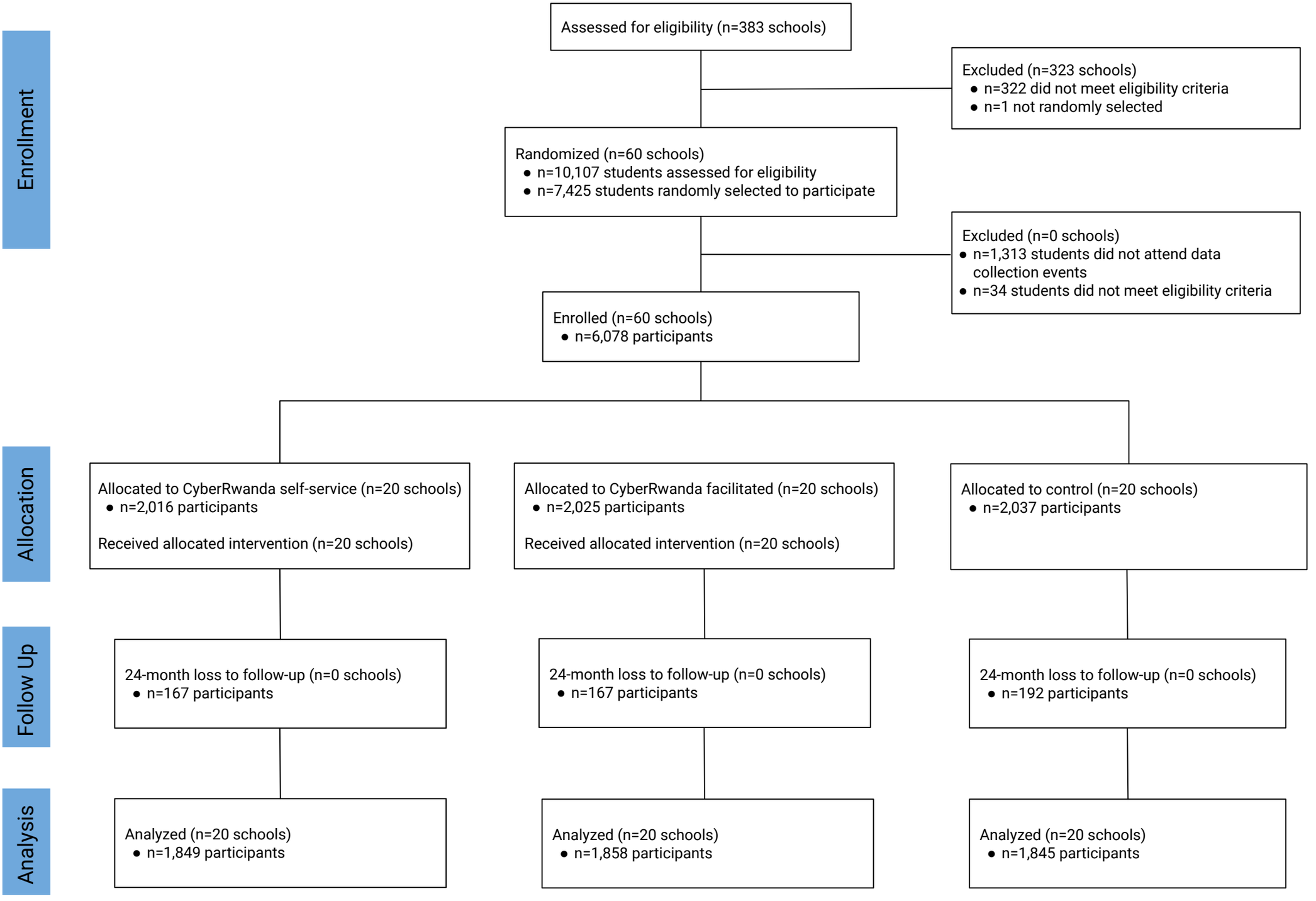
- Self-guided and group access
- Tablets, hotspots
- Peer facilitators with activity guide
- Weekly club sessions (1-2 hours) with 50-150 students

Control

Government approved Comprehensive Sexuality Education

PRIMARY OUTCOMES AT 24 MONTHS

- Use of a modern contraceptive method
- Initiation of childbearing
- HIV testing


Enrollment
Assessed for eligibility (n=383 schools)
Excluded (n=323 schools)
• n=322 did not meet eligibility criteria
• n=1 not randomly selected
Randomized (n=60 schools)
• n=10,107 students assessed for eligibility
• n=7,425 students randomly selected to participate
Excluded (n=0 schools)
• n=1,313 students did not attend data collection events
• n=34 students did not meet eligibility criteria
Enrolled (n=60 schools)
• n=6,078 participants
Allocation
Allocated to CyberRwanda self-service (n=20 schools)
• n=2,016 participants
Received allocated intervention (n=20 schools)
Allocated to CyberRwanda facilitated (n=20 schools)
• n=2,025 participants
Received allocated intervention (n=20 schools)
Allocated to control (n=20 schools)
• n=2,037 participants
Follow Up
24-month loss to follow-up (n=0 schools)
• n=167 participants
24-month loss to follow-up (n=0 schools)
• n=167 participants
24-month loss to follow-up (n=0 schools)
• n=192 participants
Analysis
Analyzed (n=20 schools)
• n=1,849 participants
Analyzed (n=20 schools)
• n=1,858 participants
Analyzed (n=20 schools)
• n=1,845 participants

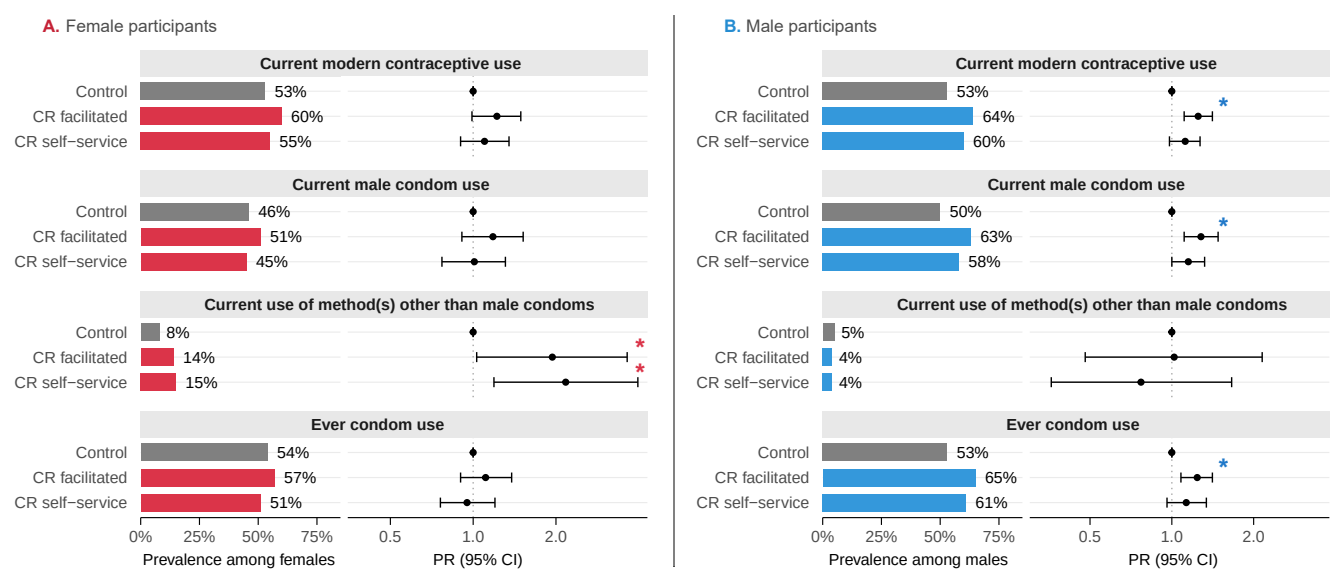

A. Female participants
Current modern contraceptive use
Control
CR facilitated
CR self−service
53%
60%
55%
Current male condom use
46%
51%
45%
Current use of method(s) other than male condoms
8%
14%
15%
*
*
Ever condom use
54%
57%
51%
0%
25%
50%
75%
0.5
1.0
2.0
Prevalence among females
PR (95% CI)
B. Male participants
Current modern contraceptive use
53%
64%
60%
*
Current male condom use
50%
63%
58%
*
Current use of method(s) other than male condoms
5%
4%
4%
Ever condom use
53%
65%
61%
*
Prevalence among males
PR (95% CI)

Table S1. Baseline characteristics of endline participants compared to those who did not participate at endline.

	Endline participants (n=5552)	Not reached at endline (n=526)	Overall (n=6078)
Age in years	15.3 ± 1.5	15.8 ± 1.5	15.4 ± 1.5
Sex			
Female	2875 (51.8%)	255 (48.5%)	3130 (51.5%)
Male	2677 (48.2%)	271 (51.5%)	2948 (48.5%)
District			
Bugesera	477 (8.6%)	40 (7.6%)	517 (8.5%)
Gasabo	1220 (22.0%)	100 (19.0%)	1320 (21.7%)
Gatsibo	380 (6.8%)	29 (5.5%)	409 (6.7%)
Huye	639 (11.5%)	81 (15.4%)	720 (11.8%)
Kayonza	185 (3.3%)	17 (3.2%)	202 (3.3%)
Nyagatare	830 (14.9%)	83 (15.8%)	913 (15.0%)
Nyarugenge	475 (8.6%)	32 (6.1%)	507 (8.3%)
Rwamagana	1346 (24.2%)	144 (27.4%)	1490 (24.5%)
School level			
Secondary 1	3221 (58.0%)	234 (44.5%)	3455 (56.8%)
Secondary 2	2331 (42.0%)	292 (55.5%)	2623 (43.2%)
Relationship status			
No partner	4484 (80.8%)	406 (77.2%)	4890 (80.5%)
Partnered	1064 (19.2%)	119 (22.6%)	1183 (19.4%)
Parental education			
None	468 (8.4%)	59 (11.2%)	527 (8.7%)
Some primary	1048 (18.9%)	120 (22.8%)	1168 (19.2%)
Completed primary	2793 (50.3%)	226 (43.0%)	3019 (49.7%)
Completed secondary	418 (7.5%)	38 (7.2%)	456 (7.5%)
Vocational training	36 (0.6%)	6 (1.1%)	42 (0.7%)
Completed university	100 (1.8%)	11 (2.1%)	111 (1.8%)
Wealth index (quartiles)			
1 – lowest	1362 (24.5%)	159 (30.2%)	1521 (25.0%)
2	1381 (24.9%)	136 (25.9%)	1517 (25.0%)
3	1407 (25.3%)	112 (21.3%)	1519 (25.0%)
4 – highest	1400 (25.2%)	119 (22.6%)	1519 (25.0%)
Religion			
Protestant	2613 (47.1%)	231 (43.9%)	2844 (46.8%)
Catholic	1933 (34.8%)	194 (36.9%)	2127 (35.0%)
Adventist	586 (10.6%)	53 (10.1%)	639 (10.5%)
Other	418 (7.5%)	47 (8.9%)	465 (7.7%)

Data reported as mean ± standard deviation for continuous variables or n (column %) for categorical variables.
Missing responses: partnered (n=5), parental education (n=755), wealth index (n=2), religion (n=3).

Table S2. Effects of CyberRwanda on behavioral outcomes among participants who reported past sexual intercourse at 24 months (n=1,477*).

	Control (n=488)	CR combined (n=989)	PR (95% CI), CR combined vs. control	CR facilitated (n=494)	PR (95% CI), CR facilitated vs. control	CR self-service (n=495)	PR (95% CI), CR self-service vs. control
Current modern contraceptive use by self or partner	257 (52.7%)	599 (60.6%)	**1.18 (1.06, 1.30)**	311 (63.0%)	**1.24 (1.12, 1.38)**	288 (58.2%)	1.11 (0.99, 1.26)
- Females	101 (52.6%)	205 (57.7%)	1.16 (0.96, 1.39)	106 (60.2%)	1.22 (0.99, 1.49)	99 (55.3%)	1.10 (0.90, 1.35)
- Males	156 (52.7%)	394 (62.1%)	**1.18 (1.07, 1.32)**	205 (64.5%)	**1.25 (1.11, 1.41)**	189 (59.8%)	1.12 (0.98, 1.27)
Current male condom use	235 (48.2%)	551 (55.7%)	**1.18 (1.06, 1.32)**	289 (58.5%)	**1.25 (1.11, 1.41)**	262 (52.9%)	1.11 (0.98, 1.26)
- Females	88 (45.8%)	170 (47.9%)	1.09 (0.86, 1.37)	90 (51.1%)	1.18 (0.91, 1.52)	80 (44.7%)	1.01 (0.77, 1.31)
- Males	147 (49.7%)	381 (60.1%)	**1.21 (1.07, 1.38)**	199 (62.6%)	**1.28 (1.11, 1.48)**	182 (57.6%)	1.15 (1.00, 1.32)
Current use of method(s) other than male condoms	29 (5.9%)	77 (7.8%)	1.41 (0.93, 2.16)	38 (7.7%)	1.43 (0.89, 2.31)	39 (7.9%)	1.40 (0.87, 2.25)
- Females	15 (7.8%)	51 (14.4%)	**2.06 (1.18, 3.60)**	24 (13.6%)	**1.94 (1.03, 3.63)**	27 (15.1%)	**2.17 (1.19, 3.97)**
- Males	14 (4.7%)	26 (4.1%)	0.88 (0.46, 1.69)	14 (4.4%)	1.02 (0.48, 2.15)	12 (3.8%)	0.77 (0.36, 1.66)
Ever condom use	260 (53.3%)	591 (59.8%)	1.13 (1.00, 1.27)	306 (61.9%)	**1.19 (1.05, 1.35)**	285 (57.6%)	1.07 (0.92, 1.24)
- Females	103 (53.6%)	191 (53.8%)	1.03 (0.85, 1.25)	100 (56.8%)	1.11 (0.90, 1.38)	91 (50.8%)	0.95 (0.76, 1.20)
- Males	157 (53.0%)	400 (63.1%)	**1.18 (1.04, 1.35)**	206 (64.8%)	**1.24 (1.08, 1.41)**	194 (61.4%)	1.13 (0.96, 1.34)
Discussed contraception with most recent sexual partner	258 (52.9%)	583 (58.9%)	**1.13 (1.02, 1.26)**	294 (59.5%)	**1.15 (1.03, 1.30)**	289 (58.4%)	1.11 (0.99, 1.25)
- Females	112 (58.3%)	204 (57.5%)	1.00 (0.85, 1.17)	104 (59.1%)	1.03 (0.85, 1.25)	100 (55.9%)	0.97 (0.82, 1.15)
- Males	146 (49.3%)	379 (59.8%)	**1.23 (1.07, 1.40)**	190 (59.7%)	**1.24 (1.07, 1.43)**	189 (59.8%)	**1.22 (1.05, 1.41)**
Ever pregnancy (females)	19 (9.9%)	50 (14.1%)	1.42 (0.81, 2.48)	20 (11.4%)	1.14 (0.59, 2.19)	30 (16.8%)	1.69 (0.93, 3.06)
Ever HIV testing	303 (62.1%)	592 (59.9%)	0.97 (0.87, 1.07)	297 (60.1%)	0.99 (0.86, 1.13)	295 (59.6%)	0.95 (0.85, 1.05)
- Females	134 (69.8%)	235 (66.2%)	0.99 (0.90, 1.10)	114 (64.8%)	1.00 (0.88, 1.12)	121 (67.6%)	0.99 (0.88, 1.12)
- Males	169 (57.1%)	357 (56.3%)	0.98 (0.84, 1.14)	183 (57.5%)	1.00 (0.83, 1.21)	174 (55.1%)	0.95 (0.81, 1.12)

CR: CyberRwanda, PR: prevalence ratio estimated via generalized linear mixed model adjusted for district with school-level random intercepts; CI: confidence interval.

Bold values indicate p<.05 based on two-sided Wald test.

*Female participants: control n=192, CR combined n=355, CR facilitated n=176, CR self-service n=179; male participants: control n=296, CR combined n=634, CR facilitated n=318, CR self-service n=316.

Missing responses: current contraceptive use (any, condoms, or other methods) n=24, ever condom use n=30, partner contraceptive discussion n=15, ever pregnancy n=5.

Table S3. CyberRwanda survey questions and outcome definitions for primary and secondary outcomes at 24 months.

Outcome	Survey Question(s)	Response Option(s)
Uptake of modern contraception		
Current modern contraceptive use†*[(a)]	What contraceptive method(s) are you (or your partner) currently using? *Note: Question asked of participants who reported past sexual intercourse (participants who reported never having sexual intercourse were inferred as non-users in primary analyses). Participants could select multiple contraceptive methods.*	Pills OR Condoms OR Female condoms OR Intrauterine devices (IUD) OR Injectables OR Implants/Jadelle OR Emergency contraceptive pills OR Diaphragm OR Foam/jelly OR Standard Days Method OR Female sterilization OR Male sterilization OR Lactational amenorrhea method (LAM)
Current male condom use*	Same as previous	Condoms
Current use of method(s) other than male condoms*	Same as previous	Pills OR Female condoms OR Intrauterine devices (IUD) OR Injectables OR Implants/Jadelle OR Emergency contraceptive pills OR Diaphragm OR Foam/jelly OR Standard Days Method OR Female sterilization OR Male sterilization OR Lactational amenorrhea method (LAM)
Ever condom use*	Have you ever used a condom with a current or previous partner? *Note: Question asked of participants who reported past sexual intercourse.*	Yes
Initiation of childbearing		
Ever pregnancy†	Have you ever been pregnant, regardless of the outcome of the pregnancy or if no child was born? *Note: Question asked of female participants who reported past sexual intercourse (participants who reported never having sexual intercourse were inferred as non-childbearing in primary analyses).*	Yes
HIV testing		
Ever HIV testing†	I don't want to know the results, but have you ever been tested for HIV/AIDs?	Yes
HIV testing in past 12 months*	1. I don't want to know the results, but have you ever been tested for HIV/AIDS? IF YES: 2. How many months ago was your most recent HIV test?	Yes AND In the past 6 months OR 7 months–1 year ago

Outcome	Survey Question(s)	Response Option(s)
Knowledge		
Knowledge of the fertile window*	1. From one menstrual period to the next, are there certain days when a woman is more likely to become pregnant? IF YES: 2. Is this time just before her period begins, during her period, right after her period has ended, or halfway between two periods?	Yes AND Half-way between two periods
Knowledge of emergency contraception*	Emergency contraception can be taken up to one month after having unprotected sex to prevent a pregnancy.	False
HIV knowledge[(b)]	1. Can a person reduce the risk of getting HIV/AIDS by having sex with only one uninfected partner who has no other partners? 2. Can a person who is living with HIV/AIDS transmit the virus to another person during sex if they are taking their medication every day? 3. Can a person get HIV/AIDS by having sex with a partner who has HIV/AIDS but is taking their medication every day? 4. Can a person reduce the risk of getting HIV/AIDS virus by using a condom every time they have sex? 5. Can a healthy-looking person have HIV/AIDS virus? 6. Can people get the HIV/AIDS virus because of witchcraft or other supernatural means? 7. Can a person get HIV/AIDS virus by sharing food with someone who is infected? 8. Can people get the HIV/AIDS virus from mosquito bites? 9. Can men reduce their risk of getting the HIV/AIDS virus by getting circumcised? 10. Can men reduce their risk of getting the HIV/AIDS virus by taking a prevention pill every day?	≥7 of 10 questions answered correctly
Knowledge of menstrual tracking tool(s)*	I know what tools are available to track my menstrual cycle. *Note: Question asked of female participants.*	Strongly agree OR Agree
Attitudes and beliefs		
Favorable views on family planning service utilization*	Family planning services are only for married men and women or women who have already had children.	Disagree OR Strongly disagree

Outcome	Survey Question(s)	Response Option(s)
Beliefs conducive to condom use*	If a girl suggested using condoms to her partner, it would mean that she didn't trust him. *Note: Question asked of participants who reported having heard of condoms.*	Disagree
Self-efficacy		
Self-efficacy for giving sexual consent[(b)]	I feel confident that I could verbally state my consent to someone I want to have sex with.	Agree
Self-efficacy for contraceptive/condom communication with partners*	How confident are you that you could get your partner(s) to use contraceptives/condoms if you desired it?	Confident OR Somewhat confident
Self-efficacy for access and utilization of contraceptive services*	I am confident that I can access and use contraceptive services if I need them.	Strongly agree OR Agree
Self-efficacy for HIV testing*	How confident are you that you can get tested for HIV if you need it?	Confident OR Somewhat confident
Other behavior		
Ever sexually active*	1. How old were you the first time you had vaginal sex/sexual intercourse? IF RESPONDED "Never had sex": 2. I want to make certain that I have the correct information. Have you ever had sex?	Selected an age at first sex OR I don't know the age, but have had sex OR Yes
Received family planning counseling in past 12 months[(b)]	Have you received family planning counseling services in the past 12 months? Family planning includes providing information on and access to contraceptive services to help with avoiding, delaying, or planning for pregnancy.	Yes
Partner contraceptive communication[(b)]	Now I'm going to ask you to think about your current partner, or if you don't currently have a partner, the most recent person you have had sexual intercourse with. […] Did you ever discuss using contraception with this person? *Note: Question asked of participants who reported past sexual intercourse.*	Yes

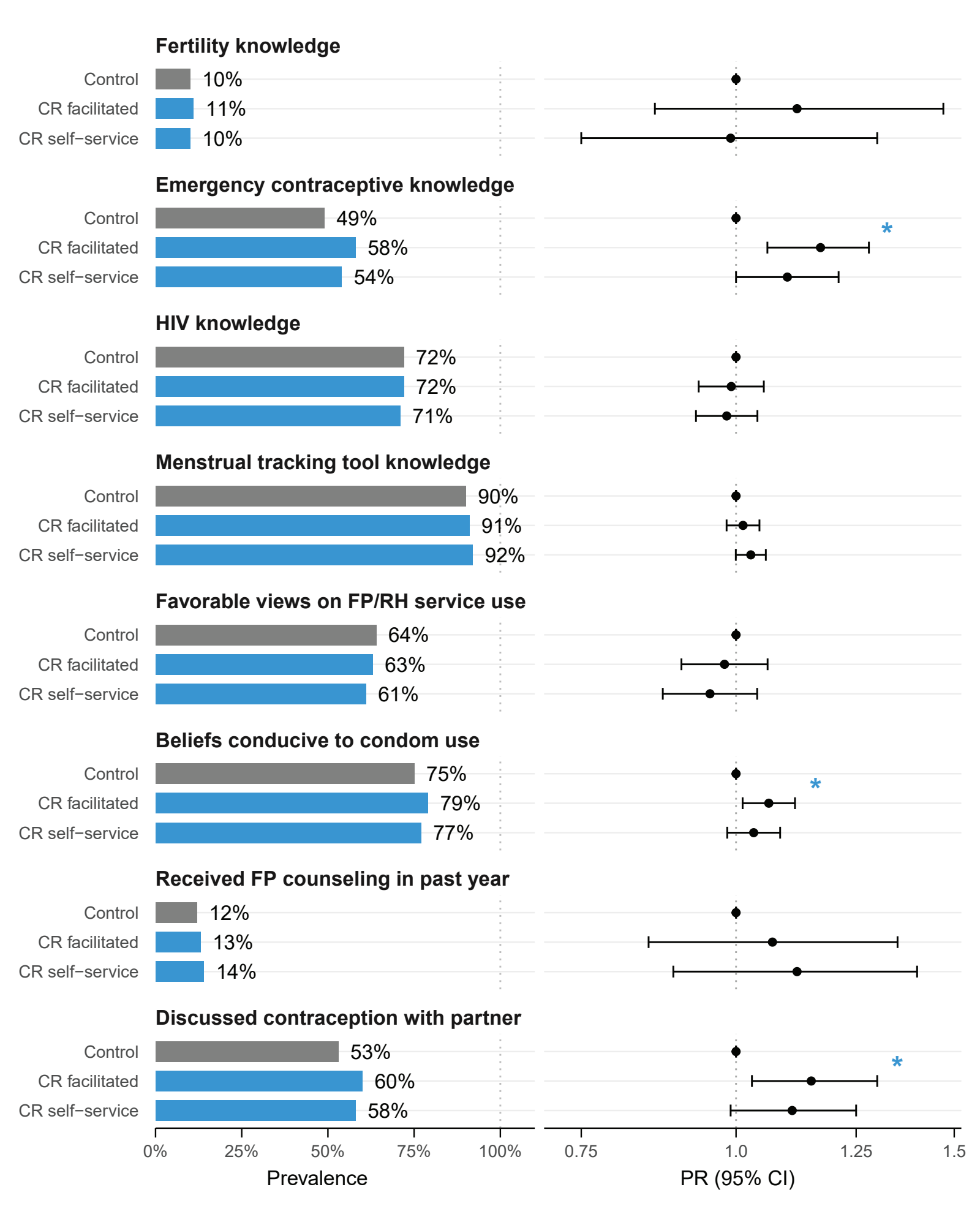
†Pre-specified primary outcome in the pre-registered analysis plan.
*Pre-specified secondary outcome in the pre-registered analysis plan.
[(a)]Current modern contraceptive use was pre-specified as a primary outcome among female participants and as a secondary outcome among male participants.
[(b)]Secondary outcome retained from 12-month interim analysis (Hémono et al. *J Adolesc Health* 2024).

Table S4. Regression model specifications for analyses comparing primary and secondary outcomes by study arm at 24 months.

Modeling Approach	Analyses	Model Specifications
Unadjusted inverse-probability-of-censoring weighted (IPCW)	Primary outcomes†	1. Logistic regression to predict probability of censoring at endline, including the following independent variables: • Baseline: district, school, age, sex, school level, partnership status, religion, parental education, wealth index, food insecurity, sexual activity • Midline: sexual activity, participation at midline • Combined baseline/midline: ever pregnant, ever reported modern contraceptive use 2. Log-binomial generalized linear mixed models to estimate prevalence ratios comparing outcomes by study arm. Models were reweighted using inverse of probability of censoring predicted in previous step, included random intercepts for school, and adjusted for district.
Complete case	Sensitivity analyses of primary outcomes† Secondary outcomes Subgroup analyses of primary and secondary outcomes	Log-binomial* generalized linear mixed models to estimate prevalence ratios comparing outcomes by study arm. Models were unweighted (complete case), included random intercepts for school, and adjusted for district. *If non-convergent, log-Poisson with robust standard errors.
Adjusted IPCW	Sensitivity analyses of primary outcomes†	Logistic generalized linear mixed models to estimate odds ratios comparing outcomes by study arm. Models were reweighted using inverse probability of censoring weights (defined above), included random intercepts for school, and adjusted for covariates measured at baseline: • Participant level: age, sex, religion, household wealth • School level: district, enrollment, student-teacher ratio, sexual health curriculum, computers

Modeling Approach	Analyses	Model Specifications
Instrumental variable	Sensitivity analyses of primary outcomes†	1. Created composite fidelity score (range: 0–8) as the sum of four indicators of school-level fidelity measured at endline (set to 0 for control arm participants): • Heard of CR (binary): 0 if no, 1 if yes • Ease of CR access (range: 0–5): 0 if had not heard of or tried to access CR, 1–5 based on ease of access rating (1 hardest, 5 easiest) • Did not report internet or table challenges (binary): 0 if reported tablet or internet challenges, 1 if did not report challenges • Did not report tablet access issues (binary): 0 if reported tablet access issues, 1 if did not report issues Calculated average fidelity score for each school. 2. Linear regression to predict participants' average school-level fidelity score including study arm and district as independent variables. 3. Logistic regression to estimate the association between predicted average school-level fidelity score and the outcomes. Models were adjusted for district, and standard errors were adjusted for school-level clustering.

CR: CyberRwanda.
†Primary outcomes: modern contraceptive use among all female participants, childbearing among all female participants, ever HIV testing among all participants.


Fertility knowledge
Control
CR facilitated
CR self−service
10%
11%
10%
Emergency contraceptive knowledge
Control
CR facilitated
CR self−service
49%
58%
54%
*
HIV knowledge
Control
CR facilitated
CR self−service
72%
72%
71%
Menstrual tracking tool knowledge
Control
CR facilitated
CR self−service
90%
91%
92%
Favorable views on FP/RH service use
Control
CR facilitated
CR self−service
64%
63%
61%
Beliefs conducive to condom use
Control
CR facilitated
CR self−service
75%
79%
77%
*
Received FP counseling in past year
Control
CR facilitated
CR self−service
12%
13%
14%
Discussed contraception with partner
Control
CR facilitated
CR self−service
53%
60%
58%
*
0%
25%
50%
75%
100%
Prevalence
0.75
1.0
1.25
1.5
PR (95% CI)