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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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3 1 **Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV**
4 **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 1.18, 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.

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Competing interests

The authors declare that they have no competing interests

66 Background

67 The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with
68 a human immunodeficiency virus (HIV) infected person.¹ Currently, an estimated 1.4 million
69 people are living with HIV in Uganda.² Having a comprehensive knowledge of HIV can prevent
70 HIV acquisition by helping individuals to assess their own risk of HIV acquisition and adopting
71 safer sexual practices.³ Comprehensive knowledge of HIV is defined as knowing that consistent
72 use of condoms during sexual intercourse and having just one uninfected faithful partner can
73 reduce the chances of getting HIV, knowing that a healthy-looking person can have HIV, and
74 rejecting the most common local misconceptions about transmission or prevention of HIV.¹
75 Comprehensive knowledge of HIV in the general population has risen by 1% per year between
76 2003 and 2015 ⁴ and this is expected to reverse the HIV incidence and prevalence. Findings from
77 a recent analysis of Demographic Health Survey (DHS) data for 15 countries in sub-Saharan
78 Africa (SSA) show that 38.6% of the population have comprehensive knowledge of HIV/Acquired
79 immune deficiency syndrome (AIDS). The data further show that a higher level of comprehensive
80 knowledge of HIV is associated with being old, having at least a primary level of education, being
81 from a wealthy household, using contraceptives, listening to the radio, and reading newspapers
82 at the individual level.⁵ At the regional level, living in an urban area and being a resident in the
83 Eastern African region is likewise associated with high comprehensive knowledge of HIV.⁵
84 Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) shows that slightly
85 more than 4 in 10 adolescent girls and young women aged 15 to 24 years have comprehensive
86 knowledge of HIV, which is associated with a more likelihood of safer sex negotiation ⁶. However,
87 limitations of the study by Frimpong et al (2021) include a lack of an appropriate comparison
88 group, a design that precluded the assessment of the impact of comprehensive knowledge of HIV
89 due to selection bias and confounding⁷, and an analytic approach that is susceptible to model
90 misspecification.⁸

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

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3 98 Few studies have attempted to examine the link between comprehensive knowledge of HIV and
4 99 sexual behaviour and where attempts have been made, there exists a significant design and
5 100 analytic limitations in establishing the true effect of comprehensive knowledge of HIV on sexual
6 101 behaviour. Currently, there is limited information about the effect of comprehensive knowledge of
7 102 HIV on risky sexual behaviours associated with HIV transmission in Uganda and the SSA region
8 103 in general. Our study analysed the 2016 Uganda DHS data from a nationally representative
9 104 survey to establish the effect of comprehensive knowledge of HIV on extramarital sexual
10 105 relationships and consistent use of condoms among those in extramarital sexual relationships in
11 106 Uganda. As a secondary objective, we examined the effect of comprehensive knowledge of HIV
12 107 on extramarital sexual relationships and consistent use of condoms in a sub-group of women and
13 108 men. We hypothesized that comprehensive knowledge of HIV reduces the likelihood of
14 109 extramarital sexual relationships in men and women, and improves consistent use of condoms
15 110 among those in extramarital sexual relationships.
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112 **Methods**

113 **Description of data source**

114 We analyzed data from a nationally representative population-based household survey, the 2016
115 Uganda Demographic Health Survey (UDHS).⁹ Data collection took place from Jun 20Dec 16,
116 2016. The survey sample was stratified and selected in two stages. The first stage consisted of
117 the selection of 697 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one
118 cluster from the Acholi sub-region was excluded for security reasons. The second stage involved
119 the sampling of households within the clusters. This was achieved through a listing of all
120 households within each of the 696 accessible selected enumeration areas between April and
121 October 2016, with some listings overlapping with fieldwork. The survey drew maps for each of
122 the sampled clusters and then listed all the households except for institutional living
123 arrangements, namely army barracks, hospitals, police camps, and boarding schools. To
124 minimize the task of household listing, each large enumeration area yielding more than 300
125 households selected for the survey was segmented, and one segment was selected for the survey
126 with probability proportional to segment size, and the household listing was conducted within the
127 segment. Therefore, in the UDHS, a cluster was regarded as either an enumeration area or a
128 segment of an enumeration area. Overall, a representative sample that consisted of 20,880
129 households corresponding to 30 per enumeration area or a segment of enumeration area was
130 randomly selected for the survey.
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3 131 All women aged 15-49 who were either permanent residents of the selected households or visitors
4 132 who stayed in the household the night before the survey were eligible to be interviewed. In one-
5 133 third of the sampled households, all men aged 15 to 54 years, including both usual residents and
6 134 visitors who stayed in the household the night before the interview, were eligible for individual
7 135 interviews.
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14 137 Data were collected using four questionnaires: the household, women, men, and the biomarker
15 138 questionnaires. The women's questionnaire collected information from all eligible women aged
16 139 15-49 and they were asked the questions on the following: 1) Husbands' background
17 140 characteristics and women's work: husbands' age, level of education, and occupation and
18 141 women's occupation and sources of earnings; 2) sexually transmitted infections (STIs) and
19 142 HIV/AIDS: knowledge of STIs and AIDS and methods of transmission, sources of information,
20 143 behaviors to avoid STIs and HIV, and stigma. The men's questionnaire was administered to all
21 144 men aged 15-54 in the sub-sample of households selected for the male survey and collected
22 145 much of the same information elicited with the women's questionnaire. However, it was shorter
23 146 because it did not contain a detailed reproductive history or questions on maternal and child
24 147 health. Data were collected on knowledge and attitudes of women and men about STIs and
25 148 HIV/AIDS, potential exposure to the risk of HIV infection (risk behaviors and condom use), and
26 149 coverage of HIV testing and counseling and other key HIV/AIDS programs. The primary objective
27 150 was to provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including
28 151 knowledge of HIV prevention methods, stigma and discrimination, number of sexual partners,
29 152 condom use, self-reported HIV testing, prevention of mother-to-child transmission of HIV, and
30 153 voluntary medical male circumcision. A detailed description of the survey can be found in the 2016
31 154 UDHS report.¹
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45 156 **Ethical considerations**
46 157 The UDHS dataset is publicly accessible at <https://dhsprogram.com/data/available-datasets.cfm>.
47 158 We applied for and received authorization to analyze the data from the DHS program
48 159 (www.dhsprogram.com). Since DHS datasets are publically available and free, no ethical
49 160 approval was required.
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162 **Study design**

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

175

176 **Variables and measurements**

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

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3 193 The covariates included sex (male or female), age group (15 to 19, 20 to 24, 25 to 29, 30 to 34,
4 194 35 to 39, 40 to 44, 45 to 49, and 50 to 54), level of education (none/no education, primary,
5 195 secondary, and higher), marital status (never in a union, currently in a union, and formerly in a
6 196 union), number of living children, wealth index (poorest, poorer, middle, richer, and richest),
7 197 religion (no religion, Anglican, Catholic, Muslim, Seventh Day Adventist, Pentecostal, and others),
8 198 and the 15 regions in Uganda (Kampala, Central 1, Central 2, Busoga, Bukedi, Bugishu, Teso,
9 199 Karamoja, Lango, Acholi, West Nile, Bunyoro, Tooro, Ankole, and Kigezi)
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201 **Data analysis**

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18 202 We used R version 4.02¹⁴ and Stata version 15.1 for the analysis. In R, we used the *MatchIt*¹⁵ and
19 203 *tableone*¹⁶ statistical packages. We descriptively summarized categorical data as frequencies and
20 204 percentages and numerical data as mean with standard deviation. We performed propensity-
21 205 scores matched analysis using eight matching covariates known to influence either the exposure
22 206 or the outcome, or both. This selection followed the unconfoundedness assumption.¹⁷⁻¹⁹
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29 208 We computed propensity scores in a logit model. We fitted comprehensive knowledge of HIV as
30 209 a function of the matching covariates and assessed the initial balance in propensity scores using
31 210 a back-to-back histogram.²⁰ We matched participants with and without compressive knowledge
32 211 of HIV on similar propensity scores²¹ using different matching approaches, namely nearest
33 212 neighbor matching with and without caliper adjustment¹⁸, and optimal pair and optimal full
34 213 matching.¹⁹ A caliper is a distance within which matching occurs, computed as 20% of the
35 214 standard deviation of the propensity score to prevent bias from distant matches. In nearest
36 215 neighbor matching without caliper adjustment, the participants were randomly matched to one
37 216 another while in the nearest neighbor matching with caliper adjustment, the matching was
38 217 performed within a caliper, all without replacement. In the optimal pair matching, matching was
39 218 done in pairs and the non-matched pairs were excluded from the analysis. In the optimal full
40 219 matching, matching was done in a ratio of 1: many or many: 1. Furthermore, we performed exact
41 220 matching where the participants were matched on the identical values of propensity scores.²² The
42 221 best matching approach was one that resulted in a balance of all the covariates between the two
43 222 groups.
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3 224 Following the matching, we checked the balance in covariates between the group with and without
4 225 comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1
5 226 considered confirmatory of good covariate balance.⁷ We further assessed covariate balance
6 227 graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was
7 228 taken to suggest covariate balance.^{7,23} After successful matching, the propensity-score matched
8 229 dataset was saved for the outcome analysis. We performed analysis on both the unmatched and
9 230 matched datasets. We fitted a logistic regression model for the unadjusted, adjusted, and PSM
10 231 analysis, reported as odds ratio (OR) and 95% confidence interval (CI).

16 232

18 233 **Sensitivity analysis**

19 234 We checked the robustness of the findings to hidden bias/unmeasured confounders and the
20 235 matching approach using the Rosenbaum Wilcoxon's signed-rank test.²⁰ We interpreted distant
21 236 gamma values to achieve statistical significance or non-significance as indicative of robustness.

25 237

27 238 **Reporting of findings**

28 239 The findings are reported following the improving the reporting quality of nonrandomized
29 240 evaluations of behavioral and public health interventions: The TREND statement shown in
30 241 Supplementary Fig 1.²⁴

34 242

36 243 **Patient and public involvement**

37 244 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination
38 245 plans of our research.

40 246 **Results**

42 247 **Characteristics of participants**

43 248 We present participants' characteristics in Table 1 both before and after PSM. We analysed data
44 249 for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before
45 250 PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning
46 251 the participants' age group, level of education, wealth index, and region, with all the variables
47 252 showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates
48 253 balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).

254 **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. (%)	No (n=12,397) No. (%)	Yes (n = 11,314) No. (%)	SMD	Overall (n=18,504) No. (%)	No (n=9,252) No. (%)	Yes (n=9,252) No. (%)	SMD
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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256 **Distribution of study outcomes before and after PSM**

257 Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched
258 sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no
259 difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%)
260 versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships,
261 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of
262 condoms was significantly lower among those without comprehensive knowledge of HIV
263 compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD
264 = 0.155.

265
266 In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a
267 statistically non-significant difference between those without and with comprehensive knowledge
268 of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who
269 reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while
270 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-
271 significant difference in the consistent use of condoms SMD = 0.080).

272 **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)	

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

274 **Additional balance diagnostics**

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

281

282 **Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV** 283 **transmission**

284 We present the results for the effect of comprehensive knowledge of HIV on having multiple
 285 sexual partners and consistent use of condoms in Table 3. The results show that comprehensive
 286 knowledge of HIV was significantly associated with extramarital sexual relationships at the
 287 unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to
 288 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome,
 289 the results show that comprehensive knowledge of HIV was significantly associated with
 290 consistent use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the
 291 PSM analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95%
 292 CI 0.95 to 1.27).

293

294 **Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated**
 295 **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)*

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

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300 **Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV** 301 **transmission by sex**

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

309 **Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated**
310 **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)

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

313

314 **Sensitivity analysis results**

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

319

320 **Discussion**

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

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3 324 Our results show that comprehensive knowledge of HIV has no effect on extramarital sexual
4 325 relationships but improves the consistent use of condoms among those in extramarital sexual
5 326 relationships. In sub-group analysis, we found comprehensive knowledge of HIV improved the
6 327 consistent use of condoms in males in extramarital sexual relationships but there was no effect
7 328 observed in females. Our study has several strengths and limitations. We analysed nationally
8 329 representative data so our findings are likely generalizable to the entire country and similar
9 330 settings. The sample size was large and the results are robust to unmeasured confounders and
10 331 the analytic approach. However, there are limitations. Although our results are robust to
11 332 unmeasured confounders, the matching was performed on observed covariates and other
12 333 covariates such as alcohol consumption and drug and substance use among others which are
13 334 known to influence the outcome were not included in the analysis. The outcomes were assessed
14 335 through self-report the possibility of social desirability bias cannot be excluded.
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25 337 The finding that compressive knowledge of HIV improves consistent use of condoms among
26 338 people in extramarital relationships is not unique because comprehensive knowledge of HIV helps
27 339 individuals to become aware of the potential risks associated with non-use of condoms and
28 340 therefore adopt safer sexual practices such as consistent use of condoms.²⁵ Inconsistent use of
29 341 condoms in extramarital sexual relationships places an individual at a greater risk of acquisition
30 342 of sexually transmitted infections (STIs) including HIV.²⁶ Our finding is consistent with several
31 343 studies in SSA. One study which analysed the Ghana DHS found exposure to family planning
32 344 messages is associated with a higher likelihood of consistent condom use among sexually active
33 345 never-married men.²⁷ If we use level of education as a proxy for comprehensive knowledge of
34 346 HIV, another study that analysed DHS data for 29 countries in SSA reports that among men who
35 347 pay for sex, men with a secondary level of education are more likely to use condoms
36 348 consistently.²⁸ With less than half of the Ugandan population aged 15-54 years having
37 349 comprehensive knowledge of HIV ¹, this result underscores a need for the AIDS Control Program
38 350 to design and implement context-relevant HIV prevention and education messages to improve
39 351 the level of comprehensive knowledge of HIV in the population and thereby control the HIV
40 352 pandemic. In sub-group analysis, we found no effect of comprehensive knowledge of HIV on
41 353 consistent use of condoms in females but in males, we found consistent use of condoms
42 354 improved.
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3 356 Although several factors such as cost, moral values, ethnicity, religion, gender inequality, lack of
4 357 dialogue among sexual partners concerning condom use among others influence inconsistent or
5 358 even non-use of condoms during sexual intercourse ²⁹, our findings agree with an earlier study
6 359 that reports HIV knowledge improves condom use self-efficacy ³⁰ and therefore its use in sexual
7 360 relationships. Recently, in a study conducted among sexually active men in Nigeria by Bolarinwa
8 361 et al (2022)³¹ knowledge of HIV equally improved condom use, which is consistent with our
9 362 results. Another study conducted among South African married couples reported that females are
10 363 less likely to use a condom if their male partner has refused to use it³², suggesting male
11 364 dominance or power imbalance between women and men in condom negotiation. Our finding
12 365 could be explained by socio-cultural differences between males and females within the context,
13 366 with females inherently being submissive to the sexual demands of males. In general, African
14 367 women find it difficult to assert themselves when it comes to condom negotiation and the majority
15 368 cannot and do not negotiate the use of condoms in a sexual relationship. Elsewhere ³³, one study
16 369 reports that compared to individual-level factors, the social environment is an independent risk
17 370 factor for HIV vulnerability in Uganda. This leaves men as sole decision-makers regarding
18 371 whether or not to use a condom. Indeed, gender equality has been reported to improve condom
19 372 use self-efficacy in both general and risky situations.³⁰

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33 374 Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual
34 375 relationships in general and in sub-group analysis requires cautious interpretation. First, we
35 376 acknowledge that HIV remains a global health problem, with 25.7 million people infected globally
36 377 ²⁶ and about 1.4 million infected people in Uganda.² However, with the rapid rollout and improved
37 378 access to antiretroviral therapy (ART) over the years, the majority of PLHIV have a nearly normal
38 379 quality of life and longevity. There is now much hope and optimism that the fight against HIV/AIDS
39 380 is nearly almost done and this has created an HIV/AIDS complacency problem in the general
40 381 population.³⁴ Concerns about HIV being a global health problem have lessened and the use of
41 382 known HIV prevention methods such as abstinence, mutual faithfulness, and consistent condom
42 383 use, among others have dwindled over the years. The issue of the HIV/AIDS complacency
43 384 phenomenon in Africa³⁵ and Uganda³⁶ has been highlighted earlier. Another plausible explanation
44 385 relates to behaviour change and the know-practice gap at an individual level. One would argue
45 386 that behaviour change is a gradual process, often with strong influences from the social, cultural,
46 387 economic, environmental, and technological dimensions.³⁷ These challenges require a strong
47 388 focus on health promotion, a combination of health education, and healthy public policy.³⁸

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3 389 For instance, health education is not sufficient without an enabling environment to achieve
4 390 behaviour change but requires the formulation and implementation of appropriate healthy public
5 391 policies. Often, shortfalls in health promotion lead to victim-blaming thus people are blamed for
6 392 their actions despite a lack of an enabling environment for behaviour change. Our findings
7 393 emphasize a need for novel approaches to achieving behaviour change in Uganda. Our findings
8 394 thus emphasized a need to complement existing behaviour change communication strategies
9 395 with other approaches that influence social and environmental determinants of risk to enable
10 396 vulnerable populations to HIV infection protect themselves.³⁹ Approaches to mitigate
11 397 complacency are important besides other tools for HIV prevention and control in bringing an end
12 398 to the HIV pandemic.⁴⁰

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21 400 **Conclusions and recommendations**

22 401 This study shows that comprehensive knowledge of HIV has no effect on extramarital sexual
23 402 relationships but increases consistent use of condoms among those in extramarital relationships,
24 403 especially men but not women. Our findings emphasize a need to address HIV complacency in
25 404 the general population through HIV programs, including the provision of consistent and correct
26 405 HIV prevention health education messages.

27 406

28 407 **Author contributions**

29 408 JI and DTK: Study conception and design. DTK: Acquisition of data. JI: Analysis and interpretation
30 409 of data. JI and DTK: Drafting of manuscript. JI and DTK: Critical revision. JI and DTK: Final
31 410 approval of manuscript.

32 411

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3 **420 Competing interests**

4 421 The authors declare that they have no competing interests.
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9
10 424 No specific funding was obtained by the authors for the preparation of this manuscript.
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14 **426 Data availability statement**

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16 427 The paper utilized the Demographic Health Survey data, and permission to use these publically
17 428 available data was obtained from <http://www.dhsprogram.com> before data download and
18 429 subsequent statistical analysis. As such, no ethical reviews and approvals were required before
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20 429 or during the preparation of the present manuscript.
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26 **432 Figure legends**

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29 434 Fig 1: Distribution of propensity-scores between participants with and without comprehensive
30 435 knowledge of HIV before (left histograms) and after matching (right histograms).
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33 436 Supplementary Fig 1: The TREND statement checklist
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37 **438 Consent**

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39 439 Not applicable.
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44 **441 Ethics Approval Statement**

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46 442 Not applicable/No human participants included.
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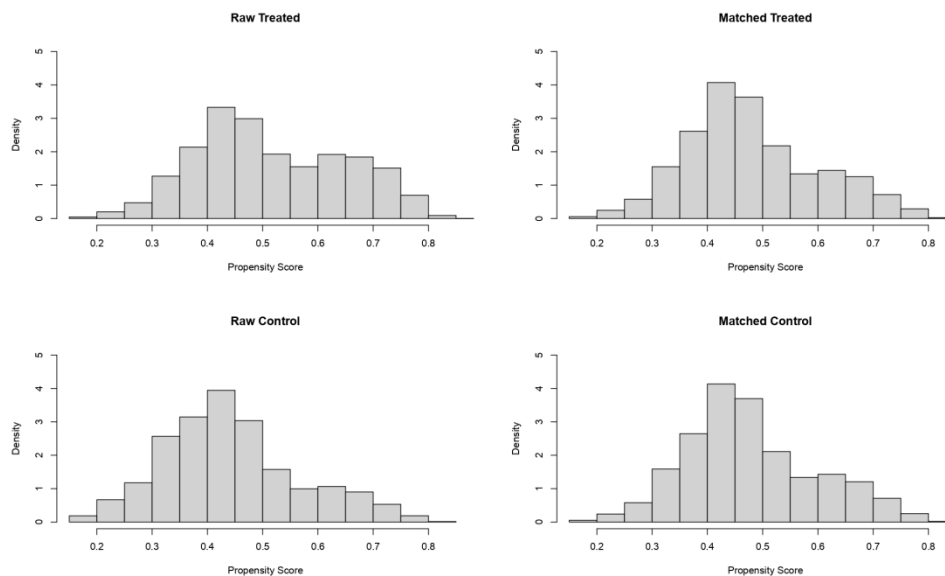



Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

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?	
				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	<ul style="list-style-type: none"> 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. 	N/A	
Unit of Analysis	10	<ul style="list-style-type: none"> Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community) 	√	7-8
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data 	√	7-8
		<ul style="list-style-type: none"> Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis 	√	7-8
		<ul style="list-style-type: none"> Methods for imputing missing data, if used 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Assignment: the numbers of participants assigned to a study condition 	N/A	
		<ul style="list-style-type: none"> Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Analysis: the number of participants included in or excluded from the main analysis, by study condition 	N/A	
		<ul style="list-style-type: none"> Description of protocol deviations from study as planned, along with reasons 	N/A	
Recruitment	13	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Data on study group equivalence at baseline and statistical methods used to control for baseline differences 	√	14

TREND Statement Checklist

Numbers analyzed	16	<ul style="list-style-type: none"> 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 Indication of whether the analysis strategy was “intention to treat” or, if not, description of how non-compliers were treated in the analyses 	√	14
Outcomes and estimation	17	<ul style="list-style-type: none"> 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 Inclusion of null and negative findings Inclusion of results from testing pre-specified causal pathways through which the intervention was intended to operate, if any 	√	13-14
Ancillary analyses	18	<ul style="list-style-type: none"> Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory 	N/A	
Adverse events	19	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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 Discussion of results taking into account the mechanism by which the intervention was intended to work (causal pathways) or alternative mechanisms or explanations Discussion of the success of and barriers to implementing the intervention, fidelity of implementation Discussion of research, programmatic, or policy implications 	√	14
Generalizability	21	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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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3 1 **Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV**
4 **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.

67 **Background**

68 The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with
69 a person living with human immunodeficiency virus (HIV).¹ Currently, an estimated 1.4 million
70 people are living with HIV in Uganda.² The 2020 Uganda Population-Based HIV Impact
71 Assessment³ reports a 5.5% HIV prevalence among people aged 15-49 years (7.1% females,
72 3.8% males). However, new HIV infections among adults (≥ 15 years) progressively declined from
73 71,000 in 2010 to 48,000 in 2020, a 32% drop. Having a comprehensive knowledge of HIV can
74 prevent HIV acquisition by helping individuals to assess their own risk of HIV acquisition and
75 adopting safer sexual practices.³ Comprehensive knowledge of HIV is defined as knowing that
76 consistent use of condoms during sexual intercourse and having just one faithful partner without
77 HIV can reduce the chance of getting HIV, knowing that a healthy-looking person can have HIV,
78 and rejecting the two most common local misconceptions about transmission or prevention of HIV
79 (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV).¹

80
81 Comprehensive knowledge of HIV in the general population increased by 1% per year between
82 2003 and 2015 ⁴ and this is expected to reverse the HIV incidence and prevalence. Analysis of
83 Demographic Health Survey (DHS) data for 15 countries in sub-Saharan Africa (SSA) show
84 38.6% of the population with comprehensive knowledge of HIV⁵. The 15 countries included
85 Burundi (2016/17), Ethiopia (2016), Rwanda (2015), Uganda (2016), Zambia (2018/19), Benin
86 (2017/18), Gambia (2019/20), Guinea (2018), Liberia (2019/20), Mali (2018), Nigeria (2018),
87 Sierra Leone (2019), Cameroon (2018/19), and Chad (2015). Data further show a higher level of
88 comprehensive knowledge of HIV is associated with being old, attaining at least a primary level
89 of education, belonging to a wealthy household, using contraceptives, listening to a radio, and
90 reading newspapers at the individual level.⁵ At the regional level, residing in an urban area or the
91 Eastern African region is similarly associated with a higher comprehensive knowledge of HIV.⁵
92 Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) found more than
93 4 in 10 adolescent girls and young women (15 to 24 years) have comprehensive knowledge of
94 HIV and are more likely to negotiate for safe sex⁶. However, limitations of Frimpong's study
95 includes a lack of appropriate comparator, a design that precluded assessment of the effect of
96 comprehensive knowledge of HIV on sexual behaviours associated with HIV transmission due to
97 selection bias and confounding⁷, and an analytic approach that susceptible to model
98 misspecification.⁸

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3 100 The 2016 Uganda DHS (UDHS) data show 48% of the population surveyed have comprehensive
4 101 knowledge of HIV⁹ but did not examine the effect of comprehensive knowledge of HIV on sexual
5 102 behaviours at population and sub-population levels. Overall, previous studies focused on the
6 103 magnitude of comprehensive knowledge of HIV and the associated factors^{5,6}.
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12 105 Between 2016 and 2019, the prevalence of HIV among married or cohabiting couples in Uganda
13 106 was 6.6%, exceeding the 6.0% prevalence among adults aged 15-49 years¹⁰. Low condom use
14 107 among married/cohabiting couples in extramarital sexual relationship is a risk for HIV infection.
15 108 The 2016 UDHS⁹ reports condom use at the last sexual intercourse among married/cohabiting
16 109 couples with ≥ 2 sexual partners in the past 12 months is higher among men (9.7%) than women
17 110 (7.9%).
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24 112 Few studies have attempted to examine the link between comprehensive knowledge of HIV and
25 113 risky sexual behaviour and where attempts have been made, significant design and analytic
26 114 limitations exists. Currently, there is limited information about the effect of comprehensive
27 115 knowledge of HIV on risky sexual behaviours associated with HIV transmission among married
28 116 or cohabiting couples in Uganda and SSA in general. Our study analysed the 2016 Uganda DHS
29 117 data from a nationally representative survey to establish the effect of comprehensive knowledge
30 118 of HIV on extramarital sexual relationships and consistent use of condoms among married or
31 119 cohabiting couples in Uganda. As a secondary objective, we examined the effect of
32 120 comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of
33 121 condoms by sex (women versus men). We hypothesized that comprehensive knowledge of HIV
34 122 reduces the likelihood of extramarital sexual relationships in men and women, and improves
35 123 consistent use of condoms among married or cohabiting couples in extramarital sexual
36 124 relationships.
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129 **Methods**

130 **Description of data source**

131 We analyzed data from a nationally representative population-based household survey, the 2016
132 UDHS⁹, conducted by the Uganda Bureau of Statistics (UBOS). Elsewhere¹¹, the dataset is
133 described. Data collection took place between Jun 20, 2016 and Dec 16, 2016. The survey sample
134 was stratified and selected in two stages. The first stage consisted of the selection of 697
135 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one cluster from the Acholi
136 sub-region in northern Uganda was excluded for security reasons. The second stage involved the
137 sampling of households within the clusters. This was achieved through a listing of all households
138 within each of the 696 accessible selected enumeration areas between April and October 2016,
139 with some listings overlapping with fieldwork. The survey drew maps for each of the sampled
140 clusters and then listed all the households except for institutional living arrangements, namely
141 army barracks, hospitals, police camps, and boarding schools. To minimize the task of household
142 listing, each large enumeration area yielding more than 300 households selected for the survey
143 was segmented, and one segment was selected for the survey with probability proportional to
144 segment size, and the household listing was conducted within the segment. Therefore, in the
145 2016 UDHS, a cluster was regarded as either an enumeration area or a segment of an
146 enumeration area. Overall, a representative sample that consisted of 20,880 households
147 corresponding to 30 per enumeration area or a segment of enumeration area was randomly
148 selected for the survey.

149
150 All women aged 15-49 years who were either permanent residents of the selected households or
151 visitors who had stayed in the household the night before the survey were eligible to be
152 interviewed. In one-third of the sampled households, all men aged 15 to 54 years, including both
153 usual residents and visitors who had stayed in the household the night preceding the interview,
154 were eligible for individual interviews. Data were collected using four questionnaires: the
155 household, women, men, and the biomarker questionnaires. The women's questionnaire
156 collected information from all eligible women aged 15-49 years and they were questioned on the
157 following among others: 1) Husbands' background characteristics and women's work: husbands'
158 age, level of education, and occupation and women's occupation and sources of earnings; 2)
159 sexually transmitted infections (STIs) and HIV/AIDS: knowledge of STIs and AIDS and methods
160 of transmission, sources of information, behaviors to avoid STIs and HIV, and stigma.

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3 161 Additional questions are described in the 2016 UDHS report. The men's questionnaire was
4 162 administered to all men aged 15-54 years in the sub-sample of households selected for the male
5 163 survey and collected much of the same information elicited with the women's questionnaire.
6 164 However, it was shorter because it did not contain a detailed reproductive history or questions on
7 165 maternal and child health.

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12 167 Data were collected on knowledge and attitudes of women and men about STIs and HIV/AIDS,
13 168 potential exposure to the risk of HIV infection (risk behaviors and condom use), and coverage of
14 169 HIV testing and counseling and other key HIV/AIDS programs. The primary objective was to
15 170 provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including knowledge of
16 171 HIV prevention methods, stigma and discrimination, number of sexual partners, condom use, self-
17 172 reported HIV testing, prevention of mother-to-child transmission of HIV, and voluntary medical
18 173 male circumcision. The 2016 UDHS data were collected by 21 trained research teams, with each
19 174 consisting of a team leader, field manager, 3 female interviewers, 1 male interviewer, 1 health
20 175 technician, and 1 driver. A detailed description of the survey can be found in the 2016 UDHS
21 176 report.¹

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31 178 **Ethical considerations**
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33 179 The UDHS dataset is publicly accessible at <https://dhsprogram.com/data/available-datasets.cfm>.
34 180 We applied for and received authorization to analyze the data from the DHS program
35 181 (www.dhsprogram.com). Since DHS datasets are publicly available and free, no ethical approval
36 182 was required.

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42 184 **Study design**
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44 185 A randomized control trial (RCT) is the gold standard design for measuring the effect of
45 186 interventions because randomization ensures balance in both known and unknown baseline
46 187 covariates thereby achieving comparability between the intervention and control groups.¹²
47 188 Nonetheless, an RCT is regarded as infeasible and unethical for interventions that are known to
48 189 be beneficial such as comprehensive knowledge of HIV. For that reason, observational data
49 190 provides an option for the measure of effect but the presence of selection bias due to lack of
50 191 randomization and confounding of the exposure-outcome relationship due to other factors is a
51 192 limitation.¹³

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3 193 We applied propensity-scores matched (PSM) analysis to remove the selection bias and
4 194 confounding and ensure that both the exposed and non-exposed groups are
5 195 comparable/balanced on measured covariates, except for the exposure.^{14,15} We, therefore,
6 196 simulated an RCT. Since no true randomization was employed, the study design is a non-
7 197 randomized, quasi-experimental study.¹⁴
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13 14 199 **Variables and measurements**

15 200 **Exposure:** Comprehensive knowledge of HIV was the exposure of interest, measured on a binary
16 201 scale (yes versus no) using five indicators, namely 1) knowing that consistent use of condoms
17 202 during sexual intercourse can reduce the chance of getting HIV; 2) knowing that having just one
18 203 faithful partner without HIV can reduce the chance of getting HIV; 3) knowing that a healthy-
19 204 looking person can have HIV; 4) rejecting that HIV can be transmitted through mosquitoes; and
20 205 5) rejecting that HIV can be transmitted by sharing of food. Indicators 4-5 are the two most
21 206 common local misconceptions about HIV transmission or prevention in Uganda. Participants with
22 207 correct responses to all the five indicators were considered having comprehensive knowledge of
23 208 HIV otherwise no. The exposed group consisted of participants with comprehensive knowledge
24 209 of HIV while the unexposed (comparison) group consisted of those without comprehensive
25 210 knowledge of HIV.
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28 211 **Outcomes:** The primary outcome was extramarital sexual relationships measured on a binary
29 212 scale (yes or no). Participants in sexual relations with another sexual partner other than the
30 213 spouse or cohabiting partner were considered to have indulged in extramarital sexual
31 214 relationships in the 12 months preceding the survey. The secondary outcome was the consistent
32 215 use of condoms measured on a binary scale, computed as the percentage of respondents who
33 216 had used a condom every time they had sex with any non-spouse or non-cohabiting partner over
34 217 the past 12 months.¹
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37 218 **Matching covariates:** These included sex (male or female), age group (15 to 19, 20 to 24, 25 to
38 219 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, and 50 to 54), level of education (none/no education,
39 220 primary, secondary, and higher), marital status (never in a union, currently in a union, and formerly
40 221 in a union), number of living children, wealth index (poorest, poorer, middle, richer, and richest),
41 222 religion (no religion, Anglican, Catholic, Muslim, Seventh Day Adventist, Pentecostal, and others),
42 223 and the 15 regions in Uganda (Kampala, Central 1, Central 2, Busoga, Bukedi, Bugishu, Teso,
43 224 Karamoja, Lango, Acholi, West Nile, Bunyoro, Tooro, Ankole, and Kigezi)
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225 Data analysis

226 We used R version 4.02¹⁶ and Stata version 15.1 for the analysis. In R, we used the *MatchIt*¹⁷ and
227 *tableone*¹⁸ statistical packages. We descriptively summarized categorical data as frequencies and
228 percentages, and numerical data using the mean with its standard deviation. We performed
229 propensity-score matched analysis using eight matching covariates known to influence either the
230 exposure or the outcome, or both based on the unconfoundedness assumption.¹⁹⁻²¹

231
232 We computed propensity scores in a logit model by fitting comprehensive knowledge of HIV as a
233 function of the matching covariates. We assessed initial balance in propensity scores using a
234 back-to-back histogram.²² We then matched participants with and without compressive
235 knowledge of HIV on similar propensity scores²³ using different matching approaches, namely
236 nearest neighbor matching with and without caliper adjustment²⁰, and optimal pair and optimal full
237 matching.²¹ A caliper is a distance within which matching occurs, computed as 20% of the
238 standard deviation of the propensity score to prevent bias from distant matches. In nearest
239 neighbor matching without caliper adjustment, the participants were randomly matched to one
240 another while in the nearest neighbor matching with caliper adjustment, the matching was
241 performed within a caliper, all without replacement. In the optimal pair matching, the matching
242 was done in pairs and the non-matched pairs were excluded from the analysis. In the optimal full
243 matching, the matching was done in a ratio of 1: many or many: 1. Furthermore, we performed
244 exact matching where the participants were matched on the identical values of propensity
245 scores.²⁴ The best matching approach was one that balanced all the covariates between the two
246 groups.

247
248 Following the matching, we checked covariate balance between the group with and without
249 comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1
250 considered confirmatory of good covariate balance.⁷ We further assessed covariate balance
251 graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was
252 taken to suggest covariate balance.^{7,25} After successful matching, the propensity-score matched
253 dataset was saved for the outcome analysis. We performed analysis on both the unmatched and
254 matched datasets. We fitted a binary logistic regression model for the unadjusted and adjusted
255 analysis, with the latter model adjusted for all the matching covariates.

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3 256 For the PSM dataset, we fitted a conditional logistic regression taking into consideration the
4 257 matched pairs. We reported odds ratio (OR) and 95% confidence interval (CI).

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8 9 259 **Sensitivity analysis**

10 260 We checked the robustness of the findings to hidden bias/unmeasured confounders and the
11 261 matching approach using the Rosenbaum Wilcoxon's signed-rank test.²² We interpreted distant
12 262 gamma values to achieve statistical significance or non-significance as indicative of robustness.

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17 18 264 **Reporting of findings**

19 265 The findings are reported following the improving the reporting quality of nonrandomized
20 266 evaluations of behavioral and public health interventions: The TREND statement shown in
21 267 Supplementary Fig 1.²⁶

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26 27 269 **Patient and public involvement**

28 270 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination
29 271 plans of our research.

30 31 272 **Results**

32 33 273 **Characteristics of participants**

34 274 We present participants' characteristics in Table 1 both before and after PSM. We analysed data
35 275 for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before
36 276 PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning
37 277 the participants' age group, level of education, wealth index, and region, with all the variables
38 278 showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates
39 279 balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).

280 **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. (%)	No (n=12,397) No. (%)	Yes (n = 11,314) No. (%)	SMD	Overall (n=18,504) No. (%)	No (n=9,252) No. (%)	Yes (n=9,252) No. (%)	SMD
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)	

281

282 **Distribution of study outcomes before and after PSM**

283 Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched
284 sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no
285 difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%)
286 versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships,
287 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of
288 condoms was significantly lower among those without comprehensive knowledge of HIV
289 compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD
290 = 0.155.

291
292 In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a
293 statistically non-significant difference between those without and with comprehensive knowledge
294 of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who
295 reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while
296 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-
297 significant difference in the consistent use of condoms SMD = 0.080).

298 **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)	

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

300 Additional balance diagnostics

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

307

308 Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV 309 transmission

310 We present the results for the effect of comprehensive knowledge of HIV on having multiple
 311 sexual partners and consistent use of condoms in Table 3. The results show that comprehensive
 312 knowledge of HIV was significantly associated with extramarital sexual relationships at the
 313 unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to
 314 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome, the
 315 results show that comprehensive knowledge of HIV was significantly associated with consistent
 316 use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the PSM
 317 analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95% CI 0.95
 318 to 1.27).

319

320 **Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated
 321 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)*

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

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

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

335 **Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated**
 336 **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)

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

339

340 **Sensitivity analysis results**

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

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348 Discussion

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

363

364 The finding that comprehensive knowledge of HIV improves consistent use of condoms among
365 married or cohabiting couples in extramarital relationships is not unique. Comprehensive
366 knowledge of HIV raises an individual's level of awareness regarding potential risks associated
367 with not using condoms and helps them adopt safer sexual practices like consistent use of
368 condoms.²⁷ Inconsistent use of condoms in extramarital sexual relationships places a couple
369 at a greater risk of acquisition of sexually transmitted infections (STIs) including HIV.²⁸ Our finding
370 is consistent with several studies in SSA. One study which analysed the Ghana DHS found
371 exposure to family planning messages is associated with a higher likelihood of consistent condom
372 use among sexually active never-married men.²⁹ Using level of education as a proxy for
373 comprehensive knowledge of HIV, one study that analysed DHS data for 29 countries in SSA
374 reports that among men who pay for sex, those that attained a secondary level of education are
375 more likely to use condoms consistently.³⁰ In Uganda, less than half of the population aged 15-
376 54 years have comprehensive knowledge of HIV¹. This finding underscores a need to design and
377 implement context-relevant HIV prevention and education messages to improve the level of
378 comprehensive knowledge of HIV in the population for better HIV pandemic control.

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3 380 We found no effect of comprehensive knowledge of HIV on consistent use of condoms among
4 381 married or cohabiting females in extramarital sexual relationships. However, in married or
5 382 cohabiting males, comprehensive knowledge of HIV improves consistent use of condoms in
6 383 extramarital sexual relationships. Although several factors such as cost, moral values, ethnicity,
7 384 religion, gender inequality, lack of dialogue among sexual partners concerning condom use
8 385 among others influence inconsistent or non-use of condoms during sexual intercourse ³¹, our
9 386 findings agree with an earlier study that reports HIV knowledge improves condom use self-efficacy
10 387 ³² and consequently its use in sexual relationships. Consistent with our results, recent study
11 388 conducted among sexually active men in Nigeria³³ show that knowledge of HIV equally improved
12 389 condom use. Another study conducted among South African married couples reported that
13 390 females are less likely to use a condom if their male partner has refused to using a condom³⁴,
14 391 suggesting male dominance or power imbalance between women and men in condom
15 392 negotiation. In our context, this finding could be explained by socio-cultural differences between
16 393 men and women, with the latter being inherently submissive to the sexual demands of the latter.
17 394 In general, African women find it difficult to assert themselves regarding condom negotiation and
18 395 the majority do not negotiate condom use in a sexual relationship. In Uganda, one study³⁵ reports
19 396 the social environment as an independent risk factor for HIV vulnerability. Men are the sole
20 397 decision-makers regarding whether or not to use a condom in a sexual relationship. However,
21 398 gender equality improves condom use self-efficacy in both general and risky situations.³²
22 399 Improving consistent use of condoms among women thus require their emancipation regarding
23 400 decision-making on matters of sexual health.

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39 402 Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual
40 403 relationships among of married or cohabiting couples in the general population and in sub-group
41 404 analysis requires cautious interpretation. First, we acknowledge that HIV is a global health
42 405 problem, with an estimated 25.7 million PLHIV globally²⁸ and in Uganda, there are 1.4 million
43 406 PLHIV.² However, with the rapid rollout and improved access to antiretroviral therapy (ART) over
44 407 the years, the majority of PLHIV have a nearly normal quality of life and longevity. There is now
45 408 much hope and optimism that the fight against HIV is nearly over leading to HIV complacency in
46 409 the general population.³⁶ Concerns about HIV being a global health problem have lessened and
47 410 the use of known HIV prevention methods such as abstinence, mutual faithfulness, and consistent
48 411 condom use, among others have dwindled over the years.

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3 412 The problem of HIV complacency in Africa³⁷ and Uganda³⁸ have been highlighted earlier. Another
4 413 plausible explanation relates to behaviour change and the wide know-do gap at the individual
5 414 level. One would argue that behaviour change is a gradual process, often with strong influences
6 415 from the social, cultural, economic, environmental, and technological dimensions.³⁹ These
7 416 challenges require a strong focus on health promotion, a combination of health education and
8 417 healthy public policy.⁴⁰ For instance, without an enabling environment to achieve the desired
9 418 behaviour change, health education is insufficient. The formulation and implementation of
10 419 appropriate healthy public policies to create an enabling environment is important to prevent
11 420 victim-blaming where people are victimized for their actions despite a lack of an enabling
12 421 environment for behaviour change. Our findings, therefore, emphasize a need for novel
13 422 approaches to achieve behaviour change in Uganda. There is a need to complement existing
14 423 behaviour change communication strategies with other approaches that lessen the influence of
15 424 social and environmental determinants (alcohol consumption and smoking, for example) that
16 425 place the population at risk for HIV infection.⁴¹ Approaches to mitigate HIV complacency besides
17 426 other tools for HIV prevention and control are important in ending the HIV pandemic.⁴² Further
18 427 research should be conducted to understand the disparity in the effect of comprehensive
19 428 knowledge of HIV on extramarital sexual relationships among married/co-habiting men and
20 429 women.

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34 431 **Conclusions and recommendations**

35 432 Comprehensive knowledge of HIV has no effect on extramarital sexual relationships among
36 433 married or cohabiting couples in Uganda. However, it increases consistent use of condoms in
37 434 extramarital relationships among married or cohabiting men but not in the married or cohabiting
38 435 women. Our findings emphasize a need to continue providing consistent and correct HIV
39 436 prevention health education messages.

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45 438 **Author contributions**

46 439 JI and DTK conceptualized and designed the study. DTK acquired the data. JI analysed the data.
47 440 JI and DTK interpreted the data and drafted the initial and final manuscripts. JI and DTK critically
48 441 revised the manuscript and approved for submission.

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451 **Competing interests**

452 The authors declare that they have no competing interests.

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457 **Data availability statement**

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

463 **Figure legends**

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

467 Supplementary Fig 1: The TREND statement checklist

469 **Consent**

470 Not applicable.

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3 472 **Ethics Approval Statement**
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5 473 Not applicable/No human participants included.
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10 475 **References**
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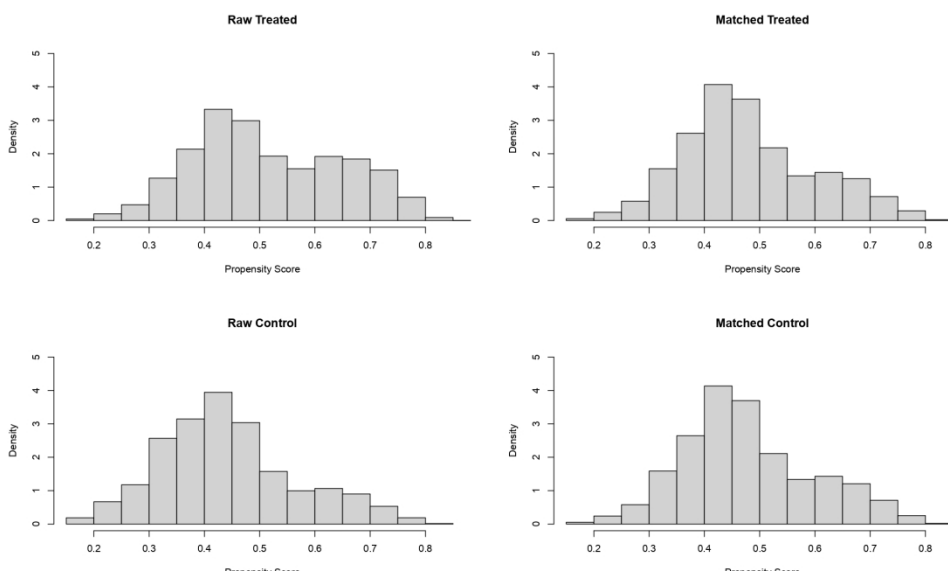



Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

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?	
				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	<ul style="list-style-type: none"> 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. 	N/A	
Unit of Analysis	10	<ul style="list-style-type: none"> Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community) 	√	7-8
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data 	√	7-8
		<ul style="list-style-type: none"> Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis 	√	7-8
		<ul style="list-style-type: none"> Methods for imputing missing data, if used 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Assignment: the numbers of participants assigned to a study condition 	N/A	
		<ul style="list-style-type: none"> Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Analysis: the number of participants included in or excluded from the main analysis, by study condition 	N/A	
		<ul style="list-style-type: none"> Description of protocol deviations from study as planned, along with reasons 	N/A	
Recruitment	13	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Data on study group equivalence at baseline and statistical methods used to control for baseline differences 	√	14

TREND Statement Checklist

Numbers analyzed	16	<ul style="list-style-type: none"> 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
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory 	N/A	
Adverse events	19	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Discussion of research, programmatic, or policy implications 	√	14-16
Generalizability	21	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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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3 1 **Effect of comprehensive knowledge of HIV on risky sexual behaviors associated with HIV**
4 **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.

67 **Background**

68 The majority of HIV transmissions in Uganda occur through heterosexual vaginal intercourse with
69 a person living with human immunodeficiency virus (HIV).¹ Currently, an estimated 1.4 million
70 people are living with HIV in Uganda.² The 2020 Uganda Population-Based HIV Impact
71 Assessment³ reports a 5.5% HIV prevalence among people aged 15-49 years (7.1% females,
72 3.8% males). However, new HIV infections among adults (≥ 15 years) progressively declined from
73 71,000 in 2010 to 48,000 in 2020, a 32% drop. Having a comprehensive knowledge of HIV can
74 prevent HIV acquisition by helping individuals to assess their own risk of HIV acquisition and
75 adopting safer sexual practices.³ Comprehensive knowledge of HIV is defined as knowing that
76 consistent use of condoms during sexual intercourse and having just one faithful partner without
77 HIV can reduce the chance of getting HIV, knowing that a healthy-looking person can have HIV,
78 and rejecting the two most common local misconceptions about transmission or prevention of HIV
79 (HIV can be transmitted by mosquito bites and by sharing food with a person who has HIV).¹

80
81 Comprehensive knowledge of HIV in the general population increased by 1% per year between
82 2003 and 2015 ⁴ and this is expected to reverse the HIV incidence and prevalence. Analysis of
83 Demographic Health Survey (DHS) data for 15 countries in sub-Saharan Africa (SSA) show
84 38.6% of the population with comprehensive knowledge of HIV⁵. The 15 countries included
85 Burundi (2016/17), Ethiopia (2016), Rwanda (2015), Uganda (2016), Zambia (2018/19), Benin
86 (2017/18), Gambia (2019/20), Guinea (2018), Liberia (2019/20), Mali (2018), Nigeria (2018),
87 Sierra Leone (2019), Cameroon (2018/19), and Chad (2015). Data further show a higher level of
88 comprehensive knowledge of HIV is associated with being old, attaining at least a primary level
89 of education, belonging to a wealthy household, using contraceptives, listening to a radio, and
90 reading newspapers at the individual level.⁵ At the regional level, residing in an urban area or the
91 Eastern African region is similarly associated with a higher comprehensive knowledge of HIV.⁵
92 Another analysis of DHS data for 30 countries in SSA by Frimpong et al (2021) found more than
93 4 in 10 adolescent girls and young women (15 to 24 years) have comprehensive knowledge of
94 HIV and are more likely to negotiate for safe sex⁶. However, limitations of Frimpong's study
95 includes a lack of appropriate comparator, a design that precluded assessment of the effect of
96 comprehensive knowledge of HIV on sexual behaviours associated with HIV transmission due to
97 selection bias and confounding⁷, and an analytic approach that susceptible to model
98 misspecification.⁸

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3 100 The 2016 Uganda DHS (UDHS) data show 48% of the population surveyed have comprehensive
4 101 knowledge of HIV⁹ but did not examine the effect of comprehensive knowledge of HIV on sexual
5 102 behaviours at population and sub-population levels. Overall, previous studies focused on the
6 103 magnitude of comprehensive knowledge of HIV and the associated factors^{5,6}.
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12 105 Between 2016 and 2019, the prevalence of HIV among married or cohabiting couples in Uganda
13 106 was 6.6%, exceeding the 6.0% prevalence among adults aged 15-49 years¹⁰. Low condom use
14 107 among married/cohabiting couples in extramarital sexual relationship is a risk for HIV infection.
15 108 The 2016 UDHS⁹ reports condom use at the last sexual intercourse among married/cohabiting
16 109 couples with ≥ 2 sexual partners in the past 12 months is higher among men (9.7%) than women
17 110 (7.9%).
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24 112 Few studies have attempted to examine the link between comprehensive knowledge of HIV and
25 113 risky sexual behaviour and where attempts have been made, significant design and analytic
26 114 limitations exists. Currently, there is limited information about the effect of comprehensive
27 115 knowledge of HIV on risky sexual behaviours associated with HIV transmission among married
28 116 or cohabiting couples in Uganda and SSA in general. Our study analysed the 2016 Uganda DHS
29 117 data from a nationally representative survey to establish the effect of comprehensive knowledge
30 118 of HIV on extramarital sexual relationships and consistent use of condoms among married or
31 119 cohabiting couples in Uganda. As a secondary objective, we examined the effect of
32 120 comprehensive knowledge of HIV on extramarital sexual relationships and consistent use of
33 121 condoms by sex (women versus men). We hypothesized that comprehensive knowledge of HIV
34 122 reduces the likelihood of extramarital sexual relationships in men and women, and improves
35 123 consistent use of condoms among married or cohabiting couples in extramarital sexual
36 124 relationships.
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129 **Methods**

130 **Description of data source**

131 We analyzed data from a nationally representative population-based household survey, the 2016
132 UDHS⁹, conducted by the Uganda Bureau of Statistics (UBOS). Elsewhere¹¹, the dataset is
133 described. Data collection took place between Jun 20, 2016 and Dec 16, 2016. The survey sample
134 was stratified and selected in two stages. The first stage consisted of the selection of 697
135 enumeration areas: 162 urban versus 535 rural. Due to land disputes, one cluster from the Acholi
136 sub-region in northern Uganda was excluded for security reasons. The second stage involved the
137 sampling of households within the clusters. This was achieved through a listing of all households
138 within each of the 696 accessible selected enumeration areas between April and October 2016,
139 with some listings overlapping with fieldwork. The survey drew maps for each of the sampled
140 clusters and then listed all the households except for institutional living arrangements, namely
141 army barracks, hospitals, police camps, and boarding schools. To minimize the task of household
142 listing, each large enumeration area yielding more than 300 households selected for the survey
143 was segmented, and one segment was selected for the survey with probability proportional to
144 segment size, and the household listing was conducted within the segment. Therefore, in the
145 2016 UDHS, a cluster was regarded as either an enumeration area or a segment of an
146 enumeration area. Overall, a representative sample that consisted of 20,880 households
147 corresponding to 30 per enumeration area or a segment of enumeration area was randomly
148 selected for the survey.

149
150 All women aged 15-49 years who were either permanent residents of the selected households or
151 visitors who had stayed in the household the night before the survey were eligible to be
152 interviewed. In one-third of the sampled households, all men aged 15 to 54 years, including both
153 usual residents and visitors who had stayed in the household the night preceding the interview,
154 were eligible for individual interviews. Data were collected using four questionnaires: the
155 household, women, men, and the biomarker questionnaires. The women's questionnaire
156 collected information from all eligible women aged 15-49 years and they were questioned on the
157 following among others: 1) Husbands' background characteristics and women's work: husbands'
158 age, level of education, and occupation and women's occupation and sources of earnings; 2)
159 sexually transmitted infections (STIs) and HIV/AIDS: knowledge of STIs and AIDS and methods
160 of transmission, sources of information, behaviors to avoid STIs and HIV, and stigma;

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3 161 3) Questions on reproduction included the number of children ever born, birth history, and current
4 162 pregnancy; 4) Family planning questions included knowledge and use of contraception, the
5 163 sources of contraceptive methods, and information on family planning; 5) Questions on maternal
6 164 and child health, breastfeeding, and nutrition included prenatal care, delivery, postnatal care,
7 165 practices of breastfeeding and complementary feeding, coverage of vaccination, diarrhea
8 166 prevalence and treatment, symptoms of acute respiratory infection (ARI), fever, knowledge of oral
9 167 rehydration salts and use of oral rehydration therapy; 6) Questions on fertility preferences
10 168 included desire for more children, the ideal number of children, gender preferences, and the
11 169 intention to use a family planning method; 7) Questions were asked regarding knowledge,
12 170 attitudes, and behaviors related to injections and smoking; 7) Additional questions focused on
13 171 adult and maternal mortality, domestic violence, and early childhood development. Additional
14 172 questions are described in the 2016 UDHS report.⁹
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25 174 The men's questionnaire was administered to all men aged 15-54 years in the sub-sample of
26 175 households selected for the male survey and collected much of the same information elicited with
27 176 the women's questionnaire. However, it was shorter because it did not contain a detailed
28 177 reproductive history or questions on maternal and child health.
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32 178
33 179 Data were collected on knowledge and attitudes of women and men about STIs and HIV/AIDS,
34 180 potential exposure to the risk of HIV infection (risk behaviors and condom use), and coverage of
35 181 HIV testing and counseling and other key HIV/AIDS programs. The primary objective was to
36 182 provide data on trends in HIV/AIDS knowledge, attitudes, and behaviors, including knowledge of
37 183 HIV prevention methods, stigma and discrimination, number of sexual partners, condom use, self-
38 184 reported HIV testing, prevention of mother-to-child transmission of HIV, and voluntary medical
39 185 male circumcision. The 2016 UDHS data were collected by 21 trained research teams, with each
40 186 consisting of a team leader, field manager, 3 female interviewers, 1 male interviewer, 1 health
41 187 technician, and 1 driver. A detailed description of the survey can be found in the 2016 UDHS
42 188 report.¹
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191 **Ethical considerations**

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

196 **Study design**

197 This was a non-randomized, quasi-experimental study since no true randomization was
198 employed.¹² We simulated a randomized control trial (RCT) from observational data by applying
199 propensity-scores matched (PSM) analysis to remove selection bias arising from a lack of
200 randomization and confounding. PSM analysis ensured that both the exposed and non-exposed
201 groups are comparable/or balanced on all measured covariates, except for the exposure.^{12,13}
202 Although an RCT is the gold standard design for measuring the effect of interventions since
203 randomization ensures balance in both known and unknown baseline covariates thereby
204 achieving comparability between the intervention and control groups¹⁴, it is infeasible and
205 unethical for beneficial interventions such as comprehensive knowledge of HIV. Observational
206 data provides an option for the measure of effect but the presence of selection bias from lack of
207 randomization and confounding of the exposure-outcome relationship due to other factors are
208 important limitations¹⁵ that have to be removed hence the use of PSM analysis.

209 **Variables and measurements**

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

221 **Outcomes:** The primary outcome was extramarital sexual relationships measured on a binary
222 scale (yes or no). Participants in sexual relations with another sexual partner other than the
223 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 4.02¹⁶ 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 scores²³ using different matching approaches, namely nearest neighbor matching with and without caliper adjustment²⁰, 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

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3 256 matched on the identical values of propensity scores.²⁴ The best matching approach was one that
4 257 balanced all the covariates between the two groups.

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9 259 Following the matching, we checked covariate balance between the group with and without
10 260 comprehensive knowledge of HIV using standardized mean differences (SMD), with an SMD<0.1
11 261 considered confirmatory of good covariate balance.⁷ We further assessed covariate balance
12 262 graphically using a jitter plot and histogram. Here, distributional similarity in propensity scores was
13 263 taken to suggest covariate balance.^{7,25} After successful matching, the propensity-score matched
14 264 dataset was saved for the outcome analysis. We performed analysis on both the unmatched and
15 265 matched datasets. We fitted a binary logistic regression model for the unadjusted and adjusted
16 266 analysis, with the latter model adjusted for all the matching covariates. For the PSM dataset, we
17 267 fitted a conditional logistic regression taking into consideration the matched pairs. We reported
18 268 odds ratio (OR) and 95% confidence interval (CI).

19 269

20 270 **Sensitivity analysis**

21 271 We checked the robustness of the findings to hidden bias/unmeasured confounders and the
22 272 matching approach using the Rosenbaum Wilcoxon's signed-rank test.²² We interpreted distant
23 273 gamma values to achieve statistical significance or non-significance as indicative of robustness.

24 274

25 275 **Reporting of findings**

26 276 The findings are reported following the improving the reporting quality of nonrandomized
27 277 evaluations of behavioral and public health interventions: The TREND statement shown in
28 278 Supplementary Fig 1.²⁶

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30 280 **Patient and public involvement**

31 281 Patients or the public were not involved in the design, or conduct, or reporting, or dissemination
32 282 plans of our research.

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3 **283 Results**

4 **284 Characteristics of participants**

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6 285 We present participants' characteristics in Table 1 both before and after PSM. We analysed data
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8 286 for 23,711 participants of whom 11,314 (47.7%) had comprehensive knowledge of HIV. Before
9
10 287 PSM, we observed systematic differences in the comprehensive knowledge of HIV concerning
11
12 288 the participants' age group, level of education, wealth index, and region, with all the variables
13
14 289 showing an SMD>0.1. We matched 18,504 participants in a ratio of 1:1, with all the covariates
15
16 290 balanced among the participants with and without comprehensive knowledge of HIV (SMD<0.1).
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291 **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. (%)	No (n=12,397) No. (%)	Yes (n = 11,314) No. (%)	SMD	Overall (n=18,504) No. (%)	No (n=9,252) No. (%)	Yes (n=9,252) No. (%)	SMD
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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293 **Distribution of study outcomes before and after PSM**

294 Table 2 presents the study outcomes before and after PSM analysis. In the PSM unmatched
295 sample, 4,187 (17.7%) participants had extramarital sexual relationships but there was no
296 difference between those without and with comprehensive knowledge of HIV: 2,056 (16.6%)
297 versus 2,131 (18.8%), SMD = 0.059. Of 4,187 participants in extramarital sexual relationships,
298 1,425 (34.0%) reported consistent use of condoms, and the proportion of consistent use of
299 condoms was significantly lower among those without comprehensive knowledge of HIV
300 compared to those with comprehensive knowledge of HIV: 623 (30.3%) versus 802 (37.6%), SMD
301 = 0.155.

302
303 In the PSM sample, 3260 (17.6%) participants had extramarital sexual relationships, with a
304 statistically non-significant difference between those without and with comprehensive knowledge
305 of HIV: 1,608 (17.4%) versus 1,652 (17.9%), SMD = 0.012. Of 1,117 (34.3%) participants who
306 reported consistent use of condoms, 520 (32.3%) had no comprehensive knowledge of HIV while
307 597 (36.1%) had comprehensive knowledge of HIV. However, we observed a statistically non-
308 significant difference in the consistent use of condoms SMD = 0.080).

309 **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)	

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

311 **Additional balance diagnostics**

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

318

319 **Effect of comprehensive knowledge of HIV on risky sexual behaviours associated with HIV** 320 **transmission**

321 We present the results for the effect of comprehensive knowledge of HIV on having multiple
 322 sexual partners and consistent use of condoms in Table 3. The results show that comprehensive
 323 knowledge of HIV was significantly associated with extramarital sexual relationships at the
 324 unadjusted analysis (OR 1.17, 95% CI 1.09 to 1.25) but not adjusted (aOR 1.07, 95% CI 0.99 to
 325 1.16) and PSM analysis (OR 1.04, 95% CI 0.96 to 1.12). Concerning the secondary outcome, the
 326 results show that comprehensive knowledge of HIV was significantly associated with consistent
 327 use of condoms at the unadjusted analysis (OR 1.39, 95% CI 1.22 to 1.58) and at the PSM
 328 analysis (OR 1.18, 95% CI 1.02 to 1.27) but not at the adjusted analysis (aOR, 1.10, 95% CI 0.95
 329 to 1.27).

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331 **Table 3: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated**
 332 **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)*

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

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

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

346 **Table 4: Effect of comprehensive knowledge of HIV on risky sexual behaviours associated**
 347 **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)

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

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351 **Sensitivity analysis results**

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

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359 Discussion

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

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367 The finding that comprehensive knowledge of HIV improves consistent use of condoms among
368 married or cohabiting couples in extramarital relationships is not unique. Comprehensive
369 knowledge of HIV raises an individual's level of awareness regarding potential risks associated
370 with not using condoms and helps them adopt safer sexual practices like consistent use of
371 condoms.²⁷ Inconsistent use of condoms in extramarital sexual relationships places an couples
372 at a greater risk of acquisition of sexually transmitted infections (STIs) including HIV.²⁸ Our finding
373 is consistent with several studies in SSA. One study which analysed the Ghana DHS found
374 exposure to family planning messages is associated with a higher likelihood of consistent condom
375 use among sexually active never-married men.²⁹ Using level of education as a proxy for
376 comprehensive knowledge of HIV, one study that analysed DHS data for 29 countries in SSA
377 reports that among men who pay for sex, those that attained a secondary level of education are
378 more likely to use condoms consistently.³⁰ In Uganda, less than half of the population aged 15-
379 54 years have comprehensive knowledge of HIV¹. This finding underscores a need to design and
380 implement context-relevant HIV prevention and education messages to improve the level of
381 comprehensive knowledge of HIV in the population for better HIV pandemic control.

382
383 We found no effect of comprehensive knowledge of HIV on consistent use of condoms among
384 married or cohabiting females in extramarital sexual relationships. However, in married or
385 cohabiting males, comprehensive knowledge of HIV improves consistent use of condoms in
386 extramarital sexual relationships. Although several factors such as cost, moral values, ethnicity,
387 religion, gender inequality, lack of dialogue among sexual partners concerning condom use
388 among others influence inconsistent or non-use of condoms during sexual intercourse ³¹, our
389 findings agree with an earlier study that reports HIV knowledge improves condom use self-efficacy
390 ³² and consequently its use in sexual relationships.

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3 391 Consistent with our results, recent study conducted among sexually active men in Nigeria³³ show
4 392 that knowledge of HIV equally improved condom use. Another study conducted among South
5 393 African married couples reported that females are less likely to use a condom if their male partner
6 394 has refused to using a condom³⁴, suggesting male dominance or power imbalance between
7 395 women and men in condom negotiation. In our context, this finding could be explained by socio-
8 396 cultural differences between men and women, with the latter being inherently submissive to the
9 397 sexual demands of the latter. In general, African women find it difficult to assert themselves
10 398 regarding condom negotiation and the majority do not negotiate condom use in a sexual
11 399 relationship. In Uganda, one study³⁵ reports the social environment as an independent risk factor
12 400 for HIV vulnerability. Men are the sole decision-makers regarding whether or not to use a condom
13 401 in a sexual relationship. However, gender equality improves condom use self-efficacy in both
14 402 general and risky situations.³² Improving consistent use of condoms among women thus require
15 403 their emancipation regarding decision-making on matters of sexual health.

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17 405 Our finding that comprehensive knowledge of HIV has no effect on extramarital sexual
18 406 relationships among of married or cohabiting couples in the general population and in sub-group
19 407 analysis requires cautious interpretation. First, we acknowledge that HIV is a global health
20 408 problem, with an estimated 25.7 million PLHIV globally²⁸ and in Uganda, there are 1.4 million
21 409 PLHIV.² However, with the rapid rollout and improved access to antiretroviral therapy (ART) over
22 410 the years, the majority of PLHIV have a nearly normal quality of life and longevity. There is now
23 411 much hope and optimism that the fight against HIV is nearly over leading to HIV complacency in
24 412 the general population.³⁶ Concerns about HIV being a global health problem have lessened and
25 413 the use of known HIV prevention methods such as abstinence, mutual faithfulness, and consistent
26 414 condom use, among others have dwindled over the years. The problem of HIV complacency in
27 415 Africa³⁷ and Uganda³⁸ have been highlighted earlier. Another plausible explanation relates to
28 416 behaviour change and the wide know-do gap at the individual level. One would argue that
29 417 behaviour change is a gradual process, often with strong influences from the social, cultural,
30 418 economic, environmental, and technological dimensions.³⁹ These challenges require a strong
31 419 focus on health promotion, a combination of health education and healthy public policy.⁴⁰ For
32 420 instance, without an enabling environment to achieve the desired behaviour change, health
33 421 education is insufficient. The formulation and implementation of appropriate healthy public policies
34 422 to create an enabling environment is important to prevent victim-blaming where people are
35 423 victimized for their actions despite a lack of an enabling environment for behaviour change.

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3 424 Our findings, therefore, emphasize a need for novel approaches to achieve behaviour change in
4 425 Uganda. There is a need to complement existing behaviour change communication strategies
5 426 with other approaches that lessen the influence of social and environmental determinants (alcohol
6 427 consumption and smoking, for example) that place the population at risk for HIV infection.⁴¹
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8 428 Approaches to mitigate HIV complacency besides other tools for HIV prevention and control are
9 429 important in ending the HIV pandemic.⁴² Further research should be conducted to understand the
10 430 disparity in the effect of comprehensive knowledge of HIV on extramarital sexual relationships
11 431 among married/co-habiting men and women.
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17 18 433 **Study strengths and limitations**

19 434 Our study has several strengths and limitations. First, we analysed nationally representative data
20 435 so our findings are likely generalizable to the entire country and other similar settings. Second,
21 436 the sample size was large and the results are robust to unmeasured confounders and the analytic
22 437 approach. However, there are limitations. For example, although our results are robust to
23 438 unmeasured confounders, the matching was performed on observed covariates and other
24 439 unobserved covariates (such as alcohol consumption and drug and substance use among others)
25 440 that are known to influence the outcome were not analysed. The outcomes were assessed
26 441 through self-report so the possibility of social desirability bias cannot be excluded.
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34 443 **Methodological considerations**

35 444 We highlight a few methodological considerations in this study. First, PSM is appropriate when
36 445 the sample size is large, typical ≥ 5000 observations. This is because PSM leads to reduction in
37 446 sample size due to unmatched observations hence might increase the likelihood of Type II error.
38 447 The specification of the propensity-score model is prone to inaccuracies so the reliance on
39 448 unconfoundedness assumption is important. The magnitude of intervention effect somewhat
40 449 depends on the type of matching used and whether it was done with or without replacement.
41 450 Another important consideration is the approach to computing the propensity score thus whether
42 451 a logistic regression or generalized boosted regression model was used since they determine the
43 452 sufficiency of the common support. Lastly, PSM does not control for unmeasured confounders so
44 453 sensitivity analysis to assess the credibility of the estimates is important.
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3 **455 Conclusions and recommendations**

4 456 Comprehensive knowledge of HIV has no effect on extramarital sexual relationships among
5 457 married or cohabiting couples in Uganda. However, it increases consistent use of condoms in
6 458 extramarital relationships among married or cohabiting men but not in the married or cohabiting
7 459 women. Our findings emphasize a need to continue providing consistent and correct HIV
8 460 prevention health education messages.

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16 **462 Author contributions**

17 463 JI and DTK conceptualized and designed the study. DTK acquired the data. JI analysed the data.
18 464 JI and DTK interpreted the data and drafted the initial and final manuscripts. JI and DTK critically
19 465 revised the manuscript and approved for submission.

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41 **476 Competing interests**

42 477 The authors declare that they have no competing interests.

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483 **Data availability statement**

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

489 **Figure legends**

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

493 Supplementary Fig 1: The TREND statement checklist

495 **Consent**

496 Not applicable.

497 **Ethics Approval Statement**

498 Not applicable/No human participants included.

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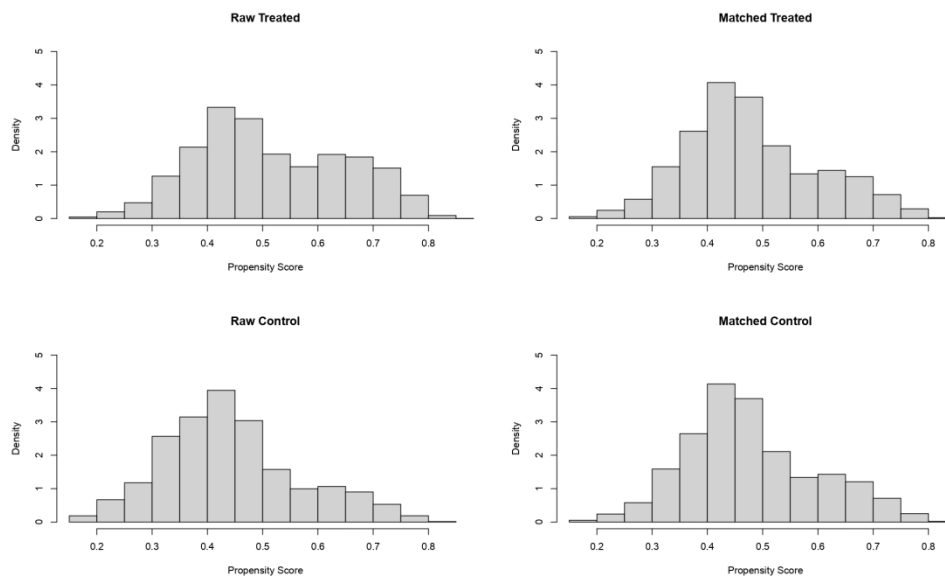



Fig 1: Distribution of propensity-scores between participants with and without comprehensive knowledge of HIV before (left histograms) and after matching (right histograms).

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?	
				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	<ul style="list-style-type: none"> 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. 	N/A	
Unit of Analysis	10	<ul style="list-style-type: none"> Description of the smallest unit that is being analyzed to assess intervention effects (e.g., individual, group, or community) 	√	7-8
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Statistical methods used to compare study groups for primary methods outcome(s), including complex methods of correlated data 	√	7-8
		<ul style="list-style-type: none"> Statistical methods used for additional analyses, such as a subgroup analyses and adjusted analysis 	√	7-8
		<ul style="list-style-type: none"> Methods for imputing missing data, if used 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Assignment: the numbers of participants assigned to a study condition 	N/A	
		<ul style="list-style-type: none"> Allocation and intervention exposure: the number of participants assigned to each study condition and the number of participants who received each intervention 	N/A	
		<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Analysis: the number of participants included in or excluded from the main analysis, by study condition 	N/A	
		<ul style="list-style-type: none"> Description of protocol deviations from study as planned, along with reasons 	N/A	
Recruitment	13	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Data on study group equivalence at baseline and statistical methods used to control for baseline differences 	√	14

TREND Statement Checklist

Numbers analyzed	16	<ul style="list-style-type: none"> 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
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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
		<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Summary of other analyses performed, including subgroup or restricted analyses, indicating which are pre-specified or exploratory 	N/A	
Adverse events	19	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	
		<ul style="list-style-type: none"> Discussion of research, programmatic, or policy implications 	√	14-16
Generalizability	21	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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/>