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Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission among adult Ugandans: a propensity-score matched analysis

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Abstract

Objective: To evaluate the effect of comprehensive knowledge of human immunodeficiency virus (HIV) on extramarital sexual relationships and consistent use of condoms.

Design: Quasi-experimental study using propensity-score matched (PSM) analysis.

Setting: 20,880 households, Uganda.

Participants: Men and women, 15 to 54 years.

Intervention: Comprehensive knowledge of HIV is defined as knowing that consistent use of condoms during sexual intercourse and having just one uninfected faithful partner can reduce the chances of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting the most common local misconceptions about transmission or prevention of HIV.

Primary and secondary outcomes: 1) Extramarital sexual relationship: having been involved in a sexual relationship with a partner other than a spouse or cohabiting partner, within the 12 months preceding the survey; 2) Consistent use of a condom: use of a condom every time one had sex with any non-spouse or non-cohabiting partner over the past 12 months.

Results: We matched 18,504 participants in a 1:1 ratio. In a PSM analysis, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (odds ratio (OR) 1.03, 95% confidence interval (CI) 0.96 to 1.11) but improved consistent use of condoms among those in extramarital sexual relationships (OR 118, 95% CI 1.02 to 1.37). In men, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms among those in extramarital sexual relationships (OR 1.31, 95% CI, 1.04 to 1.66). In females, there was no effect on both outcomes.

Conclusions: Comprehensive knowledge of HIV does not affect extramarital sexual relationships but increases the consistency of condom use among those in extramarital sexual relationships. There is a need to address HIV complacency and to consistently provide correct HIV prevention messages among sexually active adults in Uganda.

Word count: 300 Abstract; 3,699 Main text.

Keywords: Comprehensive knowledge of HIV; consistent condom use; risky sexual behaviour; risky sexual practice

Strengths and limitations (5 bullets)

- The study used a nationally representative sample.
- Large sample size
- Findings are robust to unmeasured confounders and the analytic approach.
- The study is limited by a lack of qualitative data to contextualize the quantitative findings.
- Outcome measure is limited by social desirability bias.

Funding statement

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Competing interests

The authors declare that they have no competing interests

Background

The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with a human immunodeficiency virus (HIV) infected person.[1] Currently, an estimated 1.4 million people are living with HIV in Uganda.[2] Having a comprehensive knowledge of HIV can prevent HIV acquisition by helping individuals to assess their own risk of HIV acquisition and adopting safer sexual practices.[3] Comprehensive knowledge of HIV is defined as knowing that consistent use of condoms during sexual intercourse and having just one uninfected faithful partner can reduce the chances of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting the most common local misconceptions about transmission or prevention of HIV.[1] Comprehensive knowledge of HIV in the general population has risen by 1% per year between 2003 and 2015 [4] and this is expected to reverse the HIV incidence and prevalence. Findings from a recent analysis of Demographic Health Survey (DHS) data for 15 countries in sub-Saharan Africa (SSA) show that 38.6% of the population have comprehensive knowledge of HIV/Acquired immune deficiency syndrome (AIDS). The data further show that a higher level of comprehensive knowledge of HIV is associated with being old, having at least a primary level of education, being from a wealthy household, using contraceptives, listening to the radio, and reading newspapers at the individual level.[5] At the regional level, living in an urban area and being a resident in the Eastern African region is likewise associated with high comprehensive knowledge of HIV.[5] Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) shows that slightly more than 4 in 10 adolescent girls and young women aged 15 to 24 years have comprehensive knowledge of HIV, which is associated with a more likelihood of safer sex negotiation [6]. However, limitations of the study by Frimpong et al (2021) include a lack of an appropriate comparison group, a design that precluded the assessment of the impact of comprehensive knowledge of HIV due to selection bias and confounding[7], and an analytic approach that is susceptible to model misspecification.[8]

The 2016 Uganda DHS (UDHS) data show that 48% of the population surveyed have comprehensive knowledge of HIV but the survey did not examine the effect of comprehensive knowledge of HIV on sexual behaviours at the general and sub-group levels. Largely, all the existing studies have focused on the magnitude of comprehensive knowledge of HIV and the associated factors.

Few studies have attempted to examine the link between comprehensive knowledge of HIV and sexual behaviour and where attempts have been made, there exists a significant design and analytic limitations in establishing the true effect of comprehensive knowledge of HIV on sexual behaviour. Currently, there is limited information about the effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission in Uganda and the SSA region in general. Our study analysed the 2016 Uganda DHS data from a nationally representative survey to establish the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms among those in extramarital sexual relationships in Uganda. As a secondary objective, we examined the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms in a sub-group of women and men. We hypothesized that comprehensive knowledge of HIV reduces the likelihood of extramarital sexual relationships in men and women, and improves consistent use of condoms among those in extramarital sexual relationships.

Methods

Description of data source

We analyzed data from a nationally representative population-based household survey, the 2016 Uganda Demographic Health Survey (UDHS).[9] Data collection took place from Jun 20Dec 16, 2016. The survey sample was stratified and selected in two stages. The first stage consisted of the selection of 697 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one cluster from the Acholi sub-region was excluded for security reasons. The second stage involved the sampling of households within the clusters. This was achieved through a listing of all households within each of the 696 accessible selected enumeration areas between April and October 2016, with some listings overlapping with fieldwork. The survey drew maps for each of the sampled clusters and then listed all the households except for institutional living arrangements, namely army barracks, hospitals, police camps, and boarding schools. To minimize the task of household listing, each large enumeration area yielding more than 300 households selected for the survey was segmented, and one segment was selected for the survey with probability proportional to segment size, and the household listing was conducted within the segment. Therefore, in the UDHS, a cluster was regarded as either an enumeration area or a segment of an enumeration area. Overall, a representative sample that consisted of 20,880 households corresponding to 30 per enumeration area or a segment of enumeration area was randomly selected for the survey.

All women aged 15-49 who were either permanent residents of the selected households or visitors who stayed in the household the night before the survey were eligible to be interviewed. In one-third of the sampled households, all men aged 15 to 54 years, including both usual residents and visitors who stayed in the household the night before the interview, were eligible for individual interviews.

Data were collected using four questionnaires: the household, women, men, and the biomarker questionnaires. The women's questionnaire collected information from all eligible women aged 15-49 and they were asked the questions on the following: 1) Husbands' background characteristics and women's work: husbands' age, level of education, and occupation and women's occupation and sources of earnings; 2) sexually transmitted infections (STIs) and HIV/AIDS: knowledge of STIs and AIDS and methods of transmission, sources of information, behaviors to avoid STIs and HIV, and stigma. The men's questionnaire was administered to all men aged 15-54 in the sub-sample of households selected for the male survey and collected much of the same information elicited with the women's questionnaire. However, it was shorter because it did not contain a detailed reproductive history or questions on maternal and child health. Data were collected on knowledge and attitudes of women and men about STIs and HIV/AIDS, potential exposure to the risk of HIV infection (risk behaviors and condom use), and coverage of HIV testing and counseling and other key HIV/AIDS programs. The primary objective was to provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including knowledge of HIV prevention methods, stigma and discrimination, number of sexual partners, condom use, self-reported HIV testing, prevention of mother-to-child transmission of HIV, and voluntary medical male circumcision. A detailed description of the survey can be found in the 2016 UDHS report.[1]

Ethical considerations

The UDHS dataset is publicly accessible at https://dhsprogram.com/data/available-datasets.cfm. We applied for and received authorization to analyze the data from the DHS program (www.dhsprogram.com). Since DHS datasets are publically available and free, no ethical approval was required.

Study design

A randomized control trial (RCT) is the gold standard design for measuring the impact of interventions because randomization ensures balance in both known and unknown baseline covariates thereby achieving comparability between the intervention and control groups.[10] Nonetheless, an RCT is regarded as infeasible and unethical for interventions that are known to be beneficial such as comprehensive knowledge of HIV. For that reason, observational data provides an option for the measure of impact but the presence of selection bias due to lack of randomization and confounding of the exposure-outcome relationship due to other factors is a limitation.[11] We applied propensity-scores matched (PSM) analysis to remove the selection bias and confounding and ensure that both the exposed and non-exposed groups are comparable/balanced on measured covariates, except for the exposure.[12,13] We, therefore, simulated an RCT. Since no true randomization was employed, the study design is a non-randomized, quasi-experimental study.[12]

Variables and measurements

The exposure of interest was comprehensive knowledge of HIV, measured on a binary scale (yes versus no). Comprehensive knowledge of HIV was defined as knowing that consistent use of condoms during sexual intercourse and having just one uninfected faithful partner can reduce the chance of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting the two most common local misconceptions about transmission or prevention of HIV. The two most common local misconceptions about HIV transmission in Uganda we examined included: HIV can be transmitted through mosquitoes and sharing of food. The primary outcome was extramarital sexual relationships measured on a binary scale. Participants in sexual relations with another sexual partner other than the spouse or cohabiting partner were considered to have indulged in extramarital sexual relationships in the 12 months preceding the survey. The secondary outcome was the consistent use of condoms measured on a binary scale computed as the percentage of male and female respondents who used a condom every time they had sex with any non-spouse or non-cohabiting partner over the past 12 months.[1]

The covariates included sex (male or female), age group (15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, and 50 to 54), level of education (none/no education, primary, secondary, and higher), marital status (never in a union, currently in a union, and formerly in a union), number of living children, wealth index (poorest, poorer, middle, richer, and richest), religion (no religion, Anglican, Catholic, Muslim, Seventh Day Adventist, Pentecostal, and others), and the 15 regions in Uganda (Kampala, Central 1, Central 2, Busoga, Bukedi, Bugishu, Teso, Karamoja, Lango, Acholi, West Nile, Bunyoro, Tooro, Ankole, and Kigezi)

Data analysis

We used R version 4.02[14] and Stata version 15.1 for the analysis. In R, we used the *MatchIt*[15] and *tableone*[16] statistical packages. We descriptively summarized categorical data as frequencies and percentages and numerical data as mean with standard deviation. We performed propensity-scores matched analysis using eight matching covariates known to influence either the exposure or the outcome, or both. This selection followed the unconfoundedness assumption.[17-19]

We computed propensity scores in a logit model. We fitted comprehensive knowledge of HIV as a function of the matching covariates and assessed the initial balance in propensity scores using a back-to-back histogram.[20] We matched participants with and without compressive knowledge of HIV on similar propensity scores[21] using different matching approaches, namely nearest neighbor matching with and without caliper adjustment[18], and optimal pair and optimal full matching.[19] A caliper is a distance within which matching occurs, computed as 20% of the standard deviation of the propensity score to prevent bias from distant matches. In nearest neighbor matching without caliper adjustment, the participants were randomly matched to one another while in the nearest neighbor matching with caliper adjustment, the matching was performed within a caliper, all without replacement. In the optimal pair matching, matching was done in pairs and the non-matched pairs were excluded from the analysis. In the optimal full matching, matching was done in a ratio of 1: many or many: 1. Furthermore, we performed exact matching where the participants were matched on the identical values of propensity scores.[22] The best matching approach was one that resulted in a balance of all the covariates between the two groups.

Following the matching, we checked the balance in covariates between the group with and without comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1 considered confirmatory of good covariate balance.[7] We further assessed covariate balance graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was taken to suggest covariate balance.[7,23] After successful matching, the propensity-score matched dataset was saved for the outcome analysis. We performed analysis on both the unmatched and matched datasets. We fitted a logistic regression model for the unadjusted, adjusted, and PSM analysis, reported as odds ratio (OR) and 95% confidence interval (CI).

Sensitivity analysis

We checked the robustness of the findings to hidden bias/unmeasured confounders and the matching approach using the Rosenbaum Wilcoxon's signed-rank test.[20] We interpreted distant gamma values to achieve statistical significance or non-significance as indicative of robustness.

Reporting of findings

The findings are reported following the improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement shown in Supplementary Fig 1.[24]

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Characteristics of participants

We present participants' characteristics in Table 1 both before and after PSM. We analysed data for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning the participants' age group, level of education, wealth index, and region, with all the variables showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).

Table 1: Baseline characteristics of participants before and after PSM

Variables	Level	Unmatched (original) sample				Propensity score-matched sample			
		Comprehensive knowledge of HIV				Comprehensive knowledge of HIV			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
		No. (%)	No. (%)	No. (%)		No. (%)	No. (%)	No. (%)	
Sex	Male	5295 (22.3)	2692 (21.7)	2603 (23.0)	0.031	4168 (22.5)	2037 (22.0)	2131 (23.0)	0.024
	Female	18416 (77.7)	9705 (78.3)	8711 (77.0)		14336 (77.5)	7215 (78.0)	7121 (77.0)	
Age group (years)	15 to 19	5466 (23.1)	3263 (26.3)	2203 (19.5)	0.179	3985 (21.5)	2014 (21.8)	1971 (21.3)	0.019
	20 to 24	4712 (19.9)	2311 (18.6)	2401 (21.2)		3676 (19.9)	1832 (19.8)	1844 (19.9)	
	25 to 29	3741 (15.8)	1811 (14.6)	1930 (17.1)		2914 (15.7)	1471 (15.9)	1443 (15.6)	
	30 to 34	3327 (14.0)	1610 (13.0)	1717 (15.2)		2671 (14.4)	1325 (14.3)	1346 (14.5)	
	35 to 39	2521 (10.6)	1324 (10.7)	1197 (10.6)		2030 (11.0)	997 (10.8)	1033 (11.2)	
	40 to 44	2110 (8.9)	1109 (8.9)	1001 (8.8)		1768 (9.6)	887 (9.6)	881 (9.5)	
	45 to 49	1542 (6.5)	832 (6.7)	710 (6.3)		1220 (6.6)	605 (6.5)	615 (6.6)	
	50 to 54	292 (1.2)	137 (1.1)	155 (1.4)		240 (1.3)	121 (1.3)	119 (1.3)	
Level of education	No education	2279 (9.6)	1475 (11.9)	804 (7.1)	0.459	1617 (8.7)	816 (8.8)	801 (8.7)	0.033
	Primary	13849 (58.4)	8139 (65.7)	5710 (50.5)		11276 (60.9)	5681 (61.4)	5595 (60.5)	
	Secondary	5648 (23.8)	2243 (18.1)	3405 (30.1)		4464 (24.1)	2215 (23.9)	2249 (24.3)	
	Higher	1935 (8.2)	540 (4.4)	1395 (12.3)		1147 (6.2)	540 (5.8)	607 (6.6)	
Marital status	Never in union	6681 (28.2)	3604 (29.1)	3077 (27.2)	0.049	4904 (26.5)	2469 (26.7)	2435 (26.3)	0.01
	Currently in union	14352 (60.5)	7365 (59.4)	6987 (61.8)		11441 (61.8)	5715 (61.8)	5726 (61.9)	
	Formerly in union	2678 (11.3)	1428 (11.5)	1250 (11.0)		2159 (11.7)	1068 (11.5)	1091 (11.8)	
Living children	≤2	12840 (54.2)	6648 (53.6)	6192 (54.7)	0.049	9589 (51.8)	4770 (51.6)	4819 (52.1)	0.011
	3 to 5	6681 (28.2)	3449 (27.8)	3232 (28.6)		5410 (29.2)	2714 (29.3)	2696 (29.1)	
	≥6	4190 (17.7)	2300 (18.6)	1890 (16.7)		3505 (18.9)	1768 (19.1)	1737 (18.8)	

Wealth index	Poorest	4901 (20.7)	3071 (24.8)	1830 (16.2)	0.340	3496 (18.9)	1746 (18.9)	1750 (18.9)	0.005
	Poorer	4661 (19.7)	2653 (21.4)	2008 (17.7)		3719 (20.1)	1859 (20.1)	1860 (20.1)	
	Middle	4508 (19.0)	2453 (19.8)	2055 (18.2)		3783 (20.4)	1884 (20.4)	1899 (20.5)	
	Richer	4518 (19.1)	2254 (18.2)	2264 (20.0)		3814 (20.6)	1911 (20.7)	1903 (20.6)	
	Richest	5123 (21.6)	1966 (15.9)	3157 (27.9)		3692 (20.0)	1852 (20.0)	1840 (19.9)	
Religion	No religion	350 (1.5)	201 (1.6)	149 (1.3)	0.026	258 (1.4)	119 (1.3)	139 (1.5)	0.018
	Muslim	2793 (11.8)	1468 (11.8)	1325 (11.7)		2126 (11.5)	1063 (11.5)	1063 (11.5)	
	Christianity	20568 (86.7)	10728 (86.5)	9840 (87.0)		16120 (87.1)	8070 (87.2)	8050 (87.0)	
Region	Kampala	1640 (6.9)	596 (4.8)	1044 (9.2)	0.302	1125 (6.1)	574 (6.2)	551 (6.0)	0.037
	Central1	2058 (8.7)	946 (7.6)	1112 (9.8)		1575 (8.5)	812 (8.8)	763 (8.2)	
	Central2	1864 (7.9)	930 (7.5)	934 (8.3)		1532 (8.3)	767 (8.3)	765 (8.3)	
	Busoga	1959 (8.3)	1080 (8.7)	879 (7.8)		1563 (8.4)	783 (8.5)	780 (8.4)	
	Bukedi	1554 (6.6)	845 (6.8)	709 (6.3)		1259 (6.8)	625 (6.8)	634 (6.9)	
	Bugishu	1247 (5.3)	689 (5.6)	558 (4.9)		958 (5.2)	458 (5.0)	500 (5.4)	
	Teso	1695 (7.1)	867 (7.0)	828 (7.3)		1406 (7.6)	709 (7.7)	697 (7.5)	
	Karamoja	883 (3.7)	579 (4.7)	304 (2.7)		562 (3.0)	273 (3.0)	289 (3.1)	
	Lango	1638 (6.9)	901 (7.3)	737 (6.5)		1309 (7.1)	644 (7.0)	665 (7.2)	
	Acholi	1460 (6.2)	653 (5.3)	807 (7.1)		1183 (6.4)	611 (6.6)	572 (6.2)	
	West Nile	1589 (6.7)	1113 (9.0)	476 (4.2)		913 (4.9)	452 (4.9)	461 (5.0)	
	Bunyoro	1551 (6.5)	792 (6.4)	759 (6.7)		1281 (6.9)	636 (6.9)	645 (7.0)	
	Tooro	1696 (7.2)	918 (7.4)	778 (6.9)		1421 (7.7)	710 (7.7)	711 (7.7)	
	Ankole	1672 (7.1)	853 (6.9)	819 (7.2)		1408 (7.6)	699 (7.6)	709 (7.7)	
	Kigezi	1205 (5.1)	635 (5.1)	570 (5.0)		1009 (5.5)	499 (5.4)	510 (5.5)	

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Distribution of study outcomes before and after PSM

Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%) versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships, 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of condoms was significantly lower among those without comprehensive knowledge of HIV compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD = 0.155.

In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a statistically non-significant difference between those without and with comprehensive knowledge of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-significant difference in the consistent use of condoms SMD = 0.080).

Table 2: Summary of distribution of study outcomes before and after PSM

Variables	Level	Unmatched (original) sample				Propensity score-matched sample			
		Comprehensive knowledge of HIV				Comprehensive knowledge of HIV			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
Extramarital sexual relationship	No	19524 (82.3)	10341 (83.4)	9183 (81.2)	0.059	15244 (82.4)	7644 (82.6)	7600 (82.1)	0.012
	Yes	4187 (17.7)	2056 (16.6)	2131 (18.8)		3260 (17.6)	1608 (17.4)	1652 (17.9)	
Consistent condom use #	No	2762 (66.0)	1433 (69.7)	1329 (62.4)	0.155	2143 (65.7)	1088 (67.7)	1055 (63.9)	0.080
	Yes	1425 (34.0)	623 (30.3)	802 (37.6)		1117 (34.3)	520 (32.3)	597 (36.1)	

Note: # Data are for participants in extramarital sexual relationships.

Additional balance diagnostics

Fig 1 is a histogram showing the distribution of propensity scores among participants with and without comprehensive knowledge of HIV. The propensity scores were distributed differently among the participants with (raw treated) and without (raw control) comprehensive knowledge of HIV before PSM. However, the propensity scores were distributed similarly among participants with (matched treated) and without (matched control) comprehensive knowledge of HIV after PSM.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

We present the results for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms in Table 3. The results show that comprehensive knowledge of HIV was significantly associated with extramarital sexual relationships at the unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome, the results show that comprehensive knowledge of HIV was significantly associated with consistent use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the PSM analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95% CI 0.95 to 1.27).

Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

Variable	Level	Crude analysis	Adjusted analysis	PSM analysis
Extramarital sexual relationship	No	1	1	1
	Yes	1.17 (1.09 to 1.25)***	1.07 (0.99 to 1.15)	1.03 (0.96 to 1.11)
Consistent condom use#	No	1	1	1
	Yes	1.39 (1.22 to 1.58)***	1.10 (0.95 to 1.27)	1.18 (1.02 to 1.37)*

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex

In Table 4, we display the findings for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms by sex. Among males, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms among those in extramarital sexual relationships (OR 1.31, 95% CI 1.04 to 1.66). In females, we found no effect on extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17) and consistent use of condoms among those in extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17).

Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex and age groups

Sub-group	Variable	Level	OR (95% CI)
Males	Extramarital sexual relationship	No	1
		Yes	0.95 (0.83 to 1.08)
	Consistent condom use#	No	1
		Yes	1.31 (1.04 to 1.66) *
Females	Extra marital sexual relationship	No	1
		Yes	1.06 (0.97 to 1.17)
	Consistent condom use#	No	1
		Yes	1.06 (0.97 to 1.17)

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Sensitivity analysis results

The Rosenbaum Sensitivity analysis using the Wilcoxon Signed-Rank test showed that a statistically non-significant upper bound of the gamma value occurred at 5.0 (p = 0.9798) which was distant from the point of no hidden bias where the gamma value was 1.0 (p<0.0001). This showed that the results are robust to unmeasured confounders and the analytic approach.

Discussion

In this study, we examined the effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission, specifically extramarital sexual relationships and consistent use of condoms.

Our results show that comprehensive knowledge of HIV has no effect on extramarital sexual relationships but improves the consistent use of condoms among those in extramarital sexual relationships. In sub-group analysis, we found comprehensive knowledge of HIV improved the consistent use of condoms in males in extramarital sexual relationships but there was no effect observed in females. Our study has several strengths and limitations. We analysed nationally representative data so our findings are likely generalizable to the entire country and similar settings. The sample size was large and the results are robust to unmeasured confounders and the analytic approach. However, there are limitations. Although our results are robust to unmeasured confounders, the matching was performed on observed covariates and other covariates such as alcohol consumption and drug and substance use among others which are known to influence the outcome were not included in the analysis. The outcomes were assessed through self-report the possibility of social desirability bias cannot be excluded.

The finding that compressive knowledge of HIV improves consistent use of condoms among people in extramarital relationships is not unique because comprehensive knowledge of HIV helps individuals to become aware of the potential risks associated with non-use of condoms and therefore adopt safer sexual practices such as consistent use of condoms.[25] Inconsistent use of condoms in extramarital sexual relationships places an individual at a greater risk of acquisition of sexually transmitted infections (STIs) including HIV.[26] Our finding is consistent with several studies in SSA. One study which analysed the Ghana DHS found exposure to family planning messages is associated with a higher likelihood of consistent condom use among sexually active never-married men.[27] If we use level of education as a proxy for comprehensive knowledge of HIV, another study that analysed DHS data for 29 countries in SSA reports that among men who pay for sex, men with a secondary level of education are more likely to use condoms consistently.[28] With less than half of the Ugandan population aged 15-54 years having comprehensive knowledge of HIV [1], this result underscores a need for the AIDS Control Program to design and implement context-relevant HIV prevention and education messages to improve the level of comprehensive knowledge of HIV in the population and thereby control the HIV pandemic. In sub-group analysis, we found no effect of comprehensive knowledge of HIV on consistent use of condoms in females but in males, we found consistent use of condoms improved.

Although several factors such as cost, moral values, ethnicity, religion, gender inequality, lack of dialogue among sexual partners concerning condom use among others influence inconsistent or even non-use of condoms during sexual intercourse [29], our findings agree with an earlier study that reports HIV knowledge improves condom use self-efficacy [30] and therefore its use in sexual relationships. Recently, in a study conducted among sexually active men in Nigeria by Bolarinwa et al (2022)[31] knowledge of HIV equally improved condom use, which is consistent with our results. Another study conducted among South African married couples reported that females are less likely to use a condom if their male partner has refused to use it[32], suggesting male dominance or power imbalance between women and men in condom negotiation. Our finding could be explained by socio-cultural differences between males and females within the context, with females inherently being submissive to the sexual demands of males. In general, African women find it difficult to assert themselves when it comes to condom negotiation and the majority cannot and do not negotiate the use of condoms in a sexual relationship. Elsewhere [33], one study reports that compared to individual-level factors, the social environment is an independent risk factor for HIV vulnerability in Uganda. This leaves men as sole decision-makers regarding whether or not to use a condom. Indeed, gender equality has been reported to improve condom use self-efficacy in both general and risky situations.[30]

Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual relationships in general and in sub-group analysis requires cautious interpretation. First, we acknowledge that HIV remains a global health problem, with 25.7 million people infected globally [26] and about 1.4 million infected people in Uganda.[2] However, with the rapid rollout and improved access to antiretroviral therapy (ART) over the years, the majority of PLHIV have a nearly normal quality of life and longevity. There is now much hope and optimism that the fight against HIV/AIDS is nearly almost done and this has created an HIV/AIDS complacency problem in the general population.[34] Concerns about HIV being a global health problem have lessened and the use of known HIV prevention methods such as abstinence, mutual faithfulness, and consistent condom use, among others have dwindled over the years. The issue of the HIV/AIDS complacency phenomenon in Africa[35] and Uganda[36] has been highlighted earlier. Another plausible explanation relates to behaviour change and the know-practice gap at an individual level. One would argue that behaviour change is a gradual process, often with strong influences from the social, cultural, economic, environmental, and technological dimensions.[37] These challenges require a strong focus on health promotion, a combination of health education, and healthy public policy.[38]

For instance, health education is not sufficient without an enabling environment to achieve behaviour change but requires the formulation and implementation of appropriate healthy public policies. Often, shortfalls in health promotion lead to victim-blaming thus people are blamed for their actions despite a lack of an enabling environment for behaviour change. Our findings emphasize a need for novel approaches to achieving behaviour change in Uganda. Our findings thus emphasized a need to complement existing behaviour change communication strategies with other approaches that influence social and environmental determinants of risk to enable vulnerable populations to HIV infection protect themselves.[39] Approaches to mitigate complacency are important besides other tools for HIV prevention and control in bringing an end to the HIV pandemic.[40]

Conclusions and recommendations

This study shows that comprehensive knowledge of HIV has no effect on extramarital sexual relationships but increases consistent use of condoms among those in extramarital relationships, especially men but not women. Our findings emphasize a need to address HIV complacency in the general population through HIV programs, including the provision of consistent and correct HIV prevention health education messages.

Author contributions

JI and DTK: Study conception and design. DTK: Acquisition of data. JI: Analysis and interpretation of data. JI and DTK: Drafting of manuscript. JI and DTK: Critical revision. JI and DTK: Final approval of manuscript.

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Competing interests

The authors declare that they have no competing interests.

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Data availability statement

The paper utilized the Demographic Health Survey data, and permission to use these publically available data was obtained from http://www.dhsprogram.com before data download and subsequent statistical analysis. As such, no ethical reviews and approvals were required before or during the preparation of the present manuscript.

Figure legends

Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Supplementary Fig 1: The TREND statement checklist

Consent

Not applicable.

Ethics Approval Statement

Not applicable/No human participants included.

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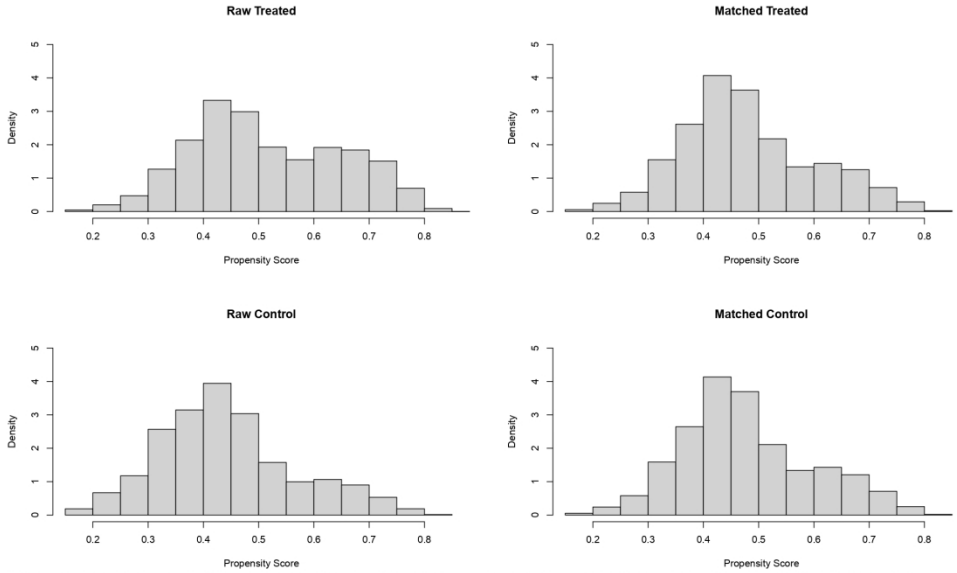

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

355x215mm (150 x 150 DPI)

TREND Statement Checklist

Paper Section/ Topic	Item No	Descriptor	Reported? ✓	Reported? Pg #
Title and Abstract				
Title and Abstract	1	• Information on how unit were allocated to interventions	√	1
		• Structured abstract recommended	√	1
		• Information on target population or study sample	√	1
Introduction				
Background	2	• Scientific background and explanation of rationale	√	3-4
		• Theories used in designing behavioral interventions	N/A	
Methods				
Participants	3	• Eligibility criteria for participants, including criteria at different levels in recruitment/sampling plan (e.g., cities, clinics, subjects)	√	4-5
		Method of recruitment (e.g., referral, self-selection), including the sampling method if a systematic sampling plan was implemented	√	4-5
		• Recruitment setting	√	4-5
		• Settings and locations where the data were collected	√	4-5
Interventions	4	• Details of the interventions intended for each study condition and how and when they were actually administered, specifically including:	√	5
		o Content: what was given?	N/A	
		o Delivery method: how was the content given?	√	5
		o Unit of delivery: how were the subjects grouped during delivery?	N/A	
		o Deliverer: who delivered the intervention?	N/A	
		o Setting: where was the intervention delivered?	√	5
		o Exposure quantity and duration: how many sessions or episodes or events were intended to be delivered? How long were they intended to last?	√	5
		o Time span: how long was it intended to take to deliver the intervention to each unit?	√	5
		o Activities to increase compliance or adherence (e.g., incentives)	N/A	
Objectives	5	• Specific objectives and hypotheses	√	4
Outcomes	6	• Clearly defined primary and secondary outcome measures	√	6
		• Methods used to collect data and any methods used to enhance the quality of measurements	√	4-5
		• Information on validated instruments such as psychometric and biometric properties	N/A	
Sample Size	7	How sample size was determined and, when applicable, explanation of any interim analyses and stopping rules	N/A	
Assignment Method	8	Unit of assignment (the unit being assigned to study condition, e.g., individual, group, community)	N/A	
		Method used to assign units to study conditions, including details of any restriction (e.g., blocking, stratification, minimization)	N/A	
		Inclusion of aspects employed to help minimize potential bias induced due to non-randomization (e.g., matching)	√	6

TREND Statement Checklist

Blinding (masking)	9	• Whether or not participants, those administering the interventions, and those assessing the outcomes were blinded to study condition assignment; if so, statement regarding how the blinding was accomplished and how it was assessed.	NA	
Unit of Analysis	10	• Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community)	√	7-8
		• If the unit of analysis differs from the unit of assignment, the analytical method used to account for this (e.g., adjusting the standard error estimates by the design effect or using multilevel analysis)	N/A	
Statistical Methods	11	• Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data	√	7-8
		• Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis	√	7-8
		• Methods for imputing missing data, if used	N/A	
		• Statistical software or programs used	√	7
Results				
Participant flow	12	Flow of participants through each stage of the study: enrollment, assignment, allocation, and intervention exposure, follow-up, analysis (a diagram is strongly recommended)	N/A	
		o Enrollment: the numbers of participants screened for eligibility, found to be eligible or not eligible, declined to be enrolled, and enrolled in the study	N/A	
		o Assignment: the numbers of participants assigned to a study condition	N/A	
		o Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention	N/A	
		o Follow-up: the number of participants who completed the follow-up or did not complete the follow-up (i.e., lost to follow-up), by study condition	N/A	
		o Analysis: the number of participants included in or excluded from the main analysis, by study condition	N/A	
		• Description of protocol deviations from study as planned, along with reasons	N/A	
Recruitment	13	• Dates defining the periods of recruitment and follow-up	N/A	
Baseline Data	14	Baseline demographic and clinical characteristics of participants in each study condition	√	9
		Baseline characteristics for each study condition relevant to specific disease prevention research	√	9
		Baseline comparisons of those lost to follow-up and those retained, overall and by study condition	N/A	
		Comparison between study population at baseline and target population of interest	√	9
Baseline equivalence	15	• Data on study group equivalence at baseline and statistical methods used to control for baseline differences	√	14

TREND Statement Checklist

Numbers analyzed	16	• Number of participants (denominator) included in each analysis for each study condition, particularly when the denominators change for different outcomes; statement of the results in absolute numbers when feasible	√	14
		• Indication of whether the analysis strategy was "intention to treat" or, if not, description of how non-compliers were treated in the analyses	N/A	
Outcomes and estimation	17	• For each primary and secondary outcome, a summary of results for each estimation study condition, and the estimated effect size and a confidence interval to indicate the precision	√	13-14
		• Inclusion of null and negative findings	N/A	
		Inclusion of results from testing pre-specified causal pathways through which the intervention was intended to operate, if any	√	13-14
Ancillary analyses	18	• Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory	N/A	
Adverse events	19	• Summary of all important adverse events or unintended effects in each study condition (including summary measures, effect size estimates, and confidence intervals)	N/A	
DISCUSSION				
Interpretation	20	• Interpretation of the results, taking into account study hypotheses, sources of potential bias, imprecision of measures, multiplicative analyses, and other limitations or weaknesses of the study	√	14
		Discussion of results taking into account the mechanism by which the intervention was intended to work (causal pathways) or alternative mechanisms or explanations	√	14-16
		Discussion of the success of and barriers to implementing the intervention, fidelity of implementation	N/A	
		• Discussion of research, programmatic, or policy implications	√	14-16
Generalizability	21	• Generalizability (external validity) of the trial findings, taking into account the study population, the characteristics of the intervention, length of follow-up, incentives, compliance rates, specific sites/settings involved in the study, and other contextual issues	√	17
Overall Evidence	22	• General interpretation of the results in the context of current evidence and current theory	√	14-16

From: Des Jarlais, D. C., Lyles, C., Crepaz, N., & the Trend Group (2004). Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement. *American Journal of Public Health*, 94, 361-366. For more information, visit: http://www.cdc.gov/trendstatement/

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Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission among adult Ugandans: a propensity-score matched analysis

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Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission among adult Ugandans: a propensity-score matched analysis

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Abstract

Objective: To evaluate the effect of comprehensive knowledge of human immunodeficiency virus (HIV) on extramarital sexual relationships and consistent condom use.

Design: Quasi-experimental study using propensity-score matched (PSM) analysis.

Setting: 20,880 households, Uganda.

Participants: Married/cohabiting men and women, 15 to 54 years.

Intervention: Comprehensive knowledge of HIV, defined as knowing that consistent use of condoms during sexual intercourse and having just one faithful partner without HIV reduces the chances of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting two local misconceptions (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV).

Primary and secondary outcomes: 1) Extramarital sexual relationship: involvement in a sexual relationship with a partner other than a spouse or cohabiting partner, within 12 months preceding the survey; 2) Consistent use of condom: using a condom every time one had sex with any non-spouse/non-cohabiting partner over the past 12 months.

Results: We matched 18,504 participants in a 1:1 ratio. In a PSM analysis, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (odds ratio (OR) 1.03, 95% confidence interval (CI) 0.96 to 1.11) but improved consistent use of condoms among married/cohabiting couples in extramarital sexual relationships (OR 1.18, 95% CI 1.02 to 1.37). In married/cohabiting men, comprehensive knowledge of HIV had no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms in extramarital sexual relationships (OR 1.31, 95% CI, 1.04 to 1.66). However, in married/cohabiting females, we found no effect on both outcomes.

Conclusions: Comprehensive knowledge of HIV has no effect on extramarital sexual relationships but increases consistent condom use among those in extramarital sexual relationships. There is a need to consistently provide correct HIV prevention messages among sexually active married/cohabiting couples in Uganda.

Word count: 298 Abstract; 3,971 main text.

Keywords: Comprehensive knowledge of HIV; consistent condom use; risky sexual behaviour; risky sexual practice

Strengths and limitations (5 bullets)

- The study used a nationally representative data.
- Large sample size.
- Findings are robust to unmeasured confounders and the analytic approach.
- The study is limited by a lack of qualitative data to contextualize the quantitative findings.
- Outcome measure is limited by social desirability bias.

Background

The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with a person living with human immunodeficiency virus (HIV).[1] Currently, an estimated 1.4 million people are living with HIV in Uganda.[2] The 2020 Uganda Population-Based HIV Impact Assessment[3] reports a 5.5% HIV prevalence among people aged 15-49 years (7.1% females, 3.8% males). However, new HIV infections among adults (≥15 years) progressively declined from 71,000 in 2010 to 48,000 in 2020, a 32% drop. Having a comprehensive knowledge of HIV can prevent HIV acquisition by helping individuals to assess their own risk of HIV acquisition and adopting safer sexual practices.[3] Comprehensive knowledge of HIV is defined as knowing that consistent use of condoms during sexual intercourse and having just one faithful partner without HIV can reduce the chance of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting the two most common local misconceptions about transmission or prevention of HIV (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV).[1]

Comprehensive knowledge of HIV in the general population increased by 1% per year between 2003 and 2015 [4] and this is expected to reverse the HIV incidence and prevalence. Analysis of Demographic Health Survey (DHS) data for 15 countries in sub-Saharan Africa (SSA) show 38.6% of the population with comprehensive knowledge of HIV[5]. The 15 countries included Burundi (2016/17), Ethiopia (2016), Rwanda (2015), Uganda (2016), Zambia (2018/19), Benin (2017/18), Gambia (2019/20), Guinea (2018), Liberia (2019/20), Mali (2018), Nigeria (2018), Sierra Leone (2019), Cameroon (2018/19), and Chad (2015). Data further show a higher level of comprehensive knowledge of HIV is associated with being old, attaining at least a primary level of education, belonging to a wealthy household, using contraceptives, listening to a radio, and reading newspapers at the individual level.[5] At the regional level, residing in an urban area or the Eastern African region is similarly associated with a higher comprehensive knowledge of HIV.[5] Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) found more than 4 in 10 adolescent girls and young women (15 to 24 years) have comprehensive knowledge of HIV and are more likely to negotiate for safe sex[6]. However, limitations of Frimpong's study includes a lack of appropriate comparator, a design that precluded assessment of the effect of comprehensive knowledge of HIV on sexual behaviours associated with HIV transmission due to selection bias and confounding[7], and an analytic approach that susceptible to model misspecification.[8]

The 2016 Uganda DHS (UDHS) data show 48% of the population surveyed have comprehensive knowledge of HIV[9] but did not examine the effect of comprehensive knowledge of HIV on sexual behaviours at population and sub-population levels. Overall, previous studies focused on the magnitude of comprehensive knowledge of HIV and the associated factors[5,6].

Between 2016 and 2019, the prevalence of HIV among married or cohabiting couples in Uganda was 6.6%, exceeding the 6.0% prevalence among adults aged 15-49 years[10]. Low condom use among married/cohabiting couples in extramarital sexual relationship is a risk for HIV infection. The 2016 UDHS[9] reports condom use at the last sexual intercourse among married/cohabiting couples with ≥2 sexual partners in the past 12 months is higher among men (9.7%) than women (7.9%).

Few studies have attempted to examine the link between comprehensive knowledge of HIV and risky sexual behaviour and where attempts have been made, significant design and analytic limitations exists. Currently, there is limited information about the effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission among married or cohabiting couples in Uganda and SSA in general. Our study analysed the 2016 Uganda DHS data from a nationally representative survey to establish the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms among married or cohabiting couples in Uganda. As a secondary objective, we examined the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms by sex (women versus men). We hypothesized that comprehensive knowledge of HIV reduces the likelihood of extramarital sexual relationships in men and women, and improves consistent use of condoms among married or cohabiting couples in extramarital sexual relationships.

Methods

Description of data source

We analyzed data from a nationally representative population-based household survey, the 2016 UDHS[9], conducted by the Uganda Bureau of Statistics (UBOS). Elsewhere[11], the dataset is described. Data collection took place between Jun 20, 2016 and Dec 16, 2016. The survey sample was stratified and selected in two stages. The first stage consisted of the selection of 697 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one cluster from the Acholi sub-region in northern Uganda was excluded for security reasons. The second stage involved the sampling of households within the clusters. This was achieved through a listing of all households within each of the 696 accessible selected enumeration areas between April and October 2016, with some listings overlapping with fieldwork. The survey drew maps for each of the sampled clusters and then listed all the households except for institutional living arrangements, namely army barracks, hospitals, police camps, and boarding schools. To minimize the task of household listing, each large enumeration area yielding more than 300 households selected for the survey was segmented, and one segment was selected for the survey with probability proportional to segment size, and the household listing was conducted within the segment. Therefore, in the 2016 UDHS, a cluster was regarded as either an enumeration area or a segment of an enumeration area. Overall, a representative sample that consisted of 20,880 households corresponding to 30 per enumeration area or a segment of enumeration area was randomly selected for the survey.

All women aged 15-49 years who were either permanent residents of the selected households or visitors who had stayed in the household the night before the survey were eligible to be interviewed. In one-third of the sampled households, all men aged 15 to 54 years, including both usual residents and visitors who had stayed in the household the night preceding the interview, were eligible for individual interviews. Data were collected using four questionnaires: the household, women, men, and the biomarker questionnaires. The women's questionnaire collected information from all eligible women aged 15-49 years and they were questioned on the following among others: 1) Husbands' background characteristics and women's work: husbands' age, level of education, and occupation and women's occupation and sources of earnings; 2) sexually transmitted infections (STIs) and HIV/AIDS: knowledge of STIs and AIDS and methods of transmission, sources of information, behaviors to avoid STIs and HIV, and stigma.

Additional questions are described in the 2016 UDHS report. The men's questionnaire was administered to all men aged 15-54 years in the sub-sample of households selected for the male survey and collected much of the same information elicited with the women's questionnaire. However, it was shorter because it did not contain a detailed reproductive history or questions on maternal and child health.

Data were collected on knowledge and attitudes of women and men about STIs and HIV/AIDS, potential exposure to the risk of HIV infection (risk behaviors and condom use), and coverage of HIV testing and counseling and other key HIV/AIDS programs. The primary objective was to provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including knowledge of HIV prevention methods, stigma and discrimination, number of sexual partners, condom use, self-reported HIV testing, prevention of mother-to-child transmission of HIV, and voluntary medical male circumcision. The 2016 UDHS data were collected by 21 trained research teams, with each consisting of a team leader, field manager, 3 female interviewers, 1 male interviewer, 1 health technician, and 1 driver. A detailed description of the survey can be found in the 2016 UDHS report.[1]

Ethical considerations

The UDHS dataset is publicly accessible at https://dhsprogram.com/data/available-datasets.cfm. We applied for and received authorization to analyze the data from the DHS program (www.dhsprogram.com). Since DHS datasets are publicly available and free, no ethical approval was required.

Study design

A randomized control trial (RCT) is the gold standard design for measuring the effect of interventions because randomization ensures balance in both known and unknown baseline covariates thereby achieving comparability between the intervention and control groups.[12] Nonetheless, an RCT is regarded as infeasible and unethical for interventions that are known to be beneficial such as comprehensive knowledge of HIV. For that reason, observational data provides an option for the measure of effect but the presence of selection bias due to lack of randomization and confounding of the exposure-outcome relationship due to other factors is a limitation.[13]

We applied propensity-scores matched (PSM) analysis to remove the selection bias and confounding and ensure that both the exposed and non-exposed groups are comparable/balanced on measured covariates, except for the exposure.[14,15] We, therefore, simulated an RCT. Since no true randomization was employed, the study design is a non-randomized, quasi-experimental study.[14]

Variables and measurements

Exposure: Comprehensive knowledge of HIV was the exposure of interest, measured on a binary scale (yes versus no) using five indicators, namely 1) knowing that consistent use of condoms during sexual intercourse can reduce the chance of getting HIV; 2) knowing that having just one faithful partner without HIV can reduce the chance of getting HIV; 3) knowing that a healthy-looking person can have HIV; 4) rejecting that HIV can be transmitted through mosquitoes; and 5) rejecting that HIV can be transmitted by sharing of food. Indicators 4-5 are the two most common local misconceptions about HIV transmission or prevention in Uganda. Participants with correct responses to all the five indicators were considered having comprehensive knowledge of HIV otherwise no. The exposed group consisted of participants with comprehensive knowledge of HIV while the unexposed (comparison) group consisted of those without comprehensive knowledge of HIV.

***Outcomes*:** The primary outcome was extramarital sexual relationships measured on a binary scale (yes or no). Participants in sexual relations with another sexual partner other than the spouse or cohabiting partner were considered to have indulged in extramarital sexual relationships in the 12 months preceding the survey. The secondary outcome was the consistent use of condoms measured on a binary scale, computed as the percentage of respondents who had used a condom every time they had sex with any non-spouse or non-cohabiting partner over the past 12 months.[1]

Matching covariates: These included sex (male or female), age group (15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, and 50 to 54), level of education (none/no education, primary, secondary, and higher), marital status (never in a union, currently in a union, and formerly in a union), number of living children, wealth index (poorest, poorer, middle, richer, and richest), religion (no religion, Anglican, Catholic, Muslim, Seventh Day Adventist, Pentecostal, and others), and the 15 regions in Uganda (Kampala, Central 1, Central 2, Busoga, Bukedi, Bugishu, Teso, Karamoja, Lango, Acholi, West Nile, Bunyoro, Tooro, Ankole, and Kigezi)

Data analysis

We used R version 4.02[16] and Stata version 15.1 for the analysis. In R, we used the *MatchIt*[17] and *tableone*[18] statistical packages. We descriptively summarized categorical data as frequencies and percentages, and numerical data using the mean with its standard deviation. We performed propensity-score matched analysis using eight matching covariates known to influence either the exposure or the outcome, or both based on the unconfoundedness assumption.[19-21]

We computed propensity scores in a logit model by fitting comprehensive knowledge of HIV as a function of the matching covariates. We assessed initial balance in propensity scores using a back-to-back histogram.[22] We then matched participants with and without compressive knowledge of HIV on similar propensity scores[23] using different matching approaches, namely nearest neighbor matching with and without caliper adjustment[20], and optimal pair and optimal full matching.[21] A caliper is a distance within which matching occurs, computed as 20% of the standard deviation of the propensity score to prevent bias from distant matches. In nearest neighbor matching without caliper adjustment, the participants were randomly matched to one another while in the nearest neighbor matching with caliper adjustment, the matching was performed within a caliper, all without replacement. In the optimal pair matching, the matching was done in pairs and the non-matched pairs were excluded from the analysis. In the optimal full matching, the matching was done in a ratio of 1: many or many: 1. Furthermore, we performed exact matching where the participants were matched on the identical values of propensity scores.[24] The best matching approach was one that balanced all the covariates between the two groups.

Following the matching, we checked covariate balance between the group with and without comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1 considered confirmatory of good covariate balance.[7] We further assessed covariate balance graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was taken to suggest covariate balance.[7,25] After successful matching, the propensity-score matched dataset was saved for the outcome analysis. We performed analysis on both the unmatched and matched datasets. We fitted a binary logistic regression model for the unadjusted and adjusted analysis, with the latter model adjusted for all the matching covariates.

For the PSM dataset, we fitted a conditional logistic regression taking into consideration the matched pairs. We reported odds ratio (OR) and 95% confidence interval (CI).

Sensitivity analysis

We checked the robustness of the findings to hidden bias/unmeasured confounders and the matching approach using the Rosenbaum Wilcoxon's signed-rank test.[22] We interpreted distant gamma values to achieve statistical significance or non-significance as indicative of robustness.

Reporting of findings

The findings are reported following the improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement shown in Supplementary Fig 1.[26]

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Characteristics of participants

We present participants' characteristics in Table 1 both before and after PSM. We analysed data for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning the participants' age group, level of education, wealth index, and region, with all the variables showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).

Table 1: Baseline characteristics of participants before and after PSM

Variables	Level	Unmatched (original) sample				Propensity score-matched sample			
		Comprehensive knowledge of HIV				Comprehensive knowledge of HIV			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
		No. (%)	No. (%)	No. (%)		No. (%)	No. (%)	No. (%)	
Sex	Male	5295 (22.3)	2692 (21.7)	2603 (23.0)	0.031	4168 (22.5)	2037 (22.0)	2131 (23.0)	0.024
	Female	18416 (77.7)	9705 (78.3)	8711 (77.0)		14336 (77.5)	7215 (78.0)	7121 (77.0)	
Age group (years)	15 to 19	5466 (23.1)	3263 (26.3)	2203 (19.5)	0.179	3985 (21.5)	2014 (21.8)	1971 (21.3)	0.019
	20 to 24	4712 (19.9)	2311 (18.6)	2401 (21.2)		3676 (19.9)	1832 (19.8)	1844 (19.9)	
	25 to 29	3741 (15.8)	1811 (14.6)	1930 (17.1)		2914 (15.7)	1471 (15.9)	1443 (15.6)	
	30 to 34	3327 (14.0)	1610 (13.0)	1717 (15.2)		2671 (14.4)	1325 (14.3)	1346 (14.5)	
	35 to 39	2521 (10.6)	1324 (10.7)	1197 (10.6)		2030 (11.0)	997 (10.8)	1033 (11.2)	
	40 to 44	2110 (8.9)	1109 (8.9)	1001 (8.8)		1768 (9.6)	887 (9.6)	881 (9.5)	
	45 to 49	1542 (6.5)	832 (6.7)	710 (6.3)		1220 (6.6)	605 (6.5)	615 (6.6)	
	50 to 54	292 (1.2)	137 (1.1)	155 (1.4)		240 (1.3)	121 (1.3)	119 (1.3)	
Level of education	No education	2279 (9.6)	1475 (11.9)	804 (7.1)	0.459	1617 (8.7)	816 (8.8)	801 (8.7)	0.033
	Primary	13849 (58.4)	8139 (65.7)	5710 (50.5)		11276 (60.9)	5681 (61.4)	5595 (60.5)	
	Secondary	5648 (23.8)	2243 (18.1)	3405 (30.1)		4464 (24.1)	2215 (23.9)	2249 (24.3)	
	Higher	1935 (8.2)	540 (4.4)	1395 (12.3)		1147 (6.2)	540 (5.8)	607 (6.6)	
Marital status	Never in union	6681 (28.2)	3604 (29.1)	3077 (27.2)	0.049	4904 (26.5)	2469 (26.7)	2435 (26.3)	0.01
	Currently in union	14352 (60.5)	7365 (59.4)	6987 (61.8)		11441 (61.8)	5715 (61.8)	5726 (61.9)	
	Formerly in union	2678 (11.3)	1428 (11.5)	1250 (11.0)		2159 (11.7)	1068 (11.5)	1091 (11.8)	
Living children	≤2	12840 (54.2)	6648 (53.6)	6192 (54.7)	0.049	9589 (51.8)	4770 (51.6)	4819 (52.1)	0.011
	3 to 5	6681 (28.2)	3449 (27.8)	3232 (28.6)		5410 (29.2)	2714 (29.3)	2696 (29.1)	
	≥6	4190 (17.7)	2300 (18.6)	1890 (16.7)		3505 (18.9)	1768 (19.1)	1737 (18.8)	

Wealth index	Poorest	4901 (20.7)	3071 (24.8)	1830 (16.2)	0.340	3496 (18.9)	1746 (18.9)	1750 (18.9)	0.005
	Poorer	4661 (19.7)	2653 (21.4)	2008 (17.7)		3719 (20.1)	1859 (20.1)	1860 (20.1)	
	Middle	4508 (19.0)	2453 (19.8)	2055 (18.2)		3783 (20.4)	1884 (20.4)	1899 (20.5)	
	Richer	4518 (19.1)	2254 (18.2)	2264 (20.0)		3814 (20.6)	1911 (20.7)	1903 (20.6)	
	Richest	5123 (21.6)	1966 (15.9)	3157 (27.9)		3692 (20.0)	1852 (20.0)	1840 (19.9)	
Religion	No religion	350 (1.5)	201 (1.6)	149 (1.3)	0.026	258 (1.4)	119 (1.3)	139 (1.5)	0.018
	Muslim	2793 (11.8)	1468 (11.8)	1325 (11.7)		2126 (11.5)	1063 (11.5)	1063 (11.5)	
	Christianity	20568 (86.7)	10728 (86.5)	9840 (87.0)		16120 (87.1)	8070 (87.2)	8050 (87.0)	
Region	Kampala	1640 (6.9)	596 (4.8)	1044 (9.2)	0.302	1125 (6.1)	574 (6.2)	551 (6.0)	0.037
	Central1	2058 (8.7)	946 (7.6)	1112 (9.8)		1575 (8.5)	812 (8.8)	763 (8.2)	
	Central2	1864 (7.9)	930 (7.5)	934 (8.3)		1532 (8.3)	767 (8.3)	765 (8.3)	
	Busoga	1959 (8.3)	1080 (8.7)	879 (7.8)		1563 (8.4)	783 (8.5)	780 (8.4)	
	Bukedi	1554 (6.6)	845 (6.8)	709 (6.3)		1259 (6.8)	625 (6.8)	634 (6.9)	
	Bugishu	1247 (5.3)	689 (5.6)	558 (4.9)		958 (5.2)	458 (5.0)	500 (5.4)	
	Teso	1695 (7.1)	867 (7.0)	828 (7.3)		1406 (7.6)	709 (7.7)	697 (7.5)	
	Karamoja	883 (3.7)	579 (4.7)	304 (2.7)		562 (3.0)	273 (3.0)	289 (3.1)	
	Lango	1638 (6.9)	901 (7.3)	737 (6.5)		1309 (7.1)	644 (7.0)	665 (7.2)	
	Acholi	1460 (6.2)	653 (5.3)	807 (7.1)		1183 (6.4)	611 (6.6)	572 (6.2)	
	West Nile	1589 (6.7)	1113 (9.0)	476 (4.2)		913 (4.9)	452 (4.9)	461 (5.0)	
	Bunyoro	1551 (6.5)	792 (6.4)	759 (6.7)		1281 (6.9)	636 (6.9)	645 (7.0)	
	Tooro	1696 (7.2)	918 (7.4)	778 (6.9)		1421 (7.7)	710 (7.7)	711 (7.7)	
	Ankole	1672 (7.1)	853 (6.9)	819 (7.2)		1408 (7.6)	699 (7.6)	709 (7.7)	
	Kigezi	1205 (5.1)	635 (5.1)	570 (5.0)		1009 (5.5)	499 (5.4)	510 (5.5)	

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Distribution of study outcomes before and after PSM

Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%) versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships, 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of condoms was significantly lower among those without comprehensive knowledge of HIV compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD = 0.155.

In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a statistically non-significant difference between those without and with comprehensive knowledge of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-significant difference in the consistent use of condoms SMD = 0.080).

Table 2: Distribution of study outcomes by comprehensive knowledge of HIV before and after PSM

Variables	Levels	Comprehensive knowledge of HIV (before PSM)				Comprehensive knowledge of HIV (after PSM)			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
Extramarital sexual relationship	No	19524 (82.3)	10341 (83.4)	9183 (81.2)	0.059	15244 (82.4)	7644 (82.6)	7600 (82.1)	0.012
	Yes	4187 (17.7)	2056 (16.6)	2131 (18.8)		3260 (17.6)	1608 (17.4)	1652 (17.9)	
Consistent condom use #	No	2762 (66.0)	1433 (69.7)	1329 (62.4)	0.155	2143 (65.7)	1088 (67.7)	1055 (63.9)	0.080
	Yes	1425 (34.0)	623 (30.3)	802 (37.6)		1117 (34.3)	520 (32.3)	597 (36.1)	

Note: # Data are for participants in extramarital sexual relationships.

Additional balance diagnostics

Fig 1 is a histogram showing the distribution of propensity scores among participants with and without comprehensive knowledge of HIV. The propensity scores were distributed differently among the participants with (raw treated) and without (raw control) comprehensive knowledge of HIV before PSM. However, the propensity scores were distributed similarly among participants with (matched treated) and without (matched control) comprehensive knowledge of HIV after PSM.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

We present the results for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms in Table 3. The results show that comprehensive knowledge of HIV was significantly associated with extramarital sexual relationships at the unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome, the results show that comprehensive knowledge of HIV was significantly associated with consistent use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the PSM analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95% CI 0.95 to 1.27).

Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

Variable	Level	Crude analysis	Adjusted analysis	PSM analysis
Extramarital sexual relationship	No	1	1	1
	Yes	1.17 (1.09 to 1.25)***	1.07 (0.99 to 1.15)	1.03 (0.96 to 1.11)
Consistent condom use#	No	1	1	1
	Yes	1.39 (1.22 to 1.58)***	1.10 (0.95 to 1.27)	1.18 (1.02 to 1.37)*

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex

In Table 4, we display the findings for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms by sex. Among males, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms among those in extramarital sexual relationships (OR 1.31, 95% CI 1.04 to 1.66). In females, we found no effect on extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17) and consistent use of condoms among those in extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17).

Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex

Sub-group	Variable	Level	OR (95% CI)
Males	Extramarital sexual relationship	No	1
		Yes	0.95 (0.83 to 1.08)
	Consistent condom use#	No	1
		Yes	1.31 (1.04 to 1.66) *
Females	Extra marital sexual relationship	No	1
		Yes	1.06 (0.97 to 1.17)
	Consistent condom use#	No	1
		Yes	1.06 (0.97 to 1.17)

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Sensitivity analysis results

The Rosenbaum sensitivity analysis using the Wilcoxon Signed-Rank test showed that a statistically non-significant upper bound of the gamma value occurred at 5.0 (p = 0.9798) which was distant from the point of no hidden bias where the gamma value was 1.0 (p<0.0001). This showed that the results are robust to unmeasured confounders and the analytic approach.

Discussion

Our study shows that among married or cohabiting couples in Uganda, comprehensive knowledge of HIV has no effect on extramarital sexual relationships but improves the consistent use of condoms among couples in extramarital sexual relationships. In sub-group analysis, comprehensive knowledge of HIV improves consistent use of condoms among married or cohabiting males in extramarital sexual relationships but has no effect on consistent use of condoms among married or cohabiting females. Our study has several strengths and limitations. First, we analysed nationally representative data so our findings are likely generalizable to the entire country and other similar settings. Second, the sample size was large and the results are robust to unmeasured confounders and the analytic approach. However, there are limitations. For example, although our results are robust to unmeasured confounders, the matching was performed on observed covariates and other unobserved covariates (such as alcohol consumption and drug and substance use among others) that are known to influence the outcome were not analysed. The outcomes were assessed through self-report so the possibility of social desirability bias cannot be excluded.

The finding that compressive knowledge of HIV improves consistent use of condoms among married or cohabiting couples in extramarital relationships is not unique. Comprehensive knowledge of HIV raises an individual's level of awareness regarding potential risks associated with not using condoms and helps them adopt safer sexual practices like consistent use of condoms.[27] Inconsistent use of condoms in extramarital sexual relationships places an couples at a greater risk of acquisition of sexually transmitted infections (STIs) including HIV.[28] Our finding is consistent with several studies in SSA. One study which analysed the Ghana DHS found exposure to family planning messages is associated with a higher likelihood of consistent condom use among sexually active never-married men.[29] Using level of education as a proxy for comprehensive knowledge of HIV, one study that analysed DHS data for 29 countries in SSA reports that among men who pay for sex, those that attained a secondary level of education are more likely to use condoms consistently.[30] In Uganda, less than half of the population aged 15-54 years have comprehensive knowledge of HIV[1]. This finding underscores a need to design and implement context-relevant HIV prevention and education messages to improve the level of comprehensive knowledge of HIV in the population for better HIV pandemic control.

We found no effect of comprehensive knowledge of HIV on consistent use of condoms among married or cohabiting females in extramarital sexual relationships. However, in married or cohabiting males, comprehensive knowledge of HIV improves consistent use of condoms in extramarital sexual relationships. Although several factors such as cost, moral values, ethnicity, religion, gender inequality, lack of dialogue among sexual partners concerning condom use among others influence inconsistent or non-use of condoms during sexual intercourse [31], our findings agree with an earlier study that reports HIV knowledge improves condom use self-efficacy [32] and consequently its use in sexual relationships. Consistent with our results, recent study conducted among sexually active men in Nigeria[33] show that knowledge of HIV equally improved condom use. Another study conducted among South African married couples reported that females are less likely to use a condom if their male partner has refused to using a condom[34], suggesting male dominance or power imbalance between women and men in condom negotiation. In our context, this finding could be explained by socio-cultural differences between men and women, with the latter being inherently submissive to the sexual demands of the latter. In general, African women find it difficult to assert themselves regarding condom negotiation and the majority do not negotiate condom use in a sexual relationship. In Uganda, one study[35] reports the social environment as an independent risk factor for HIV vulnerability. Men are the sole decision-makers regarding whether or not to use a condom in a sexual relationship. However, gender equality improves condom use self-efficacy in both general and risky situations.[32] Improving consistent use of condoms among women thus require their emancipation regarding decision-making on matters of sexual health.

Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual relationships among of married or cohabiting couples in the general population and in sub-group analysis requires cautious interpretation. First, we acknowledge that HIV is a global health problem, with an estimated 25.7 million PLHIV globally[28] and in Uganda, there are 1.4 million PLHIV.[2] However, with the rapid rollout and improved access to antiretroviral therapy (ART) over the years, the majority of PLHIV have a nearly normal quality of life and longevity. There is now much hope and optimism that the fight against HIV is nearly over leading to HIV complacency in the general population.[36] Concerns about HIV being a global health problem have lessened and the use of known HIV prevention methods such as abstinence, mutual faithfulness, and consistent condom use, among others have dwindled over the years.

The problem of HIV complacency in Africa[37] and Uganda[38] have been highlighted earlier. Another plausible explanation relates to behaviour change and the wide know-do gap at the individual level. One would argue that behaviour change is a gradual process, often with strong influences from the social, cultural, economic, environmental, and technological dimensions.[39] These challenges require a strong focus on health promotion, a combination of health education and healthy public policy.[40] For instance, without an enabling environment to achieve the desired behaviour change, health education is insufficient. The formulation and implementation of appropriate healthy public policies to create an enabling environment is important to prevent victim-blaming where people are victimized for their actions despite a lack of an enabling environment for behaviour change. Our findings, therefore, emphasize a need for novel approaches to achieve behaviour change in Uganda. There is a need to complement existing behaviour change communication strategies with other approaches that lessen the influence of social and environmental determinants (alcohol consumption and smoking, for example) that place the population at risk for HIV infection.[41] Approaches to mitigate HIV complacency besides other tools for HIV prevention and control are important in ending the HIV pandemic.[42] Further research should be conducted to understand the disparity in the effect of comprehensive knowledge of HIV on extramarital sexual relationships among married/co-habiting men and women.

Conclusions and recommendations

Comprehensive knowledge of HIV has no effect on extramarital sexual relationships among married or cohabiting couples in Uganda. However, it increases consistent use of condoms in extramarital relationships among married or cohabiting men but not in the married or cohabiting women. Our findings emphasize a need to continue providing consistent and correct HIV prevention health education messages.

Author contributions

JI and DTK conceptualized and designed the study. DTK acquired the data. JI analysed the data. JI and DTK interpreted the data and drafted the initial and final manuscripts. JI and DTK critically revised the manuscript and approved for submission.

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Competing interests

The authors declare that they have no competing interests.

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Data availability statement

The paper utilized the Demographic Health Survey data, and permission to use these publicly available data was obtained from http://www.dhsprogram.com before the data download and subsequent statistical analysis. As such, no ethical reviews and approvals were required before or during the preparation of the present manuscript.

Figure legends

Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Supplementary Fig 1: The TREND statement checklist

Consent

Not applicable.

Ethics Approval Statement

Not applicable/No human participants included.

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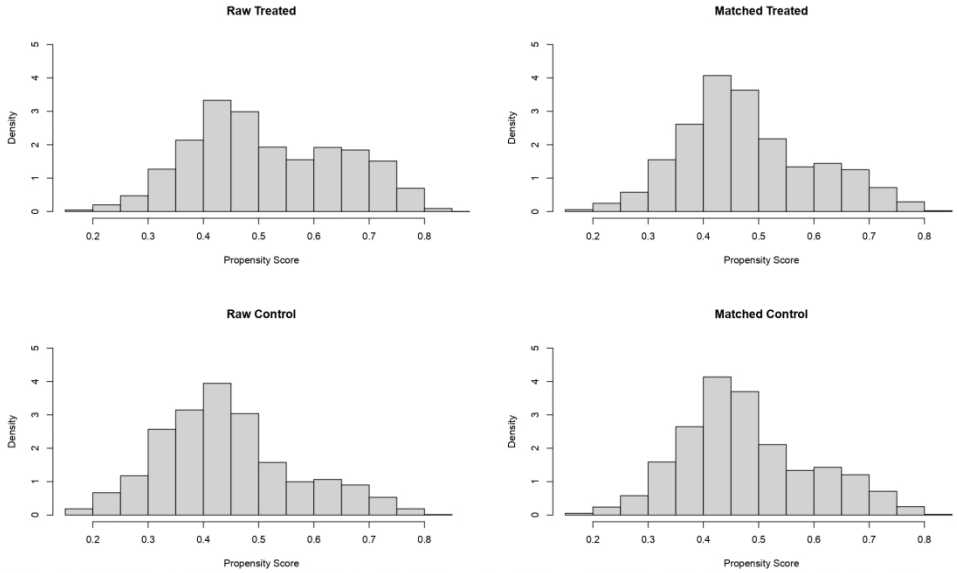

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

355x215mm (150 x 150 DPI)

TREND Statement Checklist

Paper Section/ Topic	Item No	Descriptor	Reported? ✓	Reported? Pg #
Title and Abstract				
Title and Abstract	1	• Information on how unit were allocated to interventions	√	1
		• Structured abstract recommended	√	1
		• Information on target population or study sample	√	1
Introduction				
Background	2	• Scientific background and explanation of rationale	√	3-4
		• Theories used in designing behavioral interventions	N/A	
Methods				
Participants	3	• Eligibility criteria for participants, including criteria at different levels in recruitment/sampling plan (e.g., cities, clinics, subjects)	√	4-5
		Method of recruitment (e.g., referral, self-selection), including the sampling method if a systematic sampling plan was implemented	√	4-5
		• Recruitment setting	√	4-5
		• Settings and locations where the data were collected	√	4-5
Interventions	4	• Details of the interventions intended for each study condition and how and when they were actually administered, specifically including:	√	5
		○ Content: what was given?	N/A	
		○ Delivery method: how was the content given?	√	5
		○ Unit of delivery: how were the subjects grouped during delivery?	N/A	
		○ Deliverer: who delivered the intervention?	N/A	
		○ Setting: where was the intervention delivered?	√	5
		○ Exposure quantity and duration: how many sessions or episodes or events were intended to be delivered? How long were they intended to last?	√	5
		○ Time span: how long was it intended to take to deliver the intervention to each unit?	√	5
		○ Activities to increase compliance or adherence (e.g., incentives)	N/A	
Objectives	5	• Specific objectives and hypotheses	√	4
Outcomes	6	• Clearly defined primary and secondary outcome measures	√	6
		• Methods used to collect data and any methods used to enhance the quality of measurements	√	4-5
		• Information on validated instruments such as psychometric and biometric properties	N/A	
Sample Size	7	How sample size was determined and, when applicable, explanation of any interim analyses and stopping rules	N/A	
Assignment Method	8	Unit of assignment (the unit being assigned to study condition, e.g., individual, group, community)	N/A	
		Method used to assign units to study conditions, including details of any restriction (e.g., blocking, stratification, minimization)	N/A	
		Inclusion of aspects employed to help minimize potential bias induced due to non-randomization (e.g., matching)	√	6

TREND Statement Checklist

Blinding (masking)	9	• Whether or not participants, those administering the interventions, and those assessing the outcomes were blinded to study condition assignment; if so, statement regarding how the blinding was accomplished and how it was assessed.	NA	
Unit of Analysis	10	• Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community)	√	7-8
		• If the unit of analysis differs from the unit of assignment, the analytical method used to account for this (e.g., adjusting the standard error estimates by the design effect or using multilevel analysis)	N/A	
Statistical Methods	11	• Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data	√	7-8
		• Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis	√	7-8
		• Methods for imputing missing data, if used	N/A	
		• Statistical software or programs used	√	7
Results				
Participant flow	12	Flow of participants through each stage of the study: enrollment, assignment, allocation, and intervention exposure, follow-up, analysis (a diagram is strongly recommended)	N/A	
		○ Enrollment: the numbers of participants screened for eligibility, found to be eligible or not eligible, declined to be enrolled, and enrolled in the study	N/A	
		○ Assignment: the numbers of participants assigned to a study condition	N/A	
		○ Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention	N/A	
		○ Follow-up: the number of participants who completed the follow-up or did not complete the follow-up (i.e., lost to follow-up), by study condition	N/A	
		○ Analysis: the number of participants included in or excluded from the main analysis, by study condition	N/A	
		• Description of protocol deviations from study as planned, along with reasons	N/A	
Recruitment	13	• Dates defining the periods of recruitment and follow-up	N/A	
Baseline Data	14	Baseline demographic and clinical characteristics of participants in each study condition	√	9
		Baseline characteristics for each study condition relevant to specific disease prevention research	√	9
		Baseline comparisons of those lost to follow-up and those retained, overall and by study condition	N/A	
		Comparison between study population at baseline and target population of interest	√	9
Baseline equivalence	15	• Data on study group equivalence at baseline and statistical methods used to control for baseline differences	√	14

TREND Statement Checklist

Numbers analyzed	16	• Number of participants (denominator) included in each analysis for each study condition, particularly when the denominators change for different outcomes; statement of the results in absolute numbers when feasible	√	14
		• Indication of whether the analysis strategy was "intention to treat" or, if not, description of how non-compliers were treated in the analyses	N/A	
Outcomes and estimation	17	• For each primary and secondary outcome, a summary of results for each estimation study condition, and the estimated effect size and a confidence interval to indicate the precision	√	13-14
		• Inclusion of null and negative findings	N/A	
		Inclusion of results from testing pre-specified causal pathways through which the intervention was intended to operate, if any	√	13-14
Ancillary analyses	18	• Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory	N/A	
Adverse events	19	• Summary of all important adverse events or unintended effects in each study condition (including summary measures, effect size estimates, and confidence intervals)	N/A	
DISCUSSION				
Interpretation	20	• Interpretation of the results, taking into account study hypotheses, sources of potential bias, imprecision of measures, multiplicative analyses, and other limitations or weaknesses of the study	√	14
		Discussion of results taking into account the mechanism by which the intervention was intended to work (causal pathways) or alternative mechanisms or explanations	√	14-16
		Discussion of the success of and barriers to implementing the intervention, fidelity of implementation	N/A	
		• Discussion of research, programmatic, or policy implications	√	14-16
Generalizability	21	• Generalizability (external validity) of the trial findings, taking into account the study population, the characteristics of the intervention, length of follow-up, incentives, compliance rates, specific sites/settings involved in the study, and other contextual issues	√	17
Overall Evidence	22	• General interpretation of the results in the context of current evidence and current theory	√	14-16

From: Des Jarlais, D. C., Lyles, C., Crepaz, N., & the Trend Group (2004). Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement. *American Journal of Public Health*, 94, 361-366. For more information, visit: http://www.cdc.gov/trendstatement/

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Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission among adult Ugandans: a propensity-score matched analysis

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Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV transmission among adult Ugandans: a propensity-score matched analysis

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Abstract

Objective: To evaluate the effect of comprehensive knowledge of human immunodeficiency virus (HIV) on extramarital sexual relationships and consistent condom use.

Design: Quasi-experimental study.

Setting: 20,880 households, Uganda.

Participants: Married/cohabiting men and women, 15 to 54 years.

Methods: We applied propensity-score matched (PSM) analysis and defined comprehensive knowledge of HIV as knowing that consistent use of condoms during sexual intercourse and having just one faithful partner without HIV reduces the chance of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting two local misconceptions (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV). The primary outcome was extramarital sexual relationship defined as involvement in a sexual relationship with a partner other than a spouse or cohabiting partner, within 12 months preceding the survey. The secondary outcome was consistent condom use defined as using a condom at every sexual intercourse with any non-spouse/non-cohabiting partner over the past 12 months.

Results: Among 18,504 participants matched in a 1:1 ratio, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (odds ratio (OR) 1.03, 95% confidence interval (CI) 0.96 to 1.11) but improved consistent condom use among married/cohabiting couples in extramarital sexual relationships (OR 1.18, 95% CI 1.02 to 1.37). Among married/cohabiting men, comprehensive knowledge of HIV had no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms in extramarital sexual relationships (OR 1.31, 95% CI, 1.04 to 1.66). However, among married/cohabiting females, there was no effect on both outcomes.

Conclusions: Comprehensive knowledge of HIV has no effect on extramarital sexual relationships but increases consistent condom use among those in extramarital sexual relationships. There is a need to consistently provide correct HIV prevention messages among sexually active married/cohabiting couples in Uganda.

Word count: 299 Abstract; 3,971 main text.

Keywords: Comprehensive knowledge of HIV; consistent condom use; risky sexual behaviour; risky sexual practice

Strengths and limitations

- The study used a nationally representative data.
- Large sample size.
- Findings are robust to unmeasured confounders and the analytic approach.
- The study is limited by a lack of qualitative data to contextualize the quantitative findings.
- Outcome measure is limited by social desirability bias.

Background

The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with a person living with human immunodeficiency virus (HIV).[1] Currently, an estimated 1.4 million people are living with HIV in Uganda.[2] The 2020 Uganda Population-Based HIV Impact Assessment[3] reports a 5.5% HIV prevalence among people aged 15-49 years (7.1% females, 3.8% males). However, new HIV infections among adults (≥15 years) progressively declined from 71,000 in 2010 to 48,000 in 2020, a 32% drop. Having a comprehensive knowledge of HIV can prevent HIV acquisition by helping individuals to assess their own risk of HIV acquisition and adopting safer sexual practices.[3] Comprehensive knowledge of HIV is defined as knowing that consistent use of condoms during sexual intercourse and having just one faithful partner without HIV can reduce the chance of getting HIV, knowing that a healthy-looking person can have HIV, and rejecting the two most common local misconceptions about transmission or prevention of HIV (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV).[1]

Comprehensive knowledge of HIV in the general population increased by 1% per year between 2003 and 2015 [4] and this is expected to reverse the HIV incidence and prevalence. Analysis of Demographic Health Survey (DHS) data for 15 countries in sub-Saharan Africa (SSA) show 38.6% of the population with comprehensive knowledge of HIV[5]. The 15 countries included Burundi (2016/17), Ethiopia (2016), Rwanda (2015), Uganda (2016), Zambia (2018/19), Benin (2017/18), Gambia (2019/20), Guinea (2018), Liberia (2019/20), Mali (2018), Nigeria (2018), Sierra Leone (2019), Cameroon (2018/19), and Chad (2015). Data further show a higher level of comprehensive knowledge of HIV is associated with being old, attaining at least a primary level of education, belonging to a wealthy household, using contraceptives, listening to a radio, and reading newspapers at the individual level.[5] At the regional level, residing in an urban area or the Eastern African region is similarly associated with a higher comprehensive knowledge of HIV.[5] Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) found more than 4 in 10 adolescent girls and young women (15 to 24 years) have comprehensive knowledge of HIV and are more likely to negotiate for safe sex[6]. However, limitations of Frimpong's study includes a lack of appropriate comparator, a design that precluded assessment of the effect of comprehensive knowledge of HIV on sexual behaviours associated with HIV transmission due to selection bias and confounding[7], and an analytic approach that susceptible to model misspecification.[8]

The 2016 Uganda DHS (UDHS) data show 48% of the population surveyed have comprehensive knowledge of HIV[9] but did not examine the effect of comprehensive knowledge of HIV on sexual behaviours at population and sub-population levels. Overall, previous studies focused on the magnitude of comprehensive knowledge of HIV and the associated factors[5,6].

Between 2016 and 2019, the prevalence of HIV among married or cohabiting couples in Uganda was 6.6%, exceeding the 6.0% prevalence among adults aged 15-49 years[10]. Low condom use among married/cohabiting couples in extramarital sexual relationship is a risk for HIV infection. The 2016 UDHS[9] reports condom use at the last sexual intercourse among married/cohabiting couples with ≥2 sexual partners in the past 12 months is higher among men (9.7%) than women (7.9%).

Few studies have attempted to examine the link between comprehensive knowledge of HIV and risky sexual behaviour and where attempts have been made, significant design and analytic limitations exists. Currently, there is limited information about the effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission among married or cohabiting couples in Uganda and SSA in general. Our study analysed the 2016 Uganda DHS data from a nationally representative survey to establish the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms among married or cohabiting couples in Uganda. As a secondary objective, we examined the effect of comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of condoms by sex (women versus men). We hypothesized that comprehensive knowledge of HIV reduces the likelihood of extramarital sexual relationships in men and women, and improves consistent use of condoms among married or cohabiting couples in extramarital sexual relationships.

Methods

Description of data source

We analyzed data from a nationally representative population-based household survey, the 2016 UDHS[9], conducted by the Uganda Bureau of Statistics (UBOS). Elsewhere[11], the dataset is described. Data collection took place between Jun 20, 2016 and Dec 16, 2016. The survey sample was stratified and selected in two stages. The first stage consisted of the selection of 697 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one cluster from the Acholi sub-region in northern Uganda was excluded for security reasons. The second stage involved the sampling of households within the clusters. This was achieved through a listing of all households within each of the 696 accessible selected enumeration areas between April and October 2016, with some listings overlapping with fieldwork. The survey drew maps for each of the sampled clusters and then listed all the households except for institutional living arrangements, namely army barracks, hospitals, police camps, and boarding schools. To minimize the task of household listing, each large enumeration area yielding more than 300 households selected for the survey was segmented, and one segment was selected for the survey with probability proportional to segment size, and the household listing was conducted within the segment. Therefore, in the 2016 UDHS, a cluster was regarded as either an enumeration area or a segment of an enumeration area. Overall, a representative sample that consisted of 20,880 households corresponding to 30 per enumeration area or a segment of enumeration area was randomly selected for the survey.

All women aged 15-49 years who were either permanent residents of the selected households or visitors who had stayed in the household the night before the survey were eligible to be interviewed. In one-third of the sampled households, all men aged 15 to 54 years, including both usual residents and visitors who had stayed in the household the night preceding the interview, were eligible for individual interviews. Data were collected using four questionnaires: the household, women, men, and the biomarker questionnaires. The women's questionnaire collected information from all eligible women aged 15-49 years and they were questioned on the following among others: 1) Husbands' background characteristics and women's work: husbands' age, level of education, and occupation and women's occupation and sources of earnings; 2) sexually transmitted infections (STIs) and HIV/AIDS: knowledge of STIs and AIDS and methods of transmission, sources of information, behaviors to avoid STIs and HIV, and stigma;

3) Questions on reproduction included the number of children ever born, birth history, and current pregnancy; 4) Family planning questions included knowledge and use of contraception, the sources of contraceptive methods, and information on family planning; 5) Questions on maternal and child health, breastfeeding, and nutrition included prenatal care, delivery, postnatal care, practices of breastfeeding and complementary feeding, coverage of vaccination, diarrhea prevalence and treatment, symptoms of acute respiratory infection (ARI), fever, knowledge of oral rehydration salts and use of oral rehydration therapy; 6) Questions on fertility preferences included desire for more children, the ideal number of children, gender preferences, and the intention to use a family planning method; 7) Questions were asked regarding knowledge, attitudes, and behaviors related to injections and smoking; 7) Additional questions focused on adult and maternal mortality, domestic violence, and early childhood development. Additional questions are described in the 2016 UDHS report.[9]

The men's questionnaire was administered to all men aged 15-54 years in the sub-sample of households selected for the male survey and collected much of the same information elicited with the women's questionnaire. However, it was shorter because it did not contain a detailed reproductive history or questions on maternal and child health.

Data were collected on knowledge and attitudes of women and men about STIs and HIV/AIDS, potential exposure to the risk of HIV infection (risk behaviors and condom use), and coverage of HIV testing and counseling and other key HIV/AIDS programs. The primary objective was to provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including knowledge of HIV prevention methods, stigma and discrimination, number of sexual partners, condom use, self-reported HIV testing, prevention of mother-to-child transmission of HIV, and voluntary medical male circumcision. The 2016 UDHS data were collected by 21 trained research teams, with each consisting of a team leader, field manager, 3 female interviewers, 1 male interviewer, 1 health technician, and 1 driver. A detailed description of the survey can be found in the 2016 UDHS report.[1]

Ethical considerations

The UDHS dataset is publicly accessible at https://dhsprogram.com/data/available-datasets.cfm. We applied for and received authorization to analyze the data from the DHS program (www.dhsprogram.com). Since DHS datasets are publicly available and free, no ethical approval was required.

Study design

This was a non-randomized, quasi-experimental study since no true randomization was employed.[12] We simulated a randomized control trial (RCT) from observational data by applying propensity-scores matched (PSM) analysis to remove selection bias arising from a lack of randomization and confounding. PSM analysis ensured that both the exposed and non-exposed groups are comparable/or balanced on all measured covariates, except for the exposure.[12,13] Although an RCT is the gold standard design for measuring the effect of interventions since randomization ensures balance in both known and unknown baseline covariates thereby achieving comparability between the intervention and control groups[14], it is infeasible and unethical for beneficial interventions such as comprehensive knowledge of HIV. Observational data provides an option for the measure of effect but the presence of selection bias from lack of randomization and confounding of the exposure-outcome relationship due to other factors are important limitations[15] that have to removed hence the use of PSM analysis.

Variables and measurements

Exposure: Comprehensive knowledge of HIV was the exposure of interest, measured on a binary scale (yes versus no) using five indicators, namely 1) knowing that consistent use of condoms during sexual intercourse can reduce the chance of getting HIV; 2) knowing that having just one faithful partner without HIV can reduce the chance of getting HIV; 3) knowing that a healthy-looking person can have HIV; 4) rejecting that HIV can be transmitted through mosquitoes; and 5) rejecting that HIV can be transmitted by sharing of food. Indicators 4-5 are the two most common local misconceptions about HIV transmission or prevention in Uganda. Participants with correct responses to all the five indicators were considered as having comprehensive knowledge of HIV otherwise no. The exposed group consisted of participants with comprehensive knowledge of HIV while the unexposed (comparison) group consisted of those without comprehensive knowledge of HIV.

***Outcomes*:** The primary outcome was extramarital sexual relationships measured on a binary scale (yes or no). Participants in sexual relations with another sexual partner other than the spouse or cohabiting partner were considered to have indulged in extramarital sexual

relationships in the 12 months preceding the survey. The secondary outcome was the consistent use of condoms measured on a binary scale, computed as the percentage of respondents who had used a condom every time they had sex with any non-spouse or non-cohabiting partner over the past 12 months.[1]

Matching covariates: These included sex (male or female), age group (15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, and 50 to 54), level of education (none/no education, primary, secondary, and higher), marital status (never in a union, currently in a union, and formerly in a union), number of living children, wealth index (poorest, poorer, middle, richer, and richest), religion (no religion, Anglican, Catholic, Muslim, Seventh Day Adventist, Pentecostal, and others), and the 15 regions in Uganda (Kampala, Central 1, Central 2, Busoga, Bukedi, Bugishu, Teso, Karamoja, Lango, Acholi, West Nile, Bunyoro, Tooro, Ankole, and Kigezi).

Data analysis

We used R version 4.02[16] and Stata version 15.1 for the analysis. In R, we used the *MatchIt*[17] and *tableone*[18] statistical packages. We descriptively summarized categorical data as frequencies and percentages, and numerical data using the mean with its standard deviation. We performed propensity-score matched analysis using eight matching covariates known to influence either the exposure or the outcome, or both based on the unconfoundedness assumption.[19-21] We computed propensity scores in a logit model by fitting comprehensive knowledge of HIV as a function of the matching covariates. We assessed initial balance in propensity scores using a back-to-back histogram.[22] We then matched participants with and without compressive knowledge of HIV on similar propensity scores[23] using different matching approaches, namely nearest neighbor matching with and without caliper adjustment[20], and optimal pair and optimal full matching.[21] A caliper is a distance within which matching occurs, computed as 20% of the standard deviation of the propensity score to prevent bias from distant matches. In nearest neighbor matching without caliper adjustment, the participants were randomly matched to one another while in the nearest neighbor matching with caliper adjustment, the matching was performed within a caliper, all without replacement.

In the optimal pair matching, the matching was done in pairs and the non-matched pairs were excluded from the analysis. In the optimal full matching, the matching was done in a ratio of 1: many or many: 1. Furthermore, we performed exact matching where the participants were

matched on the identical values of propensity scores.[24] The best matching approach was one that balanced all the covariates between the two groups.

Following the matching, we checked covariate balance between the group with and without comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1 considered confirmatory of good covariate balance.[7] We further assessed covariate balance graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was taken to suggest covariate balance.[7,25] After successful matching, the propensity-score matched dataset was saved for the outcome analysis. We performed analysis on both the unmatched and matched datasets. We fitted a binary logistic regression model for the unadjusted and adjusted analysis, with the latter model adjusted for all the matching covariates. For the PSM dataset, we fitted a conditional logistic regression taking into consideration the matched pairs. We reported odds ratio (OR) and 95% confidence interval (CI).

Sensitivity analysis

We checked the robustness of the findings to hidden bias/unmeasured confounders and the matching approach using the Rosenbaum Wilcoxon's signed-rank test.[22] We interpreted distant gamma values to achieve statistical significance or non-significance as indicative of robustness.

Reporting of findings

The findings are reported following the improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement shown in Supplementary Fig 1.[26]

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Results

Characteristics of participants

We present participants' characteristics in Table 1 both before and after PSM. We analysed data for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning the participants' age group, level of education, wealth index, and region, with all the variables showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).

Table 1: Baseline characteristics of participants before and after PSM

Variables	Level	Unmatched (original) sample				Propensity score-matched sample			
		Comprehensive knowledge of HIV				Comprehensive knowledge of HIV			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
		No. (%)	No. (%)	No. (%)		No. (%)	No. (%)	No. (%)	
Sex	Male	5295 (22.3)	2692 (21.7)	2603 (23.0)	0.031	4168 (22.5)	2037 (22.0)	2131 (23.0)	0.024
	Female	18416 (77.7)	9705 (78.3)	8711 (77.0)		14336 (77.5)	7215 (78.0)	7121 (77.0)	
Age group (years)	15 to 19	5466 (23.1)	3263 (26.3)	2203 (19.5)	0.179	3985 (21.5)	2014 (21.8)	1971 (21.3)	0.019
	20 to 24	4712 (19.9)	2311 (18.6)	2401 (21.2)		3676 (19.9)	1832 (19.8)	1844 (19.9)	
	25 to 29	3741 (15.8)	1811 (14.6)	1930 (17.1)		2914 (15.7)	1471 (15.9)	1443 (15.6)	
	30 to 34	3327 (14.0)	1610 (13.0)	1717 (15.2)		2671 (14.4)	1325 (14.3)	1346 (14.5)	
	35 to 39	2521 (10.6)	1324 (10.7)	1197 (10.6)		2030 (11.0)	997 (10.8)	1033 (11.2)	
	40 to 44	2110 (8.9)	1109 (8.9)	1001 (8.8)		1768 (9.6)	887 (9.6)	881 (9.5)	
	45 to 49	1542 (6.5)	832 (6.7)	710 (6.3)		1220 (6.6)	605 (6.5)	615 (6.6)	
	50 to 54	292 (1.2)	137 (1.1)	155 (1.4)		240 (1.3)	121 (1.3)	119 (1.3)	
Level of education	No education	2279 (9.6)	1475 (11.9)	804 (7.1)	0.459	1617 (8.7)	816 (8.8)	801 (8.7)	0.033
	Primary	13849 (58.4)	8139 (65.7)	5710 (50.5)		11276 (60.9)	5681 (61.4)	5595 (60.5)	
	Secondary	5648 (23.8)	2243 (18.1)	3405 (30.1)		4464 (24.1)	2215 (23.9)	2249 (24.3)	
	Higher	1935 (8.2)	540 (4.4)	1395 (12.3)		1147 (6.2)	540 (5.8)	607 (6.6)	
Marital status	Never in union	6681 (28.2)	3604 (29.1)	3077 (27.2)	0.049	4904 (26.5)	2469 (26.7)	2435 (26.3)	0.01
	Currently in union	14352 (60.5)	7365 (59.4)	6987 (61.8)		11441 (61.8)	5715 (61.8)	5726 (61.9)	
	Formerly in union	2678 (11.3)	1428 (11.5)	1250 (11.0)		2159 (11.7)	1068 (11.5)	1091 (11.8)	
Living children	≤2	12840 (54.2)	6648 (53.6)	6192 (54.7)	0.049	9589 (51.8)	4770 (51.6)	4819 (52.1)	0.011
	3 to 5	6681 (28.2)	3449 (27.8)	3232 (28.6)		5410 (29.2)	2714 (29.3)	2696 (29.1)	
	≥6	4190 (17.7)	2300 (18.6)	1890 (16.7)		3505 (18.9)	1768 (19.1)	1737 (18.8)	

Wealth index	Poorest	4901 (20.7)	3071 (24.8)	1830 (16.2)	0.340	3496 (18.9)	1746 (18.9)	1750 (18.9)	0.005
	Poorer	4661 (19.7)	2653 (21.4)	2008 (17.7)		3719 (20.1)	1859 (20.1)	1860 (20.1)	
	Middle	4508 (19.0)	2453 (19.8)	2055 (18.2)		3783 (20.4)	1884 (20.4)	1899 (20.5)	
	Richer	4518 (19.1)	2254 (18.2)	2264 (20.0)		3814 (20.6)	1911 (20.7)	1903 (20.6)	
	Richest	5123 (21.6)	1966 (15.9)	3157 (27.9)		3692 (20.0)	1852 (20.0)	1840 (19.9)	
Religion	No religion	350 (1.5)	201 (1.6)	149 (1.3)	0.026	258 (1.4)	119 (1.3)	139 (1.5)	0.018
	Muslim	2793 (11.8)	1468 (11.8)	1325 (11.7)		2126 (11.5)	1063 (11.5)	1063 (11.5)	
	Christianity	20568 (86.7)	10728 (86.5)	9840 (87.0)		16120 (87.1)	8070 (87.2)	8050 (87.0)	
Region	Kampala	1640 (6.9)	596 (4.8)	1044 (9.2)	0.302	1125 (6.1)	574 (6.2)	551 (6.0)	0.037
	Central1	2058 (8.7)	946 (7.6)	1112 (9.8)		1575 (8.5)	812 (8.8)	763 (8.2)	
	Central2	1864 (7.9)	930 (7.5)	934 (8.3)		1532 (8.3)	767 (8.3)	765 (8.3)	
	Busoga	1959 (8.3)	1080 (8.7)	879 (7.8)		1563 (8.4)	783 (8.5)	780 (8.4)	
	Bukedi	1554 (6.6)	845 (6.8)	709 (6.3)		1259 (6.8)	625 (6.8)	634 (6.9)	
	Bugishu	1247 (5.3)	689 (5.6)	558 (4.9)		958 (5.2)	458 (5.0)	500 (5.4)	
	Teso	1695 (7.1)	867 (7.0)	828 (7.3)		1406 (7.6)	709 (7.7)	697 (7.5)	
	Karamoja	883 (3.7)	579 (4.7)	304 (2.7)		562 (3.0)	273 (3.0)	289 (3.1)	
	Lango	1638 (6.9)	901 (7.3)	737 (6.5)		1309 (7.1)	644 (7.0)	665 (7.2)	
	Acholi	1460 (6.2)	653 (5.3)	807 (7.1)		1183 (6.4)	611 (6.6)	572 (6.2)	
	West Nile	1589 (6.7)	1113 (9.0)	476 (4.2)		913 (4.9)	452 (4.9)	461 (5.0)	
	Bunyoro	1551 (6.5)	792 (6.4)	759 (6.7)		1281 (6.9)	636 (6.9)	645 (7.0)	
	Tooro	1696 (7.2)	918 (7.4)	778 (6.9)		1421 (7.7)	710 (7.7)	711 (7.7)	
	Ankole	1672 (7.1)	853 (6.9)	819 (7.2)		1408 (7.6)	699 (7.6)	709 (7.7)	
	Kigezi	1205 (5.1)	635 (5.1)	570 (5.0)		1009 (5.5)	499 (5.4)	510 (5.5)	

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Distribution of study outcomes before and after PSM

Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%) versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships, 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of condoms was significantly lower among those without comprehensive knowledge of HIV compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD = 0.155.

In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a statistically non-significant difference between those without and with comprehensive knowledge of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-significant difference in the consistent use of condoms SMD = 0.080).

Table 2: Distribution of study outcomes by comprehensive knowledge of HIV before and after PSM

Variables	Levels	Comprehensive knowledge of HIV (before PSM)				Comprehensive knowledge of HIV (after PSM)			
		Overall (n =23,711)	No (n=12,397)	Yes (n = 11,314)	SMD	Overall (n=18,504)	No (n=9,252)	Yes (n=9,252)	SMD
Extramarital sexual relationship	No	19524 (82.3)	10341 (83.4)	9183 (81.2)	0.059	15244 (82.4)	7644 (82.6)	7600 (82.1)	0.012
	Yes	4187 (17.7)	2056 (16.6)	2131 (18.8)		3260 (17.6)	1608 (17.4)	1652 (17.9)	
Consistent condom use #	No	2762 (66.0)	1433 (69.7)	1329 (62.4)	0.155	2143 (65.7)	1088 (67.7)	1055 (63.9)	0.080
	Yes	1425 (34.0)	623 (30.3)	802 (37.6)		1117 (34.3)	520 (32.3)	597 (36.1)	

Note: # Data are for participants in extramarital sexual relationships.

Additional balance diagnostics

Fig 1 is a histogram showing the distribution of propensity scores among participants with and without comprehensive knowledge of HIV. The propensity scores were distributed differently among the participants with (raw treated) and without (raw control) comprehensive knowledge of HIV before PSM. However, the propensity scores were distributed similarly among participants with (matched treated) and without (matched control) comprehensive knowledge of HIV after PSM.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

We present the results for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms in Table 3. The results show that comprehensive knowledge of HIV was significantly associated with extramarital sexual relationships at the unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome, the results show that comprehensive knowledge of HIV was significantly associated with consistent use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the PSM analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95% CI 0.95 to 1.27).

Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission

Variable	Level	Crude analysis	Adjusted analysis	PSM analysis
Extramarital sexual relationship	No	1	1	1
	Yes	1.17 (1.09 to 1.25)***	1.07 (0.99 to 1.15)	1.03 (0.96 to 1.11)
Consistent condom use#	No	1	1	1
	Yes	1.39 (1.22 to 1.58)***	1.10 (0.95 to 1.27)	1.18 (1.02 to 1.37)*

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex

In Table 4, we display the findings for the effect of comprehensive knowledge of HIV on having multiple sexual partners and consistent use of condoms by sex. Among males, comprehensive knowledge of HIV showed no effect on extramarital sexual relationships (OR 0.95, 95% CI 0.83 to 1.08) but improved consistent use of condoms among those in extramarital sexual relationships (OR 1.31, 95% CI 1.04 to 1.66). In females, we found no effect on extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17) and consistent use of condoms among those in extramarital sexual relationships (OR 1.06, 95% CI 0.97 to 1.17).

Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV transmission by sex

Sub-group	Variable	Level	OR (95% CI)
Males	Extramarital sexual relationship	No	1
		Yes	0.95 (0.83 to 1.08)
	Consistent condom use#	No	1
		Yes	1.31 (1.04 to 1.66) *
Females	Extra marital sexual relationship	No	1
		Yes	1.06 (0.97 to 1.17)
	Consistent condom use#	No	1
		Yes	1.06 (0.97 to 1.17)

Note: Significance codes at 5% level: p<0.0001***, p<0.001**, p<0.05*; # denotes analysis was restricted to participants with multiple sexual partners.

Sensitivity analysis results

The Rosenbaum sensitivity analysis using the Wilcoxon Signed-Rank test showed that a statistically non-significant upper bound of the gamma value occurred at 5.0 (p = 0.9798) which was distant from the point of no hidden bias where the gamma value was 1.0 (p<0.0001). This showed that the results are robust to unmeasured confounders and the analytic approach.

Discussion

Our study shows that among married or cohabiting couples in Uganda, comprehensive knowledge of HIV has no effect on extramarital sexual relationships but improves the consistent use of condoms among couples in extramarital sexual relationships. In sub-group analysis, comprehensive knowledge of HIV improves consistent use of condoms among married or cohabiting males in extramarital sexual relationships but has no effect on consistent use of condoms among married or cohabiting females.

The finding that compressive knowledge of HIV improves consistent use of condoms among married or cohabiting couples in extramarital relationships is not unique. Comprehensive knowledge of HIV raises an individual's level of awareness regarding potential risks associated with not using condoms and helps them adopt safer sexual practices like consistent use of condoms.[27] Inconsistent use of condoms in extramarital sexual relationships places an couples at a greater risk of acquisition of sexually transmitted infections (STIs) including HIV.[28] Our finding is consistent with several studies in SSA. One study which analysed the Ghana DHS found exposure to family planning messages is associated with a higher likelihood of consistent condom use among sexually active never-married men.[29] Using level of education as a proxy for comprehensive knowledge of HIV, one study that analysed DHS data for 29 countries in SSA reports that among men who pay for sex, those that attained a secondary level of education are more likely to use condoms consistently.[30] In Uganda, less than half of the population aged 15-54 years have comprehensive knowledge of HIV[1]. This finding underscores a need to design and implement context-relevant HIV prevention and education messages to improve the level of comprehensive knowledge of HIV in the population for better HIV pandemic control.

We found no effect of comprehensive knowledge of HIV on consistent use of condoms among married or cohabiting females in extramarital sexual relationships. However, in married or cohabiting males, comprehensive knowledge of HIV improves consistent use of condoms in extramarital sexual relationships. Although several factors such as cost, moral values, ethnicity, religion, gender inequality, lack of dialogue among sexual partners concerning condom use among others influence inconsistent or non-use of condoms during sexual intercourse [31], our findings agree with an earlier study that reports HIV knowledge improves condom use self-efficacy [32] and consequently its use in sexual relationships.

Consistent with our results, recent study conducted among sexually active men in Nigeria[33] show that knowledge of HIV equally improved condom use. Another study conducted among South African married couples reported that females are less likely to use a condom if their male partner has refused to using a condom[34], suggesting male dominance or power imbalance between women and men in condom negotiation. In our context, this finding could be explained by socio-cultural differences between men and women, with the latter being inherently submissive to the sexual demands of the latter. In general, African women find it difficult to assert themselves regarding condom negotiation and the majority do not negotiate condom use in a sexual relationship. In Uganda, one study[35] reports the social environment as an independent risk factor for HIV vulnerability. Men are the sole decision-makers regarding whether or not to use a condom in a sexual relationship. However, gender equality improves condom use self-efficacy in both general and risky situations.[32] Improving consistent use of condoms among women thus require their emancipation regarding decision-making on matters of sexual health.

Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual relationships among of married or cohabiting couples in the general population and in sub-group analysis requires cautious interpretation. First, we acknowledge that HIV is a global health problem, with an estimated 25.7 million PLHIV globally[28] and in Uganda, there are 1.4 million PLHIV.[2] However, with the rapid rollout and improved access to antiretroviral therapy (ART) over the years, the majority of PLHIV have a nearly normal quality of life and longevity. There is now much hope and optimism that the fight against HIV is nearly over leading to HIV complacency in the general population.[36] Concerns about HIV being a global health problem have lessened and the use of known HIV prevention methods such as abstinence, mutual faithfulness, and consistent condom use, among others have dwindled over the years. The problem of HIV complacency in Africa[37] and Uganda[38] have been highlighted earlier. Another plausible explanation relates to behaviour change and the wide know-do gap at the individual level. One would argue that behaviour change is a gradual process, often with strong influences from the social, cultural, economic, environmental, and technological dimensions.[39] These challenges require a strong focus on health promotion, a combination of health education and healthy public policy.[40] For instance, without an enabling environment to achieve the desired behaviour change, health education is insufficient. The formulation and implementation of appropriate healthy public policies to create an enabling environment is important to prevent victim-blaming where people are victimized for their actions despite a lack of an enabling environment for behaviour change.

Our findings, therefore, emphasize a need for novel approaches to achieve behaviour change in Uganda. There is a need to complement existing behaviour change communication strategies with other approaches that lessen the influence of social and environmental determinants (alcohol consumption and smoking, for example) that place the population at risk for HIV infection.[41] Approaches to mitigate HIV complacency besides other tools for HIV prevention and control are important in ending the HIV pandemic.[42] Further research should be conducted to understand the disparity in the effect of comprehensive knowledge of HIV on extramarital sexual relationships among married/co-habiting men and women.

Study strengths and limitations

Our study has several strengths and limitations. First, we analysed nationally representative data so our findings are likely generalizable to the entire country and other similar settings. Second, the sample size was large and the results are robust to unmeasured confounders and the analytic approach. However, there are limitations. For example, although our results are robust to unmeasured confounders, the matching was performed on observed covariates and other unobserved covariates (such as alcohol consumption and drug and substance use among others) that are known to influence the outcome were not analysed. The outcomes were assessed through self-report so the possibility of social desirability bias cannot be excluded.

Methodological considerations

We highlight a few methodological considerations in this study. First, PSM is appropriate when the sample size is large, typical ≥5000 observations. This is because PSM leads to reduction in sample size due to unmatched observations hence might increase the likelihood of Type II error. The specification of the propensity-score model is prone to inaccuracies so the reliance on unconfoundedness assumption is important. The magnitude of intervention effect somewhat depends on the type of matching used and whether it was done with or without replacement. Another important consideration is the approach to computing the propensity score thus whether a logistic regression or generalized boosted regression model was used since they determine the sufficiency of the common support. Lastly, PSM does not control for unmeasured confounders so sensitivity analysis to assess the credibility of the estimates is important.

Conclusions and recommendations

Comprehensive knowledge of HIV has no effect on extramarital sexual relationships among married or cohabiting couples in Uganda. However, it increases consistent use of condoms in extramarital relationships among married or cohabiting men but not in the married or cohabiting women. Our findings emphasize a need to continue providing consistent and correct HIV prevention health education messages.

Author contributions

JI and DTK conceptualized and designed the study. DTK acquired the data. JI analysed the data. JI and DTK interpreted the data and drafted the initial and final manuscripts. JI and DTK critically revised the manuscript and approved for submission.

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Competing interests

The authors declare that they have no competing interests.

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Data availability statement

The paper utilized the Demographic Health Survey data, and permission to use these publicly available data was obtained from http://www.dhsprogram.com before the data download and subsequent statistical analysis. As such, no ethical reviews and approvals were required before or during the preparation of the present manuscript.

Figure legends

Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Supplementary Fig 1: The TREND statement checklist

Consent

Not applicable.

Ethics Approval Statement

Not applicable/No human participants included.

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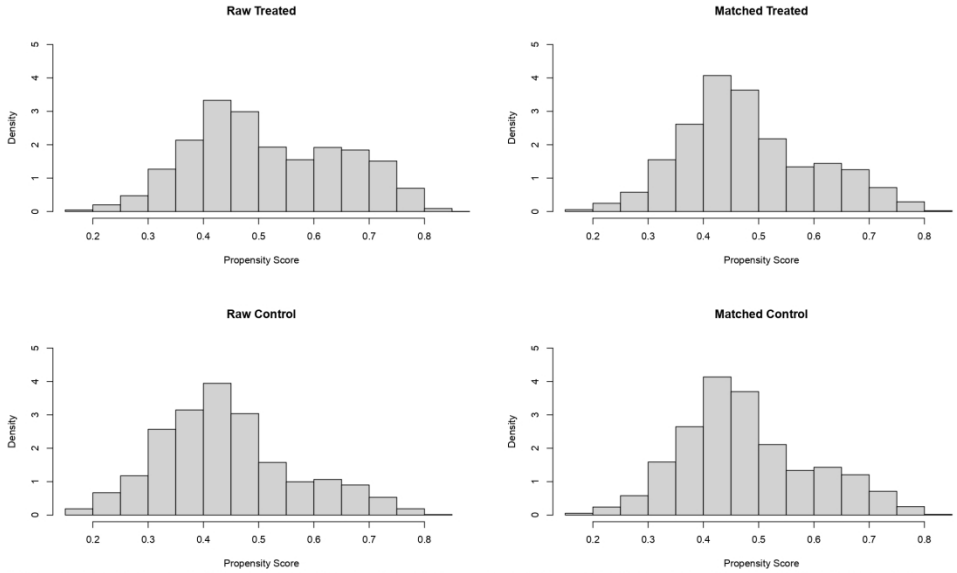

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

Fig 1:Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

355x215mm (150 x 150 DPI)

TREND Statement Checklist

Paper Section/ Topic	Item No	Descriptor	Reported? ✓	Reported? Pg #
Title and Abstract				
Title and Abstract	1	• Information on how unit were allocated to interventions	√	1
		• Structured abstract recommended	√	1
		• Information on target population or study sample	√	1
Introduction				
Background	2	• Scientific background and explanation of rationale	√	3-4
		• Theories used in designing behavioral interventions	N/A	
Methods				
Participants	3	• Eligibility criteria for participants, including criteria at different levels in recruitment/sampling plan (e.g., cities, clinics, subjects)	√	4-5
		Method of recruitment (e.g., referral, self-selection), including the sampling method if a systematic sampling plan was implemented	√	4-5
		• Recruitment setting	√	4-5
		• Settings and locations where the data were collected	√	4-5
Interventions	4	• Details of the interventions intended for each study condition and how and when they were actually administered, specifically including:	√	5
		○ Content: what was given?	N/A	
		○ Delivery method: how was the content given?	√	5
		○ Unit of delivery: how were the subjects grouped during delivery?	N/A	
		○ Deliverer: who delivered the intervention?	N/A	
		○ Setting: where was the intervention delivered?	√	5
		○ Exposure quantity and duration: how many sessions or episodes or events were intended to be delivered? How long were they intended to last?	√	5
		○ Time span: how long was it intended to take to deliver the intervention to each unit?	√	5
		○ Activities to increase compliance or adherence (e.g., incentives)	N/A	
Objectives	5	• Specific objectives and hypotheses	√	4
Outcomes	6	• Clearly defined primary and secondary outcome measures	√	6
		• Methods used to collect data and any methods used to enhance the quality of measurements	√	4-5
		• Information on validated instruments such as psychometric and biometric properties	N/A	
Sample Size	7	How sample size was determined and, when applicable, explanation of any interim analyses and stopping rules	N/A	
Assignment Method	8	Unit of assignment (the unit being assigned to study condition, e.g., individual, group, community)	N/A	
		Method used to assign units to study conditions, including details of any restriction (e.g., blocking, stratification, minimization)	N/A	
		Inclusion of aspects employed to help minimize potential bias induced due to non-randomization (e.g., matching)	√	6

TREND Statement Checklist

Blinding (masking)	9	• Whether or not participants, those administering the interventions, and those assessing the outcomes were blinded to study condition assignment; if so, statement regarding how the blinding was accomplished and how it was assessed.	NA	
Unit of Analysis	10	• Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community)	√	7-8
		• If the unit of analysis differs from the unit of assignment, the analytical method used to account for this (e.g., adjusting the standard error estimates by the design effect or using multilevel analysis)	N/A	
Statistical Methods	11	• Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data	√	7-8
		• Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis	√	7-8
		• Methods for imputing missing data, if used	N/A	
		• Statistical software or programs used	√	7
Results				
Participant flow	12	Flow of participants through each stage of the study: enrollment, assignment, allocation, and intervention exposure, follow-up, analysis (a diagram is strongly recommended)	N/A	
		○ Enrollment: the numbers of participants screened for eligibility, found to be eligible or not eligible, declined to be enrolled, and enrolled in the study	N/A	
		○ Assignment: the numbers of participants assigned to a study condition	N/A	
		○ Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention	N/A	
		○ Follow-up: the number of participants who completed the follow-up or did not complete the follow-up (i.e., lost to follow-up), by study condition	N/A	
		○ Analysis: the number of participants included in or excluded from the main analysis, by study condition	N/A	
		• Description of protocol deviations from study as planned, along with reasons	N/A	
Recruitment	13	• Dates defining the periods of recruitment and follow-up	N/A	
Baseline Data	14	Baseline demographic and clinical characteristics of participants in each study condition	√	9
		Baseline characteristics for each study condition relevant to specific disease prevention research	√	9
		Baseline comparisons of those lost to follow-up and those retained, overall and by study condition	N/A	
		Comparison between study population at baseline and target population of interest	√	9
Baseline equivalence	15	• Data on study group equivalence at baseline and statistical methods used to control for baseline differences	√	14

TREND Statement Checklist

Numbers analyzed	16	• Number of participants (denominator) included in each analysis for each study condition, particularly when the denominators change for different outcomes; statement of the results in absolute numbers when feasible	√	14
		• Indication of whether the analysis strategy was "intention to treat" or, if not, description of how non-compliers were treated in the analyses	N/A	
Outcomes and estimation	17	• For each primary and secondary outcome, a summary of results for each estimation study condition, and the estimated effect size and a confidence interval to indicate the precision	√	13-14
		• Inclusion of null and negative findings	N/A	
		Inclusion of results from testing pre-specified causal pathways through which the intervention was intended to operate, if any	√	13-14
Ancillary analyses	18	• Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory	N/A	
Adverse events	19	• Summary of all important adverse events or unintended effects in each study condition (including summary measures, effect size estimates, and confidence intervals)	N/A	
DISCUSSION				
Interpretation	20	• Interpretation of the results, taking into account study hypotheses, sources of potential bias, imprecision of measures, multiplicative analyses, and other limitations or weaknesses of the study	√	14
		Discussion of results taking into account the mechanism by which the intervention was intended to work (causal pathways) or alternative mechanisms or explanations	√	14-16
		Discussion of the success of and barriers to implementing the intervention, fidelity of implementation	N/A	
		• Discussion of research, programmatic, or policy implications	√	14-16
Generalizability	21	• Generalizability (external validity) of the trial findings, taking into account the study population, the characteristics of the intervention, length of follow-up, incentives, compliance rates, specific sites/settings involved in the study, and other contextual issues	√	17
Overall Evidence	22	• General interpretation of the results in the context of current evidence and current theory	√	14-16

From: Des Jarlais, D. C., Lyles, C., Crepaz, N., & the Trend Group (2004). Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement. *American Journal of Public Health*, 94, 361-366. For more information, visit: http://www.cdc.gov/trendstatement/