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Review Article

Effectiveness of Digital Intervention for Tobacco Cessation Among Adults: A Systematic Review

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Abstract

Background: The use of tobacco continues to pose a major public health issue worldwide, requiring effective cessation programs. Digital interventions present advantageous opportunities owing to their accessibility and scalability. This systematic review seeks to consolidate current research on the efficacy of digital interventions for tobacco cessation in adults.

Methods: We performed a search utilizing pertinent keywords and databases. The search approach encompassed terms including "digital interventions," "smoking cessation," "adults," and their permutations. Our primary focus was on academic databases including PubMed, EBSCO, Cochrane, and specialized journals pertaining to public health and smoking cessation. Search terms were limited to the English language exclusively. Databases from 2013 to 2023 were covered. Two writers independently collected data on cessation results and evaluated the likelihood of bias. A random effects meta-analysis was performed.

Findings: Following the search, 305 articles were identified. After omitting 151 duplicates, 198 unique papers were analyzed. Of the 47 publications that underwent full-text examination, 8 were finally incorporated into this analysis. Subgroup analysis examined differences in intervention efficacy according to length, intervention type, and participant attributes.

Conclusion: Digital treatments demonstrate the potential to facilitate smoke cessation in adults. Nonetheless, disparities in intervention design and participant attributes affect their efficacy. Additional studies are necessary to clarify effective intervention tactics and fill literature gaps, especially for long-term results and the scalability of digital therapies across varied populations.

Keywords: Tobacco products, Counseling, Cessation, Adult

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Introduction

The global tobacco landscape is distinctive in the extensive range of smoking and smokeless tobacco products.[1] The prevalence of detrimental substance use, particularly chewing tobacco and smoking, is rising at a concerning rate. Approximately 1.3 billion individuals globally use tobacco, with 80% residing in low- and middle-income nations. Tobacco consumption results in the deaths of over 8 million individuals annually.[2]

Tobacco consumption continues to pose a substantial public health issue worldwide, leading to numerous preventable illnesses and premature fatalities.[3] Traditional smoking cessation methods have demonstrated inconsistent success, with limitations in their reach and efficacy.[4] Digital interventions, such as mobile applications, websites, and telehealth services, have surfaced as potentially effective resources for tobacco cessation.[5] These interventions present distinct benefits, including accessibility, scalability, personalization, and immediate support.[6] Nonetheless, the efficacy of digital interventions for tobacco cessation among adults necessitates thorough assessment due to the variety of available platforms and differing levels of user engagement.[7]

Interventions utilizing smartphone applications have been extensively researched, with systematic reviews assessing their efficacy and adherence rates.[8] Furthermore, studies have investigated the cost and cost-effectiveness of mHealth interventions aimed at facilitating smoking cessation.[9] Nevertheless, additional evidence is required to identify the most effective forms of digital interventions, the factors affecting their efficacy, and their long-term impacts on smoking cessation rates and relapse prevention.

Despite encouraging results, a thorough synthesis of the research was still required to guide the formulation and execution of digital interventions for tobacco cessation.

This systematic study sought to investigate the efficacy of digital treatments for tobacco cessation in adults. The main goal was to evaluate the efficacy of these interventions in facilitating smoking cessation among adult tobacco users, concentrating on outcomes, including abstinence rates, decreased cigarette consumption, and participation in interventions. Secondary objectives included examining the attributes of effective digital interventions, including intervention components, delivery modalities, and follow-up time.

This review enhanced the current research by offering a thorough synthesis of the efficacy of digital treatments for tobacco cessation in adults. The findings had substantial significance for policymakers, healthcare professionals, and researchers engaged in tobacco control, informing the creation and execution of evidence-based programs to diminish tobacco consumption and enhance public health outcomes. This study aimed to identify the most successful digital treatments, the factors affecting their efficacy, and the gaps in existing research through a critical analysis of published studies. Comprehending the advantages and constraints of digital treatments guided the creation of more focused and evidence-based cessation programs, enhancing smoking cessation results and public health.

Methods

We employed the international PICOS framework;

P: The population comprises adults who are current smokers.

I: The intervention involved digital methods for smoking cessation.

C: The comparator group comprises tobacco users who undergo behavioral intervention.

O: The outcome pertains to the cessation rates attained in the research.

S: The studies mentioned were randomized controlled trials (RCTs) and clinical trials.

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.[10] The review methodology was registered in PROSPERO (CRD42024506990).

Review questions

1. How does the effectiveness of digital interventions compare to behavioral counseling for tobacco cessation among adults?
2. To what extent do adults engage with and adhere to digital interventions for tobacco cessation?
3. How satisfied are users with the overall experience of utilizing digital interventions for tobacco cessation?

Search strategy

We performed a search utilizing pertinent keywords and datasets. The search approach encompassed terms including "digital interventions," "smoking cessation," "adults," and their permutations. Our primary emphasis was on academic databases, including PubMed, EBSCO, Google Scholar, and specialized journals pertaining to public health and tobacco cessation. Search techniques were limited to the English language exclusively. Databases were searched for studies published from January 1, 2013 to December 31, 2023.

The primary search terms were tobacco, quitting, and digital intervention. The search algorithms are included in Supplementary file 1.

The systematic review's inclusion criteria encompassed randomized controlled trials and clinical trials centered on digital interventions for tobacco cessation, with the primary or secondary aim of evaluating secession rates and supplying comprehensive data on secession rates, follow-up rates, and other pertinent details necessary for the data abstraction sheet. Research published in English from 2013 to 2023 was included, while exclusion criteria comprised literature reviews, systematic reviews, study protocols, studies without full texts, comparator groups, or those exclusively addressing non-digital interventions or systematically ill populations. Moreover, research that integrated digital treatments with alternative methods and research conducted prior to 2013 were omitted. The criteria were rigorously used to guarantee the selection of pertinent and methodologically sound papers for the review.

Evidence selection

Figure 1 illustrates the search and retrieval procedure. The search results were initially imported into Zotero reference management software, where duplicates were eliminated. The revised library was subsequently integrated into Rayyan, a tool for screening systematic reviews. The search strategy was constrained by the timeframe from January 1, 2013, to December 31, 2023. Two investigators assessed the remaining studies by title and abstract to determine eligibility following the removal of duplicates. The investigators convened to resolve any disagreements. This masked procedure was performed in duplicate. An arbitrator made final decisions in instances of unresolved disputes.

Data extraction

The selected publications were thoroughly reviewed, and all pertinent data for the systematic review were carefully collected and arranged in an Excel extraction table. Consistent adherence to the PRISMA guidelines was upheld throughout the review and analysis phases. Crucial information, including trial characteristics, participant demographics, intervention details, outcome measures, follow-up rates, and author disclosures, was collected. In instances of discord among the primary reviewers, a third reviewer was consulted to reconcile any disagreements.

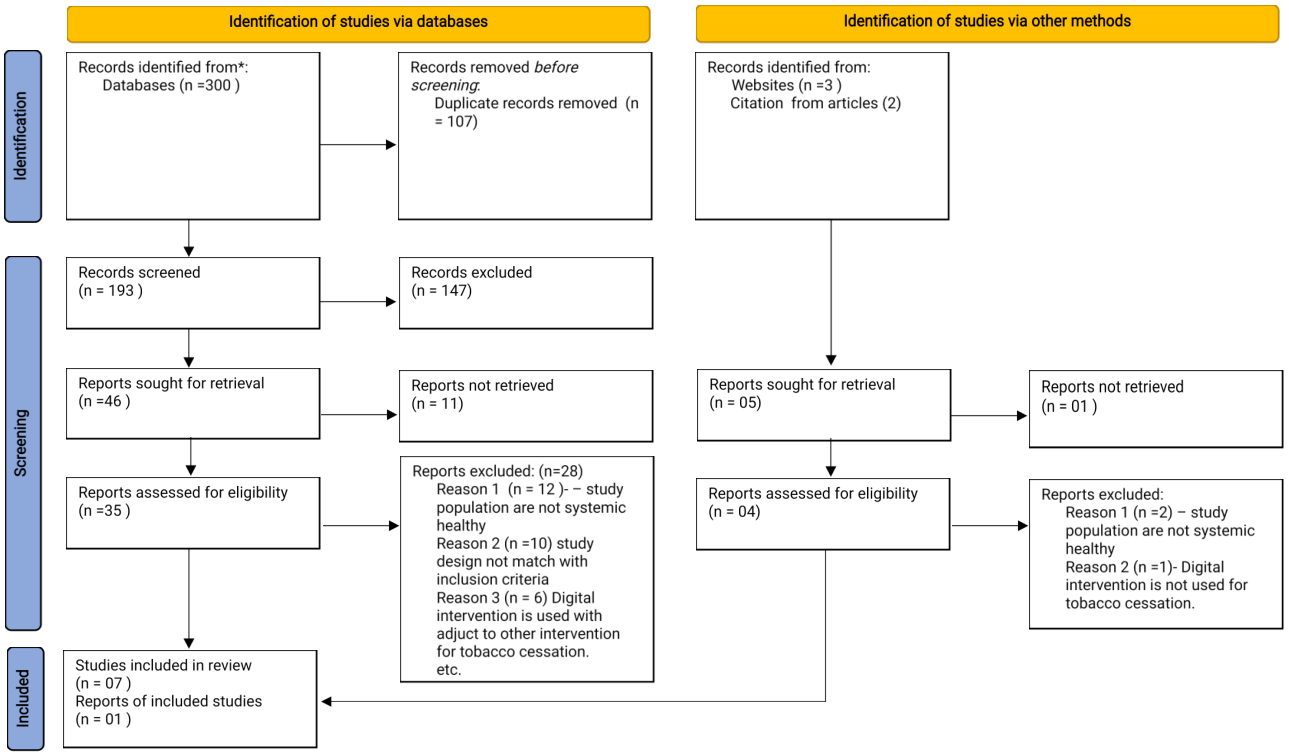

Figure 1. PRISMA Flow chart

Risk of bias assessment

The Cochrane risk of bias instrument for randomized trials version 2 (RoB 2) was used to evaluate the quality of each included study.[11] Performing an assessment across five domains, the tool provides an overall risk of bias categorization (low, some concerns, and high): (*a*) bias arising from the randomization process, (*b*) bias due to deviations from intended interventions, (*c*) bias due to missing outcome data, (*d*) bias in the measurement of the outcome, and (*e*) bias in the selection of the reported result. Each study's assessment was done by one member of the study team and then reviewed by another member. A joint decision was reached.

Results

Following the search, 305 studies were identified. A total of 198 studies were analyzed, of which 151 were discarded due to duplication. Of the 47 publications that underwent full-text examination, eight were finally incorporated into this analysis. The comprehensive summary of the extracted data is presented in Table 1.

Study and participant characteristics

The analyzed studies exhibit a wide array of participant characteristics across multiple clinical trials. Graham et al[14] and Santiago-Torres et al[19] utilized substantial sample sizes, with Graham et al[15] concentrating on young adults averaging 20.4 years of age who were predominantly White, whereas Santiago-Torres et al[19] encompassed adults from all 50 US states, averaging 38.9 years of age and exhibiting a more diverse racial composition. Santiago-Torres et al[17] concentrated on smartphone application treatments for Black adults, while Santiago-Torres et al[18] used a racially diverse sample. Nomura et al[13] and Danaher et al[12] both had limited sample sizes, with Nomura et al[13] focusing on telemedicine and Danaher et al[12] recruiting primarily female participants with an average age of around 45 years. The studies provide diverse participant demographics, including age, gender, and race/ethnicity, illustrating the heterogeneity of clinical trial groups.

Effectiveness as a tobacco cessation aid

Upon analyzing the factors throughout the cited research, numerous salient points arise. Graham et al[14] and Graham et al[15] evaluated vaping cessation strategies, with the former implementing a text messaging program and the latter adopting a combination of a website and text messaging. Graham et al[14] observed elevated abstinence rates in the intervention group relative to the control group, whereas Graham et al[16] found no significant difference between the two groups. Follow-up rates exhibited minor variations, with Graham et al[14] obtaining rates between 75% and 77% at 7 months, whilst Graham et al[15] reported rates of 76.7% at three months and 75.1% at nine months. Santiago-Torres et al[17,18] and Santiago-Torres et al[19] concentrated on smartphone application interventions, demonstrating elevated retention rates and positive abstinence results, especially with the iCanQuit application. Nomura et al[13] and Danaher et al[12] investigated telemedicine and mobile device therapies, respectively, documenting diverse

Table 1. Summary of extracted data

Author's name, year of publication, country	Study design	Sample size	Gender	Age (mean)	Race	Intervention	Comparator	Follow-up rate	Abstinence rate	Outcomes
Danaher et al (2019)[12]	Randomized controlled trial	The study involved enrolling 1271 participants from December 2015 to January 2017.	The participants were predominantly female 78% vs. 22% male	Average age: approximately 45 years	Does not contain specific information regarding the race or ethnicity of the participants.	MobileQuit: designed for mobile devices and constrained its use to smartphones. Included text messaging as part of the intervention. Embodied tunnel information architecture. Encouraged shorter, more frequent visits to the program website.	QuitOnline: Designed for nonmobile desktop or tablet computers. Text messages were not included in the intervention. Used a flexible hybrid matrix-hierarchical information architecture. Allowed variability in device access, including smartphones and other devices.	Follow-up Rates: The 3-month follow-up assessment completion rate was higher for female participants, those without a long-term partner, and those using nicotine replacement aids. The 6-month follow-up assessment completion rate was higher for older participants, those with higher education levels, those using nicotine replacement aids, and those without a long-term partner.	MobileQuit participants had significantly higher abstinence rates than QuitOnline participants. The intention-to-treat analysis showed abstinence rates of 20.7% vs. 11.4% at 3 months, and 24.6% vs. 19.3% at 6 months. Using complete case analysis, MobileQuit showed a significant advantage at 3 months and the combined 3- and 6-month assessments, but not at 6 months.	The primary outcome of self-reported 7-day point-prevalence smoking abstinence was assessed at 3 and 6 months.
Nomura et al (2019),[13]	Multicenter open-label randomized controlled noninferiority trial	The study included a total of 115 participants, with 58 participants in the telemedicine arm and 57 participants in the control arm	Male: 81% Female: 19%	The mean age of participants was 55 years (SD = 12) in the telemedicine arm and 53 years (SD = 10) in the control arm	Details not given	Telemedicine arm: Participants in the telemedicine arm received internet-based Web counseling for the smoking cessation program. They also received the CASC smartphone app and a mobile exhaled CO checker during the 24-week trial period.	Participants in the control arm received conventional face-to-face clinic visits for the smoking cessation program. Similar to the telemedicine arm, they also received the CASC smartphone app and a mobile exhaled CO checker during the 24-week trial period.	All 115 participants who were randomized into the study were included in the final analysis	Continuous abstinence rate (CAR) from weeks 9 to 12: Telemedicine arm: 81.0% (95% CI = 71–91) Control arm: 78.9% (95% CI = 68–89)	Primary Outcomecontinuous abstinence rate (CAR) from weeks 9 to 12: Telemedicine arm: The biochemically validated CAR from weeks 9 to 12 was 81.0% (95% CI = 71–91) Control arm: The biochemically validated CAR from weeks 9 to 12 was 78.9% (95% confidence interval = 68–89) The absolute difference in CAR between the telemedicine and control groups was 2.1% (95% CI = 12.8–17.0) The odds ratio (OR) for CAR between the telemedicine and control groups was 1.14 (95% CI = 0.45–2.88)

Table 1. Continued.

Author's name, year of publication, country	Study design	Sample size	Gender	Age (mean)	Race	Intervention	Comparator	Follow-up rate	Abstinence rate	Outcomes
Graham et al (2021),[14] US	Parallel, 2-group, double-masked, individually randomized clinical trial design	Total participants: 2588 Control arm: 1284 Intervention arm: 1304	Female: 50.3% Male: 48.4% Non-binary or other: 1.0% Refused: 0.2%	Mean age: 20.4 years (SD 1.7)	White: 83.4% Asian: 4.8% Black: 1.5% American Indian/Alaska Native: 0.7% Multiracial: 6.3% Other: 1.9% Refused: 1.1%	Vaping cessation among young adult e-cigarette users using a text message program called "This is Quitting" (TIQ). Participants in the active intervention arm received monthly assessments via text message about e-cigarette use in addition to the TIQ program.	The control arm received no additional intervention beyond the assessments	The follow-up rates at 7 months ranged from 75% to 77%, higher than those typically seen in similar studies.	Self-reported 30-day point prevalence abstinence (PPA) at 7 months post-randomization: Control arm: 18.6% (95% CI = 16.7%–20.8%) Intervention arm: 24.1% (95% CI = 21.8%–26.5%) Odds ratio: 1.39 (95% CI = 1.15–1.68) *P*-value: < 0.001	Outcomes indicate the effectiveness of the text message intervention program in promoting vaping cessation among young adult e- cigarette users, with a significantly higher abstinence rate in the intervention arm compared to the control arm at the 7-month follow-up.
Graham et al (2022),[15] US	Masked, parallel, two-group, individually randomized clinical trial	Total participants: 618 Control arm: 307 Intervention arm: 311	Female: 67.2% Male: 32.8%	Average age: 37.8 years	Non-White: 29.6% Hispanic:17.2%	The treatment arm (WEB + TXT) received access to the website and text messaging.	Control arm (WEB) received access to the website alone.	The follow-up rates in the study were 76.7% at 3 months and 75.1% at 9 months. Specifically, at 3 months, the follow-up rate was 79.8% for the WEB arm and 73.6% for the WEB + TXT arm. At 9 months, the follow-up rate was 77.2% for the WEB arm and 73.0% for the WEB + TXT arm 4	At 9 months post-randomization, the abstinence rates were 23.1% among participants in the WEB + TXT intervention arm and 23.2% among those in the WEB control arm. The odds ratio for abstinence between the two arms was 1.00, with a 95% confidence interval of 0.69–1.45	The primary outcome measured was self-reported 30-day point prevalence abstinence at 9 months post-randomization, analyzed under intent to treat (ITT). Secondary outcomes included 3-month measures of 30-day point prevalence abstinence, intervention engagement, and intervention satisfaction

Table 1. Continued.

Author's name, year of publication, country	Study design	Sample size	Gender	Age (mean)	Race	Intervention	Comparator	Follow-up rate	Abstinence rate	Outcomes
Graham et al (2022),[16] US	Randomized controlled trial	Total sample size: 1829 young adults	Female: 46.3% Male: 52.2% Non-binary or other/refused: 1.5%	The mean age of participants in the study was approximately 20.3 years at baseline	Race: White: 78.0% Asian: 6.9% Black: 3.5% American Indian/Alaskan Native: 1.0% Multiracial: 7.4% Other: 2.2% Refused: 1.0%	The intervention used in the study was "This is Quitting" (TIQ) an automated, tailored, interactive text message program designed for vaping cessation among teens and young adults.	The control group in the study received an "assessment-only control" intervention. After confirming enrollment, participants in the control group only received incentivized text messages asking about e-cigarette abstinence.	The 7-month follow-up rate in the study was 76.0%, with 1967 participants providing data at that time point. Data on combusted tobacco product (CTP) use was missing for 138 participants who reported only their 7-month vaping status. Therefore, the full analytic sample included 1829 participants with complete data on e-cigarette and CTP use at the 7-month follow-up 3	At the 7-month follow-up, the study reported the following abstinence rates among participants: 22.1% were dual abstinent (abstinent from both e-cigarettes and CTPs) and 44.8% were exclusive e-cigarette users. 6.3% were exclusive CTP users, 26.8% were dual users (using both e-cigarettes and CTPs) combining exclusive CTP users and dual users, and 33.1% reported past 30-day CTP use at the 7-month follow-up, representing a 10.3 percentage point reduction from baseline.	The primary outcome of interest in the study was the proportion of participants who achieved dual abstinence, defined as being abstinent from both e-cigarettes and combusted tobacco products (CTPs) at the 7-month follow-up. The study compared treatment arm differences, differences by baseline tobacco product use (exclusive e-cigarette users vs. dual users), treatment arm differences among exclusive e-cigarette users, and treatment arm differences among dual users. Confidence intervals for abstinence rates and *P*-values for between-group comparisons were calculated based on a normal approximation to the binomial distribution.
Santiago-Torres et al (2022)[17], US	Randomized controlled trial (RCT)	Total participants: 897 QuitGuide ($n=437$) iCanQuit ($n=460$) smartphone applications	Female: 72% Male: 28%	Mean age: 36.9 years	White: 61% Black or African American: 27% The remaining participants: other racial categories	Smartphone app: iCanQuit application	Smartphone app: QuitGuide	The study reported high follow-up rates among participants using smartphone applications for smoking cessation. The retention rates were 87%, 90%, and 88% at the 3, 6, and 12-month follow-ups, respectively.	The self-reported complete-case 30-day point prevalence abstinence (PPA) at 12 months was 27% for participants using the iCanQuit application, compared to 20% for those using the QuitGuide application.	The primary outcome was self-reported complete-case 30-day point prevalence abstinence (PPA) at 12 months. Secondary outcomes included 7-day PPA, missing-as-smoking and multiple imputation, prolonged abstinence, and cessation of all tobacco products at 12 months.

Table 1. Continued.

Author's name, year of publication, country	Study design	Sample size	Gender	Age (mean)	Race	Intervention	Comparator	Follow-up rate	Abstinence rate	Outcomes
Santiago-Torres et al (2022) US[18]	A two-arm randomized controlled trial	A sample of 554 Black adults was randomized to receive either the iCanQuit or QuitGuide smartphone application.	Not specified in the article	Mean age: 37.7 years	The study focused on recruiting a racially/ethnically diverse sample of Black adults for the research.	Smartphone app: iCanQuit application	Smartphone app: QuitGuide	The study had a high retention rate, with 89% of participants completing the 12-month follow-up assessment. There was no significant difference in study retention between the iCanQuit and QuitGuide arms.	The study reported the following abstinence rates at different time points: 30-day point prevalence abstinence (PPA) at 3 months: 19% for iCanQuit vs. 11% for QuitGuide. 30-day PPA at 6 months: 28% for iCanQuit vs. 14% for QuitGuide. 30-day PPA at 12 months: 28% for iCanQuit vs. 20% for QuitGuide. Prolonged abstinence at 12 months: 15% for iCanQuit vs. 6% for QuitGuide. 30-day PPA of all tobacco products at 12 months: 25% for iCanQuit vs. 15% for QuitGuide.	The study found that the complete-case 30-day PPA was higher for iCanQuit participants compared to QuitGuide participants at 12 months. Additionally, iCanQuit participants showed higher engagement with the intervention compared to QuitGuide participants
Santiago-Torres et al (2023), US[19]	Randomized controlled trial (RCT)	A total of 2415 adults from all 50 US states.	Female: 72.9%Male: 27.1%	Mean age: 38.9 years	The study provided a breakdown of race and ethnicity among the participants: American Indian or Alaska Native: 39 (2.5%) Asian: 341 (21.8%) Black or African American: 341 (21.8%) Native Hawaiian or Pacific Islander: 2 (0.1%) White: 1050 (67.2%) Multiracial: 103 (6.6%) Hispanic or Latino ethnicity: 130 (8.3%)	Smartphone app: iCanQuit application	Smartphone app: QuitGuide	The study included a subsample of 1562 participants out of a total sample of 2415, resulting in a follow-up rate of 64.7%. This follow-up rate indicates a substantial portion of the initial sample contributing to the study's outcomes.	The study reported a 12-month quit smoking rate of 28% in the iCanQuit app group compared to 21% in the QuitGuide app group. Additionally, the study found that in the QuitGuide arm, adopting e-cigarettes was not associated with 12-month combustible cigarette smoking cessation, with a cessation rate of 18.7% among e-cigarette adopters compared to 19.9% among nonadopters.	The study found that e-cigarette users had lower odds of prolonged abstinence from cigarette smoking than nonadopters. Additionally, 12-month combustible cigarette smoking cessation rates were significantly lower among adopters in the iCanQuit arm than among nonadopters, while no significant difference was observed in the QuitGuide arm.

abstinence and follow-up rates. The efficacy of therapies varied among research, underscoring the necessity for customized strategies in smoking cessation.

Quality of evidence

The studies exhibited a high probability of bias overall. Table 2 illustrates the risk-of-bias evaluation employing the RoB2 method for each included study. The evaluation is founded on five domains: the randomization procedure, deviations from intended interventions, absent outcome data, measurement of the outcome, and selection of the reported result. Each domain is classified as low risk, some concerns, or high risk, reflecting the degree of bias inherent in that facet of the study. This graphic visually depicts the quality of evidence from the included studies, enabling readers to swiftly evaluate the overall risk of bias in the systematic review. The quality of evidence from many studies was evaluated according to different criteria. The investigations by the Graham et al[14] study were assessed as low risk, Graham et al[15] raised some concerns, and Graham and colleagues' study[16] was deemed high risk. Santiago Torres et al[19] did not provide specific risk assessments in their studies.

Santiago Torres et al[19] indicated that their randomization method was robust, suggesting a minimal risk in D1. However, another study by the same authors noted deviations from the targeted interventions (D2). Nomura et al[13] lacked outcome data (D3), and Danaher et al[12] encountered difficulties with outcome measurement (D4). The quality of evidence varied among studies, with some taking rigorous measures while others exhibiting issues such as departures from planned interventions or no outcome data. Table 3 and Figure 2 present the risk-of-bias assessment under the intention-to-treat approach, showing the percentage distribution of studies categorized into different risk levels. The legend indicates this analysis follows the intention-to-treat principle, where participants are analyzed according to their assigned group, regardless of adherence or protocol deviations. The chart illustrates the distribution of studies across various degrees of bias risk, offering insight into the overall quality of evidence and the potential influence of bias on the findings of the systematic review.

Discussion

Of the 198 individual studies examined in the systematic review, eight were ultimately included after a comprehensive assessment. The studies exhibited considerable variation in participant demographics and interventions, indicating a range of methods for smoking cessation. Prominent instances encompass Graham et al[14] and Santiago-Torres et al,[19] both of which featured substantial sample sizes and diverse racial compositions. Graham et al[14] concentrated on young White people with an average age of 20.4 years, whereas Santiago-Torres et al[19] encompassed a wider age spectrum and racial diversity throughout all US states. Other research, such as Nomura et al[13] and Danaher et al,[12] focused on telemedicine and

Table 2. Risk of bias (RoB2 tool) quality assessment

Unique ID	Study ID	D1	D2	D3	D4	D5	Overall
1.	Danaher et al[12]	+	!	+	-	-	-
2.	Nomura et al[13]	+	+	+	+	+	+
3.	Graham et al[14]	+	+	+	-	-	-
4.	Graham et al[15]	+	+	+	+	-	-
5.	Graham et al[16]	+	+	+	+	!	+
6.	Santiago Torres et at[17]	+	+	+	+	-	-
7.	Santiago Torres et al[18]	+	+	+	+	-	-
8.	Santiago Torres et al[19]	+	+	+	-	-	-

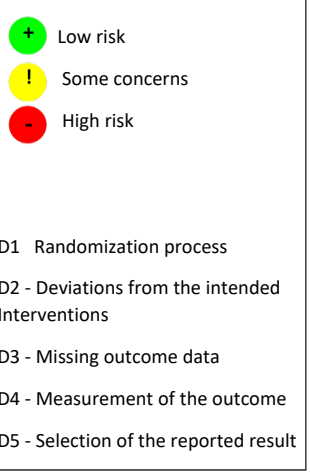

Table 3. Assignment to intervention (the 'intention-to-treat' effect)

	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall bias
Total number of studies = 8						
Low risk	100	87.5	100	62.5	12.5	25
Some concerns	0	12.5	0	0	12.5	0
High risk	0	0	0	37.5	75	75

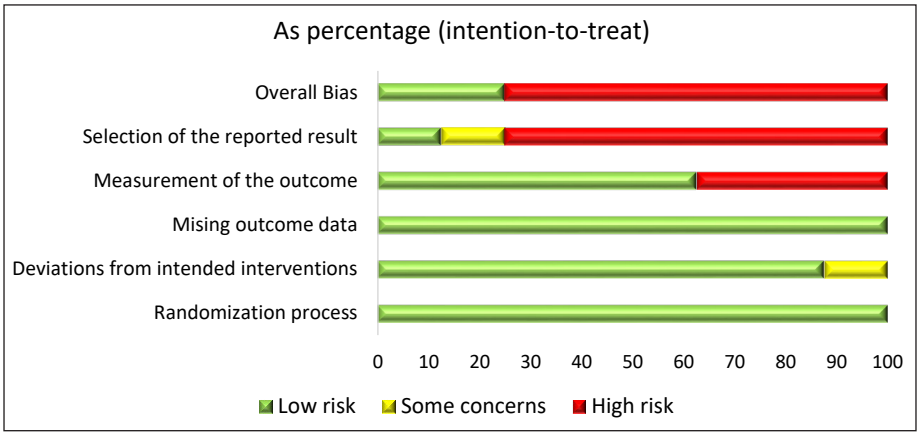

Figure 2. Percentage distribution of studies categorized as low risk, some concerns, and high risk of bias across different domains of the RoB 2 tool (intention-to-treat analysis)

mobile device therapies, mostly including middle-aged and predominantly female participants, respectively.

The efficacy of smoking cessation interventions varies across different modalities. Graham et al[14,15] demonstrated higher abstinence rates with a text message program compared to no intervention, whereas Graham et al[16] found no significant difference between website-only and combined website-text message approaches. Santiago-Torres et al[17-19] reported positive outcomes with the iCanQuit smartphone application, particularly among racially diverse populations, including Black adults. However, differences in engagement levels rather than inconsistencies in interventions may account for variations in efficacy. Similarly, Nomura et al[13] observed comparable abstinence rates between telemedicine and traditional in-person therapies, though challenges with missing outcome data were noted. Danaher et al[12] found higher abstinence rates with a mobile-optimized intervention relative to a desktop-based program but reported difficulties with outcome assessment, possibly due to self-reported data limitations.

The overall quality of evidence was inconsistent, with several studies showing varying risks of bias. Graham et al[14] identified a spectrum of risk, ranging from low to high, influenced by study design and participant adherence. Santiago-Torres et al[17] employed a strong randomization strategy, but engagement variability may have influenced intervention effectiveness. These findings underscore the importance of tailoring smoking cessation strategies to individual and population-specific needs, optimizing intervention design for greater efficacy. The heterogeneity in effectiveness and quality of evidence highlights the necessity for further studies to enhance and standardize these therapies.

Numerous systematic reviews and meta-analyses[20,21] have examined the efficacy of digital treatments for smoke cessation, yielding significant insights into their influence on smoking cessation results. A meta-analysis by Whittaker et al[22] revealed that digital treatments substantially enhanced smoking cessation rates relative to control circumstances, with pooled odds ratios demonstrating a modest impact size. A systematic evaluation by Vilardaga et al[23] showed that digital interventions yielded superior cessation rates relative to non-digital therapies, especially when they included personalized feedback and social support elements.

Effectiveness of text message interventions in vaping cessation: Graham et al[14] established the efficacy of text message interventions in facilitating vaping cessation among young adult e-cigarette users. The study indicated a markedly elevated abstinence rate in the intervention group relative to the control group at the 7-month follow-up, suggesting the efficacy of text message programs such as "This is Quitting" (TIQ) in diminishing vaping behavior. A study by Chan et al[24] evaluated the efficacy of SmokeFreeTeen , a text-messaging smoking cessation strategy for adolescents, and found considerable dropout rates along with low response and abstinence rates. In this study, 64.54% of the participants discontinued before the conclusion of the intervention, with dropout rates reaching their peak on the cessation day. Response rates to inquiries regarding smoking status routinely fell below 30%. Abstinence rates were significantly low, with merely 2.63% of initiators and 6.09% of completers attaining abstinence at the conclusion of the intervention. Significantly, pre-cessation duration correlated with diminished dropout rates and enhanced abstinence, whereas multiple cessation attempts were linked to elevated response and abstinence rates. The data[25-27] suggest that although SmokeFreeTeen has promise, substantial enhancements are required to boost its involvement and effectiveness.

Graham et al[15] conducted a randomized clinical study to compare web-based therapies that included text messaging against those that did not, specifically for smoking cessation. The study revealed no substantial difference in abstinence rates between the intervention group (WEB + TXT) and the control group (WEB) at the

9-month follow-up, indicating that the incorporation of text messaging did not improve the efficacy of web-based therapies alone.

Santiago-Torres et al[17,18] and Santiago-Torres et al[19] assessed the efficacy of smartphone applications, including iCanQuit and QuitGuide for smoking cessation. Both studies indicated elevated retention rates among participants and exhibited superior abstinence rates in the iCanQuit app group relative to the QuitGuide app group at several time intervals, suggesting the potential effectiveness of smartphone-based therapies for smoking cessation. Bricker et al[28] demonstrated analogous results in randomized clinical trials assessing the efficacy of an ACT-based smartphone application (iCanQuit) compared to a USCPG-based application (QuitGuide) for smoking cessation. Among 2415 adult smokers, iCanQuit users exhibited markedly greater probabilities of smoking cessation at the 12-month follow-up in comparison to QuitGuide users. At 12 months, the 30-day point prevalence abstinence (PPA) was 28.2% for iCanQuit users compared to 21.1% for QuitGuide users (OR = 1.49; 95% CI = 1.22-1.83; $P < 0.001$). Comparable notable effects were noted for secondary measures, encompassing 7-day PPA, extended abstinence, and cessation of all tobacco products. The results indicate that ACT-based therapies administered using smartphone applications may surpass traditional USCPG-based methods in efficacy for smoking cessation.

Nomura et al[13] executed a multicenter open-label randomized controlled trial to compare telemedicine-based smoking cessation treatments with traditional in-person clinic visits. The research[29] revealed similar continuous abstinence rates between the telemedicine and control groups, indicating that telemedicine interventions may be as successful as conventional clinic-based methods in facilitating smoking cessation.

Danaher et al[12] conducted a comparative analysis of the efficacy of MobileQuit and QuitOnline programs for smoking cessation. The study indicated markedly superior abstinence rates in the MobileQuit group relative to the QuitOnline group at both three and six-month follow-ups, underscoring the potential benefits of mobile-based therapies over web-based methods.

Nevertheless, a systematic review conducted by Guo et al[30] revealed no significant difference between the smartphone app group and the comparator groups (OR = 1.25, 95% CI = 0.99–1.56, $P = 0.06$). Sub-analyses revealed no significant differences when comparing smartphone applications to alternative therapies. Nonetheless, the integration of smartphone interventions with medication markedly enhanced smoking cessation rates (OR = 1.79, 95% CI = 1.38–2.33). Increased compliance with smartphone interventions yielded improved outcomes (OR = 1.48, 95% CI = 1.20–1.84).

Etter et al[31] undertook a two-arm, parallel-group, individually randomized, double-masked, controlled experiment to assess the efficacy of the Stop-tabac app in facilitating smoking cessation among 5293 daily smokers in France and Switzerland. Although the Stop-tabac group exhibited prolonged app usage (23 days compared to 11 days), the smoking cessation rate at the 6-month mark was comparable between the Stop-tabac group (9.9%) and the control group (10.3%) (OR = 0.96, 95% CI = 0.80–45, $P = 0.63$). The utilization of nicotine medicines was markedly greater in the Stop-tabac group (38% compared to 30%, respectively, $P = 0.004$). A greater percentage of Stop-tabac participants indicated that the app substantially aided their smoking cessation efforts (26% vs. 8%, respectively, $P < 0.001$). Consequently, although the application did not elevate smoking quitting rates, it did improve the utilization of nicotine therapies and user contentment.

The systematic review of digital therapies for tobacco cessation in adults reveals both strengths and drawbacks. The strengths encompass a thorough methodology that meticulously analyzes various digital intervention methods, including smartphone applications, telemedicine, and web-based platforms, thereby augmenting comprehension across several technologies. A rigorous technique, compliant with PRISMA recommendations and utilizing the Cochrane risk of bias tool, facilitated a transparent evaluation of research quality and reduced bias. Furthermore, the incorporation of varied participant demographics provided insights into the efficacy of interventions across distinct populations, hence augmenting clinical relevance. Nevertheless, constraints encompass spatial limitations to US-based studies, which may hinder generalizability and neglect international research. Publication bias due to dependence on published research and heterogeneity among interventions may obscure findings and impede direct comparisons. Moreover, the limitations in long-term follow-ups in some research hinder the evaluation of enduring efficacy. Although offering useful insights, these limitations highlight the necessity for additional research and the consideration of varied contexts in tobacco cessation initiatives.

Conclusion

In conclusion, this systematic study offers significant insights into the efficacy of digital interventions for tobacco cessation in adults, while recognizing its benefits and limits. The results highlight the efficacy of various digital platforms, such as smartphone applications, telemedicine, and online interventions, in facilitating smoking cessation initiatives. Notable limitations include methodological rigor, comprehensive analysis, geographic restriction to US-based studies, and limited long-term follow-up. Expanding the scope to incorporate international evidence and addressing long-term efficacy

gaps can improve the relevance and applicability of findings for global tobacco cessation initiatives. This study enhances the existing knowledge on digital interventions for tobacco cessation, underscoring the necessity for ongoing research and customized strategies to address tobacco use and enhance global public health outcomes.

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Supplementary Files
Supplementary file 1. Search strategy.

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