REVIEW ARTICLE

The impact of digital health interventions on HIV testing uptake among adolescents: a systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

While digital media has been widely employed for promoting sexual health, its application in boosting HIV testing rates among adolescents remains relatively restricted. This systematic review seeks to gauge the efficacy of digital health in enhancing HIV testing uptake within the youth population. The study included original studies published in English, quantitative with RCT, involving adolescents that were published from 2013 to 2023. The publications were identified using CINAHL, Embase, MEDLINE, PubMed, Scopus, and Web of Science electronic databases, with keywords such as adolescent, telemedicine, and HIV testing. We also used the hand-searching method from other systematic review and meta-analysis articles. We conducted a critical appraisal and found a low-risk bias in four RCT studies. All included articles were coded according to relevant exposures or outcomes and analyzed to assess frequencies. Four studies from the United States, the United Kingdom, and China were included in the synthesis. Uptake of HIV testing among adolescents who were given digital media interventions showed a significant difference of 1.90 times compared to the group that did not receive digital media intervention ($p<0.00001$). Digital media intervention significantly increased HIV testing engagement among adolescents. HIV screening programs using digital media are needed to optimize access to HIV testing services.

Key words:
adolescent; digital health; HIV testing

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INTRODUCTION

Promoting good health and well-being for people of all ages is a key objective outlined in the 2030 Sustainable Development Goals (SDGs) agenda. Despite this, the global health challenge posed by Human Immunodeficiency Virus (HIV) persists. It is anticipated that there will be 1.3 million [1.0 million–1.7 million] new HIV infections in 2022. On a global scale, around 210,000 [130,000–300,000] adolescent girls and young women (aged 15–24 years) contracted HIV in 2022, which is half the number reported in 2010. During the same period, 140,000 [67,000–210,000] adolescent boys and young men (aged 15–24 years) acquired HIV.[1]

A new HIV infection can only be known if a person has been tested. Early detection of HIV is a crucial step for reducing its transmission and improving the success of HIV treatment. The sooner HIV gets detected, the faster treatment can be done to control the infection and prevent it from developing into AIDS.[2] Comprehensive HIV/AIDS awareness is essential for adolescents to avoid new HIV infections. The health promotion program with sex education for adolescents, should be structured following existing social, cultural, and religious practices to discourage risky reproductive health behavior.[3] According to a previous study, being older, married, more educated, and wealthier are all related to having more comprehensive knowledge[4]. However, many adolescents still lack knowledge.[5] Furthermore, many individuals still have misconceptions about HIV transmission and the severity of the stigma.[6] In fact, good knowledge of HIV/AIDS is related to the uptake of HIV testing among adolescents.[4]

Digital health treatments are particularly promising in the 5.0 era because they provide flexibility and a broad reach.[7] Sexual health interventions are increasingly being delivered through digital technology (e-sexual health). These include HIV testing through the internet (e-HIV testing).[8–10] Frequently, this testing method enables users to request a test kit from an online service (via a website or mobile app), gather their samples, send the test samples to a lab, and receive results via short messaging service (SMS), text message, or telephone.[11–13] For numerous young individuals who are HIV-positive, utilizing digital-based HIV care navigation can address disparities in connecting to and staying in care while enhancing their overall involvement in HIV care. It can serve various purposes, including guiding individuals through HIV care, delivering health promotion and education, conducting motivational interviews, and providing social support[13]. Another study found that interactive digital interventions had a favorable impact on sexual health promotion and HIV prevention knowledge, intentions, and behaviors.[14,15]

The utilization of digital health interventions for enhancing HIV testing uptake among adolescents is a critical area of research that warrants attention. While previous studies have explored various aspects of digital health and HIV prevention,[16] there remains a gap in understanding the specific impact of digital-based health education on adolescent HIV testing rates. There was a systematic review on the impact of digital health and HIV prevention, but the review does not include specific intervention studies. Hence, we conducted a systematic review and meta-analysis focused on randomized controlled trials (RCTs) to provide a comprehensive evaluation of the effectiveness of digital interventions in increasing HIV testing engagement among youth.

By addressing this gap in the literature, this study aims to systematically review and meta-analyze RCTs focused on the impact of digital health interventions (specifically websites and mobile

applications), on increasing HIV testing rates among adolescents.

METHODS

The protocol for this systematic review and meta-analysis has been registered in PROSPERO (registration number: CRD42021290765).[17] The research involved a comprehensive examination through systematic review and meta-analysis, focusing on randomized controlled trials (RCTs) that juxtaposed digital media interventions with traditional or non-digital approaches, such as printed materials like leaflets and pamphlets. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. It adhered to the Cochrane systematic review methodology tailored for interventions in health promotion and public health.[18,19]

Searching strategy

We conducted a comprehensive literature search using the Publish or Perish software across the following databases: CINAHL, Embase, MEDLINE, PubMed, Scopus, and Web of Science. The articles considered for the study were required to be in English and published between 2013 and 2023. We initiated the search by using relevant critical terms for both databases and in subsequent stages, specific keywords and phrases were applied to the literature search. Three concepts of the main keywords: adolescent, telemedicine, and HIV testing. Besides, we also used the hand-searching method from other systematic review and meta-analysis articles *(supplementary 1 and 2)*.

Eligibility criteria

We applied specific inclusion and exclusion criteria during the search process. Studies that did not meet the inclusion criteria or addressed topics unrelated to the study were excluded. Our inclusion criteria encompassed the study design of randomized controlled trials (RCTs) because RCT study designs are considered the gold standard in scientific research to measure the impact of health intervention.[20] The research focused on adolescents as the subject population, the use of digital media (websites or mobile apps) as the intervention method, a comparison with general media (non-digital media, such as pamphlets), and the presence of an outcome related to HIV testing uptake. We excluded various types of research, including quasi-experiments, observational studies, qualitative research, systematic reviews, meta-analyses, opinion pieces, and narrative reviews. Additionally, RCT articles needing complete analysis data, such as risk ratios (RR) and confidence intervals (CI) necessary for meta-analysis, were also excluded.

The exclusion criteria related to RCT articles requiring complete analysis data, such as risk ratios (RR) and confidence intervals (CI) for meta-analysis, will be reevaluated to ensure that genuine data are not overlooked. This adjustment aims to minimize bias in the research process and enhance the credibility of the findings.

Data charting process

We imported the refined articles into Mendeley software to identify and eliminate any duplicate publications. Following that, an independent screening process was carried out by the authors. In the initial stage, the authors assessed the articles based on the PICO framework using their titles and abstracts. Any reports that did not pertain to RCT studies protocols or were solely abstracts were excluded from this study. Subsequently, other authors scrutinized the full-text articles that pertained to digital interventions (websites or mobile apps),

focused on HIV testing, and presented data including risk ratios (RR) and confidence intervals (CI). The authors then compared their findings, and any discrepancies were resolved through consensus. Finally, a qualitative and quantitative analysis of the refined articles was conducted.

Data items

We retrieved the data using a standardized form and assessed studies by designating them as eligible, non-eligible, or perhaps eligible according to the eligibility and inclusion criteria. If the title and abstract of the research were relevant and could not be eliminated, it was considered eligible, and the procedure depended on the supervisor's approval. A reviewer might be recruited to independently analyze eligibility to check for consistency and clarity in the data or to resolve disputes about which studies should be included. First author and year, nation subject/study location/sample size, research design, digital intervention techniques, and result were all retrieved. The data extraction findings were then separately supervised.

Critical appraisal of individual sources of evidence

Evaluation of the quality of individual sources of evidence was conducted jointly by two author assistants under the supervision of other authors. To assess bias, we employed the Cochrane risk-of-bias tool for cluster-randomized trials (RoB 2 CRT), which was the version as of March 18, 2021. The Cochrane risk of bias tool for randomized trials is widely recommended for RCTs and is suitable for individually-randomized, parallel-group, and cluster-randomized trials.[21] Rob 2.0 identifies five potential domains for bias: (a) Risk of bias related to the randomization process and the timing of participant cluster identification or recruitment in a cluster-randomized trial; (b) Risk of bias due to deviations from intended interventions (i.e., adherence to the intervention); (c) Risk of bias due to missing outcome data; (d) Risk of bias in the measurement of the outcome; (e) Risk of bias in the selection of reported results. We also assessed the overall risk of bias using this tool. Each domain's risk of bias was categorized as low risk, some concern, or high risk.[22]

The case representativeness, research methodology, and study results were all reviewed on the evaluation sheet. A few practical suggestions under the five heads of critical analysis of randomized controlled trials include the correct question, the right population, the proper research design, the correct data, and the right interpretation.[20]

Bias of publication study

To address potential inconsistencies in data procedures, a more objective approach will be adopted, incorporating expert opinions beyond the supervisor's perspective. By considering a wider range of viewpoints, the research methodology will be strengthened, reducing the likelihood of bias and ensuring a more robust analysis of the data.

An asymmetric funnel indicates a relationship between digital media intervention estimate and study precision. The use of funnel plot techniques aids in detecting potential publication bias or small study effects.[23]

Synthesis of results

The pooled estimate for the percentage of increased HIV testing was calculated using a meta-analysis of proportions. For the analysis, we utilized Review Manager (REVMAN) 5.4. Before combining the data, it was weighted to account for the diverse samples from different studies and prevent the pooling of the data as if it came from a single sample. We calculated the effect size using a standardized mean difference (SMD) along with a 95% confidence interval and a two-tailed p-value of less than 0.05, indicating a

statistically significant distinction between the groups. We used a table and a forest plot to illustrate the data.[19,24]

The I^2 statistic will be used to report between-study heterogeneity. An I^2 score greater than 50% implies a high amount of heterogeneity. Fixed-effects analysis models are employed when heterogeneity is detected in less than 50% of cases, and the p-value is more significant than 0.05. However, we used random-effects analysis models if the I^2 score was more than 50%.[24] The researchers utilized a fixed-effects analysis using a binomial distribution to describe within-study variability and a maximum likelihood approach to estimate parameters. The confidence intervals (CI) for between-study variance will be calculated using the Jackson technique. The total proportions will be shown, along with the 95% confidence interval.[19]

RESULTS

We acquired a total of 1088 research papers from online databases, including CINAHL, Embase, MEDLINE, PubMed, Scopus, and Web of Science, along with an additional 284 articles identified through hand searching. All of these papers were published between 2013 and 2023. Upon removing duplicate entries, we were left with 987 unique abstracts. After a thorough abstract review, 57 publications were chosen for a full-text assessment. Of these, 53 articles were excluded for various reasons, such as not focusing on adolescents, utilizing non-digital media interventions, lacking outcomes related to HIV testing uptake, or not evaluating the desired outcome. Ultimately, four articles met the inclusion criteria and were included in the qualitative synthesis. This is a sufficient result, according to the concept of meta-analysis as a statistical analysis that integrates results from two or more studies, providing a single numerical value of the overall treatment effect for that group of studies.[25] The article selection process is visually represented in Figure 1 of the PRISMA flowchart.

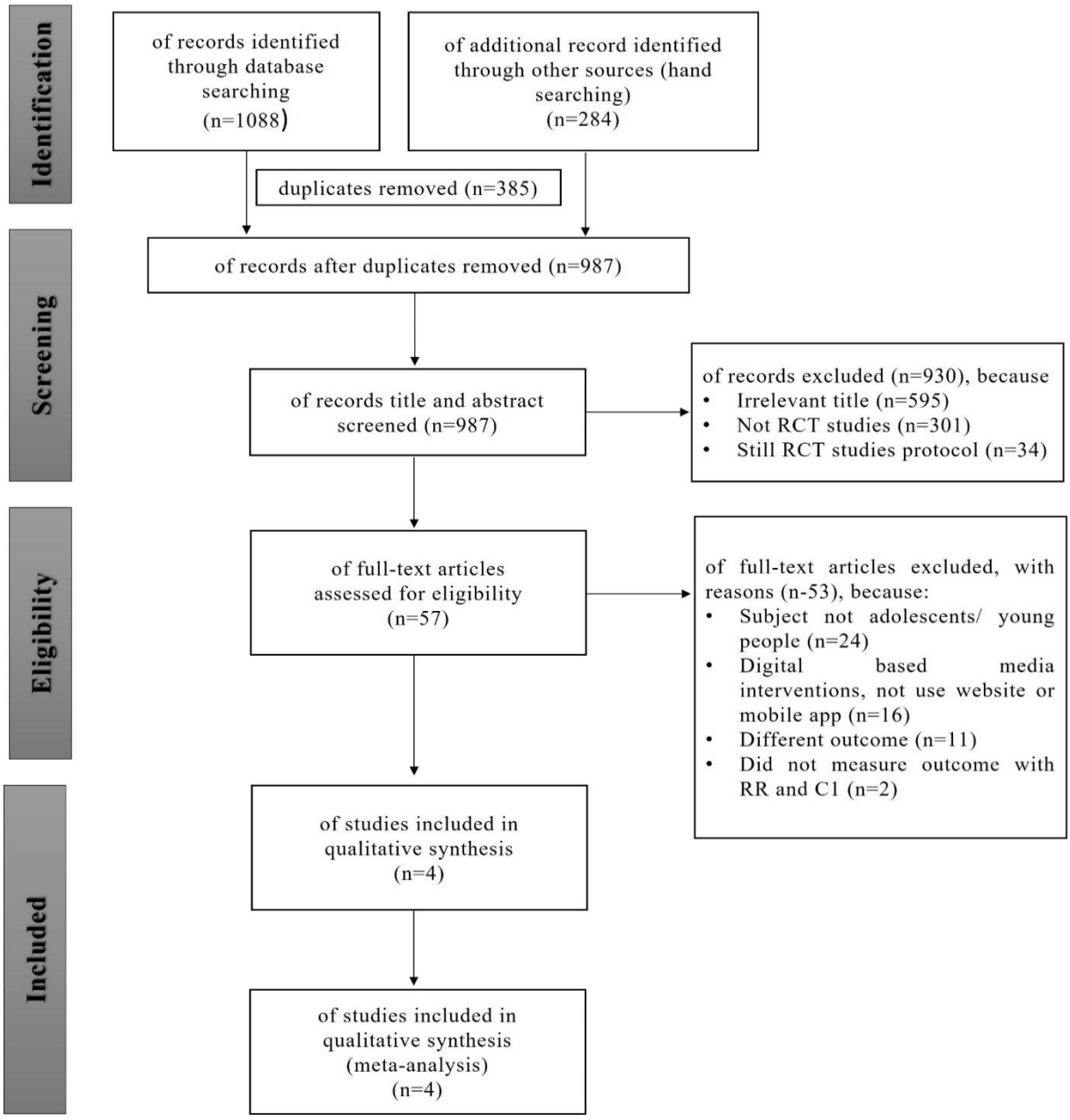

Figure 1. PRISMA flow diagram

The characteristics of included studies

Table 1 lists the features of the documented studies. The research parameters were the author/year, country, study design, respondent's age, sample size, type of digital media, duration of intervention, outcome, the estimate of risk ratio (RR), and confidence interval (CI). Two studies were carried out in the United Kingdom, one in the United States, and one in China. The study sample sizes varied from 48 to 1032. Three studies employed websites for digital media intervention, while one study used mobile applications, with intervention periods ranging from four to twenty-four weeks. The risk ratio of digital media intervention increased adolescent HIV testing uptake from 1.87 to 8.45 (95% CI=1.07 to 34.17).

Such criteria are crucial for upholding methodological precision and research significance, facilitating a rigorous examination of digital media's influence on adolescent HIV testing. Additionally, the distinct inclusion criteria solely for RCT studies present an innovative aspect of this research, distinguishing it from past systematic reviews that encompassed various article types beyond RCTs.

Table 1. Characteristics of the included studies

No	Author/ Year	Country	Design	Age (years old)	Sample size		Type of digital media	Type of intervention	Duration of intervention	Outcome	Risk Ratio (RR)	Confidence Interval (CI)
					IG	CG						
1	Patel et al., 2019	USA	RCT	18-24	52	48	Website	Online education	4 weeks	HIV test uptake	8.45	2.09 to 34.17
2	Wilson et al., 2017	UK	RCT	16-30	1031	1032	Website	Online education	6 weeks	HIV test uptake	1.87	1.63 to 2.15
3	Wilson et al., 2019	UK	RCT	16-30	244	284	Website	Online education	6 weeks	HIV test uptake	1.88	1.47 to 2.40
4	Zhu et al., 2019	China	RCT	18-29	50	50	Mobile app	Online education	24 weeks	HIV test uptake	1.99	1.07 to 3.84

Bias and Quality of Included Studies

The assessment of study quality was conducted independently by all researchers using the Cochrane risk-of-bias tool for cluster-randomized trials (RoB 2 CRT), as of March 18, 2021. As a result, all the included study articles were found to have a low risk of bias. Nevertheless, some critical appraisals within the articles acknowledged the potential for bias in various domains. The outcomes of HIV testing relied on self-reported data from patients. Although this method may be susceptible to social desirability bias, there were no statistically significant differences in sociodemographic factors between the HIVST and control groups.[26] Data for the outcome were not available for all or nearly all participants within clusters, as only 50.0% of the intervention group had completed an STI test compared to 26.6% in the control group.[10] A similar situation was observed, where 45.3% of the intervention group completed at least one STI test, compared to 24.1% of the control group.[9] To address missing outcome data, their primary analyses used multivariate imputation techniques, assuming that the data were missing at random.[9,10] There is a potential for selection bias because the inclusion criteria required individuals to agree to self-administer the oral HIVST kit at the baseline. To mitigate this bias, the study ensured that all participants received the same information by watching a brief video created by the project team on how to self-administer the oral HIVST kit.[27]

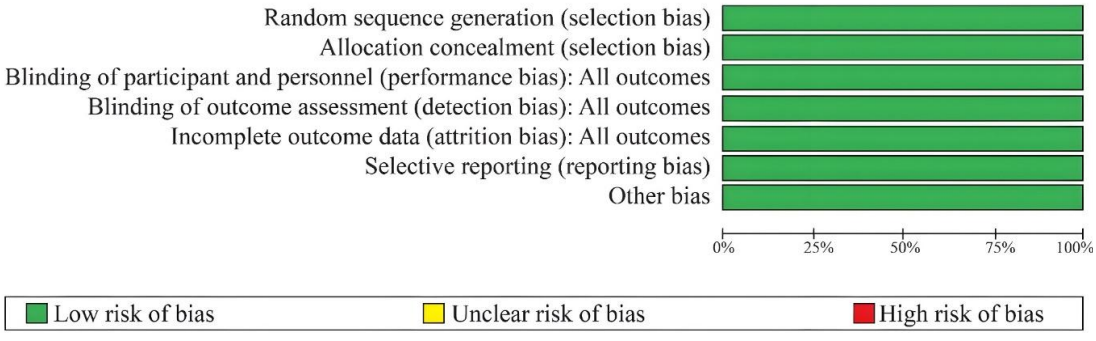

Figure 2. Risk of bias graph of the overall included studies

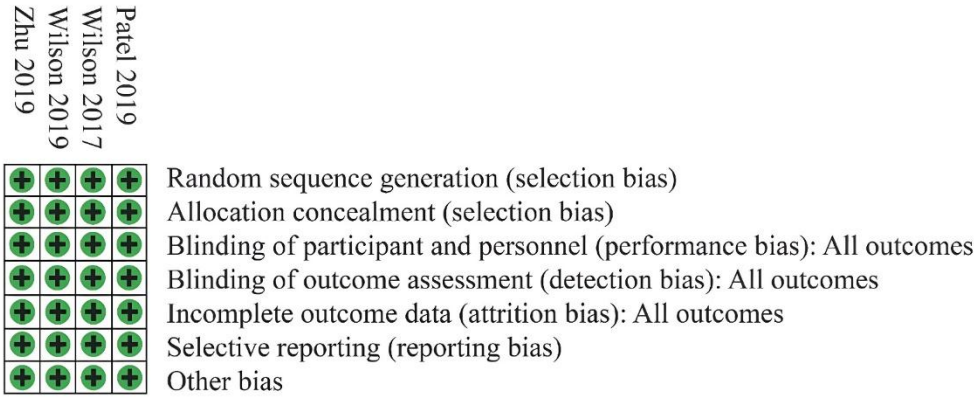

Figure 3. Risk of bias summary of the overall included studies

According to the findings presented in Figure 3, the distribution of studies appears to be asymmetric, suggesting a publication bias, as it does not form an inverted funnel shape. Additionally, one study on the right side exhibits a standard error greater than 0.6

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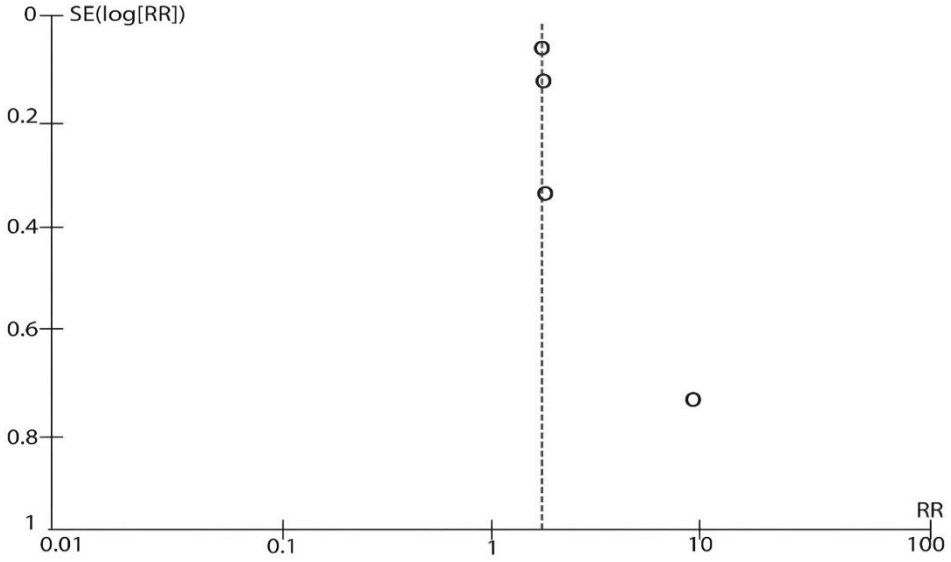

Figure 4. Funnel plot of the overall included studies

The effects of the intervention on HIV testing uptake

Figure 3 presents a summary of the effect sizes and 95% confidence intervals (CI) for the studies included in the analysis. Four studies investigated the impact of digital media on HIV testing uptake among teenagers. Considering the relatively low to moderate variability among these studies, we employed a fixed-effect model to evaluate differences in HIV testing uptake between the control and intervention groups. The results indicated that the intervention group had a significantly higher rate of HIV testing uptake when compared to the control group. The pooled effect size, represented as the standardized mean difference (SMD), was 1.90 (95% CI = 1.69 to 2.13), and it was statistically significant ($p < 0.00001$), favouring the use

of digital media over standard care. However, there was some variability across trials in terms of changes in HIV testing uptake (I2 = 33%; p = 0.22) (as shown in Figure 3).

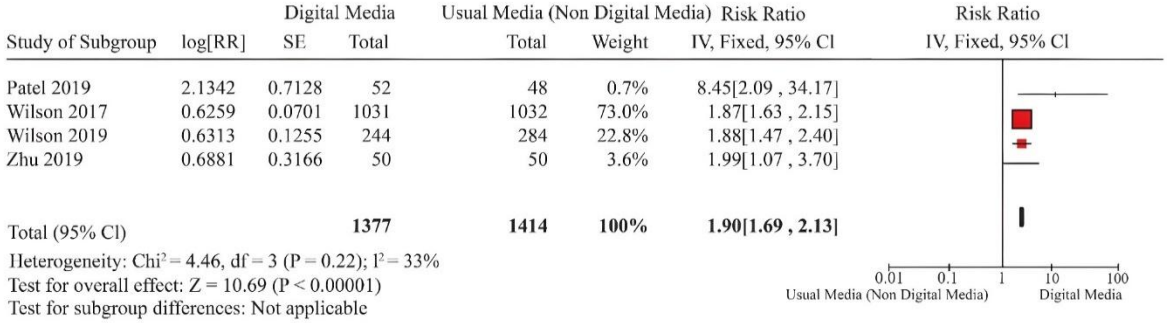

Figure 5. Forest plot of the overall included studies

DISCUSSION

Overall, this study highlights the significance of incorporating digital technologies in public health initiatives and underscores the potential for digital interventions to drive positive changes in healthcare delivery and outcomes. By contextualizing this research within the larger academic landscape and demonstrating its potential impact on improving HIV testing uptake among young individuals, this study contributes valuable insights to the field. The findings underscore the importance of utilizing digital media interventions in healthcare settings to enhance testing rates and reduce barriers to access.

The systematic review explored the impact of incorporating digital media into the process of HIV testing among young individuals, systematically reviewed four randomized controlled trials to ensure the reliability of the results. Specifically, this systematic review and meta-analysis focused exclusively on randomized controlled trials to maintain the highest level of result validity. The intervention involved the utilization of digital or mobile technology through websites or applications, as compared to conventional care methods (either directly or using non-digital media) in young individuals. The findings of this study revealed a significant improvement in HIV testing among participants in the intervention groups when digital media was employed. Additionally, a previous study indicated that the integration of e-STI testing alongside standard care could enhance STI testing uptake and reduce the time it takes to undergo testing, particularly among young individuals, including those in high-risk groups.[9,10] Another study explored various aspects of digital health and HIV prevention,[16] with a gap in understanding the specific impact of digital-based health education on adolescent HIV testing rates, but the review does not include specific intervention studies.

The meta-analysis highlighted a significant influence of integrating digital media into HIV testing uptake, with an estimated improvement of 1.90 times. Despite low to moderate heterogeneity between the included studies, noticeable inconsistency in substantial effects was observed, attributed to variations in intervention characteristics, sample sizes, intervention durations, and the types of digital interventions used. Previous research supported these findings, indicating that technology-based interventions could effectively boost HIV

testing rates among young individuals in clinical settings.[12] Moreover, another study suggests that employing technology-based interventions may effectively boost HIV testing rates among young individuals in clinical settings. Among the three interventions examined, two led to a notable increase in HIV testing rates.

The limited number of articles included in this study could be attributed to the strict exclusion criteria applied during the literature search. The criteria focused on the specific study design (RCT), target population (adolescents), intervention method (digital media), and outcome measure (HIV test uptake). These criteria are important to maintain methodological rigor and research relevance, ensuring focused analysis of the impact of digital media on HIV testing among adolescents. Furthermore, the more specific inclusion criteria solely for RCT studies constitute the novelty of this study, setting it apart from previous systematic reviews that also analyzed articles other than RCTs.

Although the inclusion of only four articles may seem limiting, this reflects a deliberate selection process aimed at prioritizing high-quality research that meets predetermined criteria. The challenges faced in identifying a larger body of relevant research underscore the specificity and rigor of research focus, emphasizing the importance of methodological transparency and consistency in the research process. The concept of meta-analysis as a statistical analysis that integrates results from two or more studies, providing a single numerical value of the overall treatment effect for that group of studies.

The implications of the limited number of included articles for the overall consistency and generalizability of the findings should be acknowledged. The scope of the study may be limited by the selected articles, but the application of strict inclusion criteria will increase the internal validity and reliability of the results within the specified parameters. It is important to recognize the trade-off between inclusivity and methodological rigor in systematic reviews and meta-analyses, with a focus on quality over quantity to ensure the credibility and robustness of research findings.

All the articles included in the study are randomized controlled trials (RCTs). RCTs are considered the gold standard in scientific research and have played a foundational role in evidence-based medicine (EBM). When conducting a critical appraisal of RCTs, the articles need to adhere to five fundamental principles: formulating the right research question, involving the appropriate study population, using the correct study design, collecting accurate data, and interpreting the results correctly.[20,28] In our analysis, we conducted a critical appraisal of the four included RCT articles using the Cochrane risk-of-bias tool for cluster-randomized trials (RoB 2 CRT) as of March 18, 2021. This tool, recommended for RCTs, is widely acknowledged as a standard for assessing bias in research studies.[21]

Our study was designed to address a critical gap in the literature concerning the impact of digital media interventions on HIV testing uptake among young individuals, particularly adolescents. Previous research in this area has shown promising results but has been limited by various biases, such as small sample sizes, inconsistent methodologies, and publication biases.[14,16,31] By acknowledging these limitations in prior studies, we sought to build upon existing knowledge and provide a more robust and reliable assessment of the effectiveness of digital health interventions in promoting HIV testing.

All of the research articles included in the study demonstrated a low risk of bias. Among these studies, three employed the single-blind technique,[9,10,27] while the remaining one utilized the double-blind approach during the randomization process

and outcome interpretation.[25] Although missing outcome data were observed in all four articles, such instances were anticipated and accounted for using the Missing at Random (MAR) analysis. In the context of randomized controlled trials, bias can manifest during various stages, including study design, planning, execution, and even in the publication and dissemination of findings.[29] To mitigate bias, it is advisable to employ blinded outcome assessments, particularly in open-label trials. In cases where blinded outcome assessment is not feasible, modifying the definition or assessment method of the outcome can be a useful strategy to reduce the risk of bias.[30]

There was low/moderate heterogeneity among the included studies because I^2 scored less than 50%, and the p-value was more than 0.05. Nevertheless, there was noticeable inconsistency in the substantial effects, which was evident in the variability of intervention characteristics. This happens because of several possibilities: Firstly, although it has the same study design that is RCT, the articles included in this study were conducted in different locations, including the United States, United Kingdom, and China. This variation means that the samples studied have different cultural characteristics.[3] Secondly, the four studies also had varying sample sizes and different durations of intervention. Lastly, although both use digital interventions, this type of digital intervention is in the form of websites and mobile apps.

The strength of the study

This study possesses several notable strengths. To begin, it conducted a systematic review and meta-analysis adhering to the PRISMA methodology. Second, it adopted a comprehensive search strategy to collect all relevant articles. All the selected papers originate from reputable journals and exhibit a low bias, as confirmed through a rigorous critical appraisal using the latest version of RoB 2 CRT. Third, the assessment process was conducted meticulously by two independent reviewers. Fourth, only randomized controlled trials were considered in this analysis to uphold a high level of result validity. Lastly, the inclusion criteria focused on studies conducted within the last decade (2013-2023), ensuring that the research data remains current and up to date.

The limitation of the study

This analysis exhibits a few limitations. First, as the study was limited to English-language publications, the researchers considered the potential for publication bias, although no such preference was identified through statistical analysis. Second, the researchers needed to ascertain any unpublished works meeting the criteria for this investigation. Third, the study displayed variations in sample size, intervention duration, and study location, potentially leading to heterogeneity.

The study implication for public health

Lack of understanding and stigma can hinder the implementation of HIV testing, because adolescents are less aware that they are at risk. Meanwhile, HIV prevention programs with early detection are important, especially for adolescents, to help the government plan for an HIV/AIDS strategy for Three Zero 2030. Therefore, health education about HIV/AIDS according to the needs of adolescents should be carried out. In the era of technological 5.0, there is an opportunity to develop digital health for HIV testing. In this condition, our study results can estimate the effectiveness of digital media intervention, such as a website or mobile app, to improve HIV knowledge and testing among adolescents.[9,10,26,27,32]

Subsequently, those responsible for planning HIV programs should be aware of the barriers to extending access, which include factors like smartphone ownership, digital literacy, access to Wi-Fi, and connectivity (commonly referred to as the 'digital divide'). These challenges should inform the development of digital health promotion initiatives. One approach could involve establishing public-private partnerships aimed at temporarily providing mobile phones or free Wi-Fi access for clinical or healthcare services. Additionally, HIV testing programs with digital support could explore collaboration with reputable organizations known for delivering high-quality clinical services. Digital assistance might be provided via various mediums, such as websites or mobile apps. Low and middle-income countries might have access to digital programs through government assistance and innovative public-private partnerships.[32]

In addressing the gap in previous research, this study contributes valuable insights by emphasizing the importance of digital media interventions in healthcare settings to enhance testing rates and reduce barriers to access. By conducting a systematic review and meta-analysis of RCTs, the study provides robust evidence supporting the efficacy of digital interventions in improving HIV testing uptake among adolescents. The low risk of bias observed in the included studies enhances the credibility of the findings and underscores the reliability of the results.

Moving forward, there is a need for more RCTs for future research to delve deeper into the specific mechanisms through which digital interventions influence testing behaviors and tailor interventions to diverse cultural contexts and populations to maximize effectiveness. By acknowledging the limitations and strengths of the study, researchers can further refine digital health initiatives to optimize access to HIV testing services and improve health outcomes among young individuals, particularly in high-risk groups.

CONCLUSION

Utilization of digital media interventions, including websites and mobile applications, has demonstrated a significant increase in the use of HIV testing to identify new HIV infections among adolescents. This review study of four articles recommends that to increase accessibility to HIV testing services, the use of digital media for online education is very important. This study also highlights the importance of digital media in supporting the counseling service process by considering ease of access and privacy, thereby influencing adolescents' openness in discussing their problems. Based on the findings of only four RCT articles in this study, we recommend the need for more RCT articles focused on the impact of digital health interventions (specifically websites and mobile applications) on increasing HIV testing rates among adolescents. Digital health initiatives have the potential to simplify HIV services, contributing to the achievement of the Sustainable Development Goals (SDGs) and the 2030 'Three Zero' targets, particularly in identifying new HIV cases through testing. Nevertheless, it is recommended to conduct further evaluation studies, including subgroup analyses, especially in low- and middle-income countries, to gain a more comprehensive understanding of the specific uses of digital media in this context.

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