Evidence and implication of interventions across various socioecological levels to address HIV testing uptake among men who have sex with men in the United States: A systematic review

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Abstract
Objectives: Strengthening HIV testing uptake is critical to curtail the HIV epidemics among men who have sex with men in the United States. Despite the implementation of various interventions to promote HIV testing among men who have sex with men, few aggregated evidence is presented to reflect the “lessons learned” and inform future directions. The objective of this systematic review is to comprehensively summarize published studies that described, tested, and evaluated outcomes (e.g. efficacy, effectiveness, acceptability, feasibility and/or qualitative opinions) associated with an HIV testing intervention and identify gaps as well as opportunities to inform the design and implementation of future interventions to enhance HIV testing uptake among men who have sex with men in the United States.

Methods: We followed the PRISMA guidelines and conducted a systematic review of articles (published by 23 July 2021) by searching multiple databases (PubMed, MEDLINE, Web of Science and PsycINFO).

Results: Among the total number of 3505 articles found through multiple databases, 56 papers were included into the review. Interventional modules that demonstrated acceptability, feasibility and efficacy to improve HIV testing uptake among men who have sex with men include: HIV self-testing, interpersonal-level (e.g. peer-led, couple-based) interventions, personalized interventions and technology-based interventions (e.g. mHealth). Aggregated evidence also reflects the lack of individualized interventions that simultaneously address time-varying needs across multiple socioecological levels (e.g. individual, interpersonal, community, structural and societal).

Conclusion: Development of interventions to improve HIV testing rates and frequency of men who have sex with men has proliferated in recent years. Our review presents important implications in sustaining and improving interventions to address HIV testing uptake among men who have sex with men in the United States.

Keywords
HIV testing, AIDS, intervention, men who have sex with men, systematic review, United States

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HIV testing is the entry point into the HIV care cascade. HIV testing is also a requirement and core component for PrEP (initiation, continuation), and test-and-treat. The expansion of HIV testing and early initiation of these biomedical HIV prevention strategies is critical to curtail the epidemic among HIV-affected populations. In addition, awareness of HIV status was reported to be significantly associated with greater condom use, through which onward transmission of HIV could be prevented. In addition to conventional facility-based HIV testing, different testing modalities including rapid home self-testing (an oral fluid test with rapid provision of testing results), mail-in self-test (dried blood self-collection from a fingerstick for laboratory testing) and couples HIV testing and counseling (CHTC, a couple-based HIV testing service called Testing Together) have been designed and implemented for MSM in the United States to facilitate testing uptake among this subgroup.

Despite the proven HIV prevention benefits and increase in accessibility, HIV testing uptake remains suboptimal among MSM in general. A meta-analysis conducted among Internet-using MSM suggested that only 58% had tested for HIV in the prior year. The prevalence of HIV testing among same-sex male couples was even lower, where no more than 30% of them had gotten tested for HIV every 6 months. Low HIV testing rates among MSM in the United States could be attributed to a variety of factors at multiple levels, including individual (e.g. lack of knowledge on testing locations, fear of a positive result and worries about confidentiality), interpersonal (e.g. lack of support), institutional/policy (e.g. lack of financial support for HIV testing programs) and social-cultural (e.g. stigma and discrimination) levels.

The number of behavioral and structural interventions aimed at improving MSM’s engagement in HIV testing has increased since 2005. One of the early randomized controlled trials (RCTs) was “Many Men, Many Voices” with Black MSM residing in New York City. This intervention aimed to improve their knowledge of and attitudes toward HIV and address structural barriers to testing such as racism and homophobia. Participants were observed to have greater odds of HIV testing compared to the waitlist comparison condition (odds ratio (OR) = 1.81, 95% confidence interval (95% CI): 1.08 - 3.01). The limitations of the study included the cost associated with organizing an intervention retreat and diminished retention rate across study periods.

More novel psychosocial interventions (e.g. couple-based, social media, behavioral economics, peer-driven) had been designed and implemented targeting MSM to enhance their HIV testing uptake. While these interventions were successful to promote HIV testing among MSM in a defined period of time, they also have had various levels of limitations in generalizability and sustainability post the intervention period.

Despite an increasing body of literature in designing and evaluating interventions to promote HIV testing, few in-depth, systematic summary of the contents, opportunities, strengths and limitations of these interventions is presented for MSM in the United States. The aggregated evidence from existing interventions with a goal to increase HIV testing uptake among MSM may provide prevention scientists with important information regarding which intervention components, modalities and frameworks may work best for various subgroups of MSM; equally important, what interventional aspects may need to be further strengthened to better enhance HIV testing for MSM in the United States. To this end, the objective of this systematic review is to comprehensively summarize published studies that described, tested, and evaluated outcomes (e.g. efficacy, effectiveness, acceptability, willingness, feasibility, barrier/facilitator, and/or qualitative opinions) associated with an HIV testing intervention, and identify gaps as well as opportunities to inform the design and implementation of future interventions to enhance HIV testing uptake among MSM in the United States.

Methods

Literature search strategy

This systematic review was conducted by searching published articles via multiple databases (PubMed, MEDLINE, Web of Science and PsycINFO) published by 23 July 2021, following the PRISMA guidelines (see supplemental material—PRISMA Checklist). The final search terms included: (“gay” OR “men who have sex with men” OR “bisexual” OR “homosexual” OR “homosexuality” OR “same-gender-loving” OR “sexual minority”) AND (“HIV” OR “human immunodeficiency virus”) AND (“testing” OR “test” OR “diagnosis” OR “screening”) AND (“intervention” OR “trial” OR “experiment” OR “randomized” OR “pre-post”). We also conducted cross-referencing by reviewing the reference list of the included studies to identify potential papers for consideration.

Inclusion/exclusion criteria

Generally, studies were included in the systematic review if they met the following criteria: (1) published journal articles excluding abstracts or conference proceedings; (2) conducted in the United States; (3) this study and/or the parent trial was based on an experimental or quasi-experimental design (e.g. RCT, one-group pre-post) to test an HIV testing intervention; (4) reported HIV testing–related outcomes (e.g. efficacy, effectiveness, acceptability, intention and willingness) with relevant determinants (e.g. any demographic, behavioral and psychosocial factors); (5) conducted among participants identified as gay, bisexual and other MSM in the original studies; and (6) published in English.

condomless sex, multiple sex partners and social stigma about HIV and/or their sexual orientation and identity. Vinylflex nature, social-cultural (e.g. stigma and discrimination) levels.

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To achieve our goal of comprehensively summarizing the content, scope and factors affecting the implementation of HIV testing interventions for MSM, we also included the following studies for potential evaluation: (1) studies conducted among mixed population groups (e.g. MSM and other sex and gender minorities) if data were reported separately for MSM; (2) studies that used an experimental design to evaluate secondary outcomes (e.g. acceptability, feasibility or cost-effectiveness) with or without reporting efficacy/effectiveness; (3) studies using non-experimental design (e.g. qualitative or cross-sectional study) to assess aforementioned secondary outcomes of an HIV testing intervention if details about the intervention design could be retrieved from their published parent trials by checking the reference lists; (4) we also included protocols that elaborated the design and conceptual frameworks to supplement our summary of the original HIV testing interventions. Any existing reviews, meta-analyses or articles that commented on an existing HIV testing intervention were not included in the current review. We also excluded studies that described the development or adaptation of eligible interventions.

Statistical analysis

All articles identified through database search were stored and managed using a reference management tool (EndNote X9). Titles and abstracts of all identified records were first screened for relevancy and duplicate removal by two independent reviewers (Y.W. and Y.L.). The full-text review and data extraction were then conducted independently by one author (Y.W.) and further cross-checked by the other author (Y.L.) for accuracy. Disagreements were iteratively discussed until agreement was reached. A standardized Excel sheet was used to extract the following information from eligible articles: study location, study/recruitment period, study design, recruitment strategy, participant characteristics, intervention content, theoretical/conceptual framework, barriers to HIV testing addressed by the intervention, control, sample size and retention, HIV testing–related outcome measures and findings (e.g. acceptability, feasibility, cost-effectiveness and efficacy).

Methodological quality assessment

The quality of each study was assessed independently by one author (Y.W.), following the guidance for study assessment. The other author (Y.L.) further cross-checked the appraisal for accuracy. Conflicts in appraisal were resolved through iterative discussion until agreement was reached. The methodological quality of included studies with a control group was evaluated using National Heart, Lung, and Blood Institute (NHLBI) quality assessment tool of controlled intervention studies. This assessment tool was comprised of 14 questions, which evaluated selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and intervention providers), detection bias (blinding of outcome assessors), attrition bias (drop-out), information bias (measurement of outcomes) and other sources of bias. We rated yes, no, cannot determine, not reported or not applicable for each criterion. For example, if authors reported method of randomization, but we were unable to determine whether the randomization was adequate and would respond “cannot determine” to this criterion. If authors did not mention the method of randomization, we scored “not reported” for this criterion. The remaining pretest–posttest studies were similarly assessed using NHLBI quality assessment tool for before–after (pre–post) studies with no control group. Two assessment tools have been described in detail elsewhere.

Results

Search results

A total number of 3505 articles were found through multiple databases. Of 73 full-text papers assessed for eligibility, 56 papers representing 42 interventions were included into the final review. Thirty-seven papers evaluated the acceptability, feasibility, efficacy or cost-effectiveness of interventions aimed at improving MSM’s uptake of HIV testing. Seventeen articles described the protocols for the implementation of interventions. Study selection process was reported in Figure 1.

Study characteristics

Table 1 presented the characteristics of 42 interventions identified from 56 included publications. Reported study locations/settings in the United States included Oregon, Nevada, New York, California, Michigan, North Carolina, Minnesota, Texas, Pennsylvania, Tennessee, Louisiana, Maryland, Massachusetts, Nevada, Florida, Minnesota and D.C. Nineteen interventions were conducted nationally, and others were implemented after 2000. Nine RCTs are still ongoing. Thirty-one interventions were evaluated by RCTs. Eleven studies were evaluated by using a quasi-experimental design. Of the 11 used a pretest–posttest design.

Regarding recruitment, offline/in-person approaches ranged from outreach (e.g. at local venues, communities, LGBT health care organizations and sexual health clinics), advertisements placed in communities, venues, and print media frequented or used by MSM, to referrals from other participants, friends of participants, and clinicians. Peer recruitment within their social networks or venues-based peer outreach were also reported. Online recruitment included advertisements placed on gay-oriented
sexual networking websites, social media sites and social magazines. Participants were MSM only, or a mixture of MSM with other populations (e.g. heterosexual IV drug users, women or transgender people). Of note, some studies targeted Black, or a mixture of MSM with other populations (e.g. heterosexual IV drug users, women or transgender people).

Methodological quality assessment

Methodological quality assessment for studies with and without a control group was summarized in Tables 2 and 3, respectively. Of 37 controlled intervention studies, one study received a score of 11 and were considered good quality, and 24 received a score of 5 to 10 and were considered fair quality. Twelve studies received a score of <5 due to the non-randomized design or lack of evaluation data (i.e. protocols). Five pretest–posttest studies had a mean score of 5.8 (standard deviation = 1.30). All five studies had clear objectives, well-defined interventions that were consistently applied to the participants, and appropriate statistical analyses.

Measurement of outcome

Knowledge of HIV testing and testing locations as outcome measures were reported. Attitudes toward HIV testing were measured by motivation to receive testing on a 5-point Likert-type scale or willingness to refer other MSM to get
### Table 1. Summary of study characteristics.

| Source | Location/setting | Recruitment/visit period | Study design | Recruitment strategy | Population characteristics | Intervention component | Theoretical framework or intervention model | Barriers addressed by the intervention | Control | Outcome measures | Findings (acceptability, feasibility or cost-effectiveness) |
|--------|------------------|--------------------------|-------------|----------------------|---------------------------|-----------------------|--------------------------------------------|---------------------------------------|---------|------------------|----------------------------------------------------------|
| Foley et al. | Oregon | August 1996–March 1997 | Quasi-experimental | Not reported | | A mix of MSM and heterosexual drug users and female prostitutes | Anonymous HIV testing (1996–1997) | Not reported | | | | |
| Wilson et al. | New York, NY | August 2005–November 2006 | RCT | Street outreach at drop-in centers, work sites, bar settings, parks, and street corners | | | | | | | | |
| Marinova et al. | Northern San Diego County, CA | June–December 2006 | Quasi-experimental | | | Seven low-risk venues (a drive-thru, a relocation center, a senior center, and a bar) | Social-cognitive framework | Intrapersonal: lack of HIV knowledge Social-cultural: lack of social support, discrimination, and stigma | | | |
| Ouellet et al. | Drummond, Q | 2006–2008 | RCT | Peer outreach at community venues providing seminars and workshops for African American MSM and young people in general | | | | | | | |
| Rhodes et al. | Atlanta, GA | February–July 2009 | Preregister | Recruitment at chat rooms | | | | | | | |
| Hersfield et al. | Northeastern Nevada | April–June 2008 | RCT | Online chat room providing social support and networking for MSM in northwestern Nevada | | | | | | | |
| Acapulco et al. | Los Angeles, CA | September 2007–January 2011 | RCT | Internet-based outreach to gay and bisexual men in Los Angeles | | | | | | | |

**Notes:**
- **RCT** indicates randomized controlled trial.
- **Preregistered** indicates participants were pre-registered for the study.
- **Baseline** indicates the baseline assessment.
- **Pretest** indicates the pre-test assessment.
- **Posttest** indicates the post-test assessment.
- **Outcome measures** include various measures of acceptability, feasibility, and efficacy.
- **Findings** include acceptability, feasibility, and cost-effectiveness of the intervention.

**Table Continued...**
| Source | Location/setting | Recruitment/ study period | Study design | Recruitment strategy | Population characteristics | Intervention (components) | Theoretical/conceptual framework | Multidisciplinary barriers addressed by the intervention | Control | Outcome measures | Findings (acceptability, feasibility, efficacy, cost-effectiveness) |
|--------|-----------------|--------------------------|-------------|----------------------|---------------------------|--------------------------|-------------------------------|--------------------------------|--------|--------------|---------------------------------------------------------------|
| Bauermeister et al. | Southeast Michigan | Not reported | RCT | In-person recruitment at LGBTQ pride celebrations, distributing photo cards in various bars and clubs that served LGBTQ; Facebook ads, endline and follow-up interviews; Michigan-based LGBTQ social magazine | Young MSM (mean ± SD): 21 ± 3.2; White: 65.6%; Black: 9.5%; Latino: 12.6%; Gay men: 14.8% | “Get Connected”: a tailored website-based intervention | Self-determination theory and integrated behavioral model | Individual: lack of knowledge of HIV testing, attitudes and risk-taking behaviors; lack of social support and social norms | Provider-based barriers | Baseline: 86 vs. 44; Day 30: 93 (60%) | Efficacy: 6.16 vs. 0.18; Cohen’s $d$ = 2.4; Feasibility: Recruited and retained over 2 years; Efficacy: 6.16 vs. 0.18; Cohen’s $d$ = 2.4; Feasibility: Recruited and retained over 2 years |
| Efficacy evaluation Katz et al. | Washington State | January 2010–October 2014 | Quasi-experimental | Secondary analysis of STD surveillance partner services (PS) and HIV/AIDS database | MSM with STIs (King County residents, including Seattle): 38% | Integrating HIV testing as an outcome of STD PS: Health departments in Washington State modified STD PS programs with the objective of promoting HIV testing at all MSM with STDS and with thrashing that those without a prior HIV diagnosis tested for HIV infection | Not reported | Institutional: lack of testing resources | Protocol: IMS333 Innovated in period 48BD | Efficacy: HIV testing among MSM who received PS increased from 63% to 79% ($p$ < 0.001); Cost: Time spent on HIV testing <5 minutes per interview; Total STD PS program cost per HIV test: US $988–US $9467 |
| Meeks et al. | Atlanta, GA | January–March 2015 | Pretest-posttest | Word of mouth, phone calls, and Web-based advertisements on dating websites for gay and bisexual men | MSM (4%) and transgender female sex workers (TFSW): 27% | A video chat and peer-based intervention: Participants engaged with the peer counselor in person: HIV counseling, self-administration of the HIV test via video chat. The counseling included a practical and tailored sexual education about substance use, barriers to testing, etc. | Not reported | Institutional: lack of peer support | Protocol: 20 Week 2 & 18 Month: 3–8 | Acceptability: Satisfaction with intervention at the 3-month; Feasibility: HIV testing appointment completion: 87% | Efficacy: Past 12-month HIV testing rated on a Likert-type scale (1 strongly disagree to 6 strongly agree) |
| Rhodes et al. | Four geographically focused social media sites: Atlanta/GA, Baltimore/MD, Columbus/Ohio, and San Francisco/CA | July 2013–June 2014 | RCT | Not reported | MSM (44% of participants) and transgender (43%): Age (mean ± SD): 40 ± 11.3 | A social media-based intervention: Within social media sites for MSM, the health educator at a public perfil on his profile about HIV, the importance of testing to availability to provide information and access questions about testing, and local, nongovernmental health testing agencies | Not reported | Intrapersonal: lack of support | Protocol: 333 Innovated in period 48BD | Efficacy: Past 12-month HIV testing at posttest: 63.7% vs. 42.0% (OR = 2.9, 95% CI: 1.7–4.9) |
| Bauermeister et al. | Nationwide | November 2016 | RCT | Online ad placed on online social and sexual networking sites | Online ad placed on online social and sexual networking sites | “My Doc”: a tailored online-based intervention | Integrative behavioral model: Content will focus on the reduction of mentors, norms, perceived difficulties of behavior in MSM; social norms; anticipated regret, perceived behavioral control | Intrapersonal: lack of knowledge | Protocol: 20 Week 2 & 18 Month: 3–8 | Acceptability: Satisfaction with intervention at the 3-month; Feasibility: HIV testing appointment completion: 87% |
| Protocol: Mejia et al. | New York, NY | June 2016–February 2017 | RCT | Online advertising, face-to-face outreach, and participants web | Black MSM (88%) and transgender (12%): Age (mean ± SD): 21 ± 13; Gay/lesbian gender identity: 66.7% | “All About Me”: A tailored computer-based intervention | Self-determination theory, social cognitive theory, and social information processing | Intrapersonal: lack of knowledge | Protocol: 18 Week 3 & 22 Month: 3–8 | Acceptability: Satisfaction with intervention at the 3-month; Feasibility: HIV testing appointment completion: 87% |
| Protocol: Mejia et al. | Two sexual health clinics in Oakland and Hollywood, CA | October 2016–June 2017 | Quasi-experimental | In-person recruitment at study clinics and community social networking sites | Young MSM (mean ± SD): 23 ± 3; Hispanic/Latino: 43% | “Stick To It”: A website-based intervention using gamification | Self-determination theory and integrated behavioral model | Intrapersonal: lack of knowledge of HIV testing, attitudes and risk-taking behaviors; lack of social support and social norms | Protocol: 18 Week 3 & 22 Month: 3–8 | Acceptability: Satisfaction with intervention at the 3-month; Feasibility: HIV testing appointment completion: 87% |

**Table 1. (Continued)**
### Table 1. (Continued)

| Source | Location/setting | Recruitment/ study period | Study design | Recruitment strategy | Population characteristics | Intervention (components) | Theoretical/conceptual framework | Multibarrier barriers addressed by the intervention | Control | Simplex or multisite vs. intervention vs. control | Outcome measures | Findings (acceptability, feasibility, efficacy or cost-effectiveness) |
|--------|------------------|---------------------------|-------------|---------------------|---------------------------|---------------------------|-----------------------------|----------------------------------|--------|-------------------------------|-----------------|--------------------------------------------------|
| Feinstein et al.  | Chicago, IL | January–October 2015 | RCT         | Targeted Facebook ads versus traditional recruitment (e.g., local community groups, outreach from HIV testing and primary care programs in a local LGBT health care organization) | Young male couples Indigenous status: 50% White; 31% Black; 35% Hispanic; 28% Asian; 5% other; Mean age: 29.3 | "2GETHER": a couples-based intervention | (1) Information/Motivation/Behavioral risk reduction and coping strategies for coping with minority stress and relationship stress; (2) communication skills training; (3) healthy sexuality for couples and existing a relationship agreement. | (L) Information/Motivation/Behavioral Skills model Information: couples-specific HIV knowledge (e.g., HIV risk in couples). Motivation: attitudes and peer norms relevant to couples (e.g., discussions about safer sex and HIV testing). | Pretest–posttest | Increase from baseline to 3-month follow-up | Efficacy: Month 3: increased from 53.6% at baseline to 65.0% (prevalence ratio = 1.20, 95% CI: 1.06–1.36) Month 6: increased from 53.6% to 70.2% (prevalence ratio = 1.28, 95% CI: 1.11–1.47) | Acceptability: More acceptability ratings across intervention sessions 4.3–4.7 Feasibility: Recruited a diverse sample and maintained continuous intervention engagement Effectiveness: Dyadic motivation to receive couples-based HIV testing measured based on a Sport-Likenmeyer scale |
| Wang et al. | Chicago, IL | May–September 2015 | RCT         | Peer support for couples and creating a relationship agreement. | Humanists; 3% Asian; 2% Hispanic; Mean age: 32.5 | "HOA on Groups": a traditional intervention | Social cognitive theory, empowerment education, and traditional Hispanic/Latino values | Interpersonal: lack of HIV knowledge and motivation; Intrapersonal: lack of recruitment and knowledge on HIV and testing locations. | Pretest–posttest | Increase from baseline to 3-month follow-up | Efficacy evaluation: Ybarra et al. Pretest–posttest assessment of HIV testing behavior with the same number of questions and items focused on testing in past 6 months (OR = 13.84, 95% CI: 7.56–25.33) | Acceptability: More acceptability ratings across intervention sessions 4.3–4.7 Feasibility: Recruited a diverse sample and maintained continuous intervention engagement Effectiveness: Dyadic motivation to receive couples-based HIV testing measured based on a Sport-Likenmeyer scale |

(Continued)
The trial is ongoing.

Follow-up assessments conducted at 3, 6, 9 and 12 months.

Boudewyns et al. (2021) suggested that the "Locator" component of Boudewyns et al. (2021) is a communication campaign designed to increase awareness and knowledge of HIV among Black MSM. The campaign includes a mobile app and peer-to-peer support, with the goal of reducing stigma and increasing HIV testing among the target population.

Usability evaluation of an internet-based HIV testing intervention showed that the Usability of the intervention was rated by experts, with scores ranging from 0.4-2.6 (0 = no problem to 4 = usability catastrophe).

Katz et al. (2021) described a study with two arms: an Attention-control arm and an Intervention arm. The Attention-control arm included participants who received access to the "Locator" component of Boudewyns et al. (2021), while the Intervention arm received access to the full "Testing Makes Us Stronger" (TMUS) intervention.

Lightfoot et al. (2021) reported on the "MyPEEPs" intervention, which is a mobile app-based intervention designed to improve HIV knowledge and motivation among Black MSM. The intervention includes didactic content, multiple-choice quizzes, and social support from network members.

McManus et al. (2021) also described an intervention called "MOTIVES" and an internet-based intervention called "testing makes us stronger" (TMUS), which were delivered through multiple social media platforms.

Social-cultural factors, such as lack of social support and contextual risk factors, were found to be significant predictors of HIV testing among Black MSM. For example, in Katz et al. (2021), the "testing makes us stronger" (TMUS) intervention resulted in increased HIV testing among Black MSM, with more HIV testing events in the treatment group compared to the control group.

Additional factors such as age, race, and ethnicity were also considered in the analysis, with Katz et al. (2021) reporting that Black MSM aged 27-47 had higher rates of HIV testing compared to younger or older age groups. Racial and ethnic minority statuses (e.g., African American or Latino) were associated with lower rates of HIV testing.

Table 1. (Continued)
| Source | Location/setting | Recruitment/ study period | Study design | Recruitment strategy | Population characteristics | Intervention (component) | Theoretical/constructual framework | Multilevel barriers addressed by the intervention | Control | Simple aim and intervention (a vs. intervention) | Outcome measures (a vs. control) | Findings (acceptability, feasibility, efficacy or cost-effectiveness) |
|--------|-----------------|---------------------------|-------------|---------------------|---------------------------|--------------------------|-------------------------------|-----------------------------------|---------|-----------------------------|--------------------------------|--------------------------------------------------|
| Stephenson et al. | Detroit, Flint, and Ann Arbor, MI | Launched in April 2017 | RCT | Web-based ad on social media websites (e.g., Facebook, Grindr) in-person recruitment, viral� and community outreach in the region | Young MSM and transgender adults aged 15–29 years old | “Swerve”: a tailored intervention Component included: (1) implementing motivational interviewing to explore solutions, use, and concerning sexual-risk-taking with cultural and developmental tailoring for participants, and (2) risk reduction counseling for HIV-negative participants or linkage and retention with HIV care among newly HIV-diagnosed individuals | Social cognitive theory, motivational interviewing, and self-determination theory | Social cognitive factors that impact behavior change: knowledge and motivation | Standard HIV counseling, testing, and referral | Participants will be followed for 18 months, with follow-up assessments conducted every 3 months | Preliminary efficacy (eTEST vs. standard vs. control): HIV testing at least once at 7 months: 100% (0.007) | (Continued) |
| Pilot trial: Wray et al. | Northeastern United States | Launched in January 2019 | RCT | Gay-oriented smartphone dating apps (e.g., Grindr and Scruff), social networking sites (e.g., Facebook and Instagram), and in-person outreach (e.g., flyers) | High-risk MSM only | (1) “St��’: a mobile app-based intervention Participants received HIV self-testing kits equipped with devices that detected when kits were opened. Within 24h of opening the kit, a counselor will call participants to conduct post-test counseling and refer them to other needed services. (2) Standard HIV self-testing kits with no follow-up | Social cognitive theory: Constructs: self-regulation: self-monitoring and self-efficacy for HIV testing and prevention and an individually tailored HIV testing plan | Institutional: no access to transportation and testing locations Socio-cultural: stigma | Not reported | Institutional: no access to transportation and testing locations Social-cultural: stigma | The proportion of participants who obtained at least 2 tests at least 3 months apart within 12 months | The trial is ongoing. |
| Protocol: Balla et al. | Boston, MA, and Bronx, NY | Launched in October 2018 | RCT | Recruitment at organizations and venues where HIV testing, fly-by, posters, and cards are placed in these venues and advertisements on popular Web-based social media websites (e.g., Facebook, Grindr, etc.) | MSM aged 15 to 24 years | “MyChoices”: a mobile app-based intervention Core elements included: tailored information on self-regulation of HIV risk, self-efficacy for HIV testing and prevention and an individually tailored HIV testing plan | Social cognitive theory: Constructs: self-regulation: self-monitoring and self-efficacy for HIV testing and prevention and an individually tailored HIV testing plan | Institutional: no access to transportation and testing locations Social-cultural: stigma | Test messages will be sent to participants every 3 months to remind them to get tested for HIV at a local clinic and provide them with information about free clinic-based testing in the area. | Participants will be followed for 12 months, with follow-up assessments conducted at baseline, 4 months, 8 months, and 12 months | The proportion of participants in each group who (1) tested for HIV in any year over the 12-month period (2) tested within the 12 months prior to the year-long study | Preliminary efficacy (eTEST vs. standard vs. control): HIV testing at least once at 7 months: 100% (0.007); Repeat testing: 81.0% vs. 77.2% vs. 40.9% (p=0.001) | (Continued) |
| Gamarel et al. | Nationwide | Launched in June 2017 | RCT | Online ad placed on key social media websites (e.g., Facebook) and in social media sites aimed specifically at MSM (e.g., Grindr) | MSM aged 15–34 years and their partners | “We Prevent”: a couple’s video-chat based intervention Two tailored delivered sessions are (1) a technical chat to build communication skills in a relationship and (2) couples HIV testing and counseling and prevention planning. Both sessions are attended by both members of the dyad. | Relationship-Oriented Information-Motivation-Behavioral Skills: Information: YMSM-specific knowledge (e.g., within dyads and with outside partners), Motivation: attitudes and peer norms about HIV and prevention in relationships, and Behavioral Skills: motivational interviewing and self-regulation | Institutional: no access to transportation and testing locations Social-cultural: stigma | Participants will be followed for 6 months, with follow-up assessments conducted at 6 months | Participants will be followed for 12 months, with follow-up assessments conducted at baseline, 6 months, and 12 months | Acceptability: Mean System Usability Scale (0–100) score 71.1 ± 10.8 Feasibility: Frequency of using the app: 80% on average over the 3-month period | (Continued) |

(Continued)
Table 1. (Continued)

| Source | Location/testing | Recruitments/ study period | Study design | Recruitment strategy | Treatment arms | Population characteristics | Intervention (components) | Theoretical conceptual framework | Multilevel barriers addressed by the intervention | Control | Simple data and information (intervention vs. control) | Outcome measures | Findings (acceptability, feasibility, efficacy or cost-effectiveness) |
|--------|------------------|----------------------------|--------------|---------------------|----------------|--------------------------|--------------------------|-------------------------------|--------------------------------|---------|--------------------------------|-----------------|-----------------------------------------------|
| Protocol Liu et al. | Not reported | Lunchinl, October 2018 | RCT | Web-based and social media strategies (Graphical, social networking sites, etc.), distributing posters, flyers, printed cards, direct outreach at local venues frequented by MSM, and direct-based recruitment including screening random during referrals | MSM aged 15–24 years | “LUVN!” a mobile app-based intervention on The app included information, due to track sexual behaviors, a personalized mining risk assessment, social media, sharing the result, sexual behavior, et al. and personal social networking sites. Personalized testing reminders (HIV STI testing day and personal HIV risk factors and behavioral skills. Home-based HIV testing options and instructions, personalized testing area and links to HIV care information. Social cognitive theory. Theory constructs (e.g., information, relevance, norms, barriers, and self-efficacy). | Information: Privacy, Behavioral Skills, social information, Personalized HIV risk assessment, sexual behavior, et al. and personal HIV risk factors and behavioral skills. Home-based HIV testing options and instructions, personalized testing area and links to HIV care information. Social cognitive theory. Theory constructs (e.g., information, relevance, norms, barriers, and self-efficacy). | Key personal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | RCT | 1. HIV testing frequency: number of HIV tests during study and 2. HIV testing knowledge, attitude, and behaviors measured by National HIV Behavioral Surveillance. | Participants will be followed for 24 weeks with follow-up assessments conducted in 12 and 24 weeks. | (1) HIV testing: frequency of HIV testing during study and (2) HIV testing knowledge, attitude, and behaviors measured by National HIV Behavioral Surveillance for all 10 men who see sex with men at-risk. Acceptability: Very convenient to use test kit in future: 80%. Extremely confident in correct use of test: 80% |
| Salvin et al. | Oregon, WI, New York, City, NY, and Atlanta, GA | January–November 2018 | RCT | Targeted banner ads (e.g., Facebook), traditional print ads (e.g., bars, public events), recruitment at venues includes referrals from community service providers; and expansion outreach | MSM aged 19 years and older | “MyGuru!” a mobile app-based intervention The intervention includes a mobile app with information and video messages for participants. The messages included condom use, HIV testing, etc. | Multilevel barriers addressed by the intervention | Key personal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | Social cognitive theory. Theory constructs (e.g., information, relevance, norms, barriers, and self-efficacy). | Waitlist control: participants were given the option of accessing the intervention app at nine months post enrollment. | RCT | Well at control: participants were given the option of accessing the intervention app at nine months post enrollment. | A total of 1229 MSM were enrolled. Participants were followed for 9 months with follow-up assessments conducted at 3, 6, and 9 months. | HIV screening behaviors in the past 12 months. | HIV screening behaviors in the past year. The result has not been reported. |
| Edwards et al. | Los Angeles County Men’s Central Jail and residential reentry facilities in the county | Launchinl, November 2019 | RCT | Referral by staff at residential facilities and in-person enrollment in jail | MSM and transgender men living in jail | A mobile app and peer-based intervention Participants will receive customized wellness goals in addition to Graphical, personal, and intrapersonal support provided. | Multilevel barriers addressed by the intervention | Key personal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | Social Cognitive Theory. Environmental factors include the experience of social support, social norms, availability of care services, competencies, barriers, needs for care, and support. The behavioral factors include lack of knowledge about HIV prevention and the skills to perform and maintain related behaviors; and behavioral factors include self-efficacy, outcome expectations, goal setting, and problem solving. | Intrapersonal: lack of HIV knowledge and motivation. | RCT | Intrapersonal: lack of HIV knowledge and motivation. | Participants receive usual care. | Participants will be followed for 9 months with follow-up assessments conducted at 3, 6, and 9 months. | HIV screening behaviors in the past 12 months. | The end is ongoing. |
| Harwas et al. | Los Angeles, CA | October 2015–April 2017 | RCT | Direct outreach at public venues, community-based organizations, parks, and events; provider referrals from physicians; public venues, and online recruitment via Graphical, social networking sites, and a study website | Black MSM (age: 18 and older): 44% | “The Passport to Wellness” a peer-led intervention Intervention components included (1) a customized wellness plan (or Passport) that included information on health and support services and reminders for accessing those services; (2) incentives for completing documentation of completed Passport activities; (3) a trained peer who provided support, encouragement, and navigation and (4) a referral to health and social services. | Multilevel barriers addressed by the intervention | Key personal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | Intrapersonal: lack of HIV knowledge and motivation. Institutional: lack of peer support. | RCT | Non-peer mentor intervention arm | Participants will receive the Passport intervention arm. | Participants will be followed for 9 months with follow-up assessments conducted at 3, 6, and 9 months. | HIV screening behaviors in the past year. | The end is ongoing. |
| Harwas et al. | Las Vegas, NV; Minneapolis, MN; and New Orleans, LA | March 2017–May 2018 | RCT | Targeted school-based and social networking platforms (Gendr, Sort of Facebook) | MSM only | “The Passport to Wellness” a peer-led intervention Intervention components included (1) a customized wellness plan (or Passport) that included information on health and support services and reminders for accessing those services; (2) incentives for completing documentation of completed Passport activities; (3) a trained peer who provided support, encouragement, and navigation and (4) a referral to health and social services. | Multilevel barriers addressed by the intervention | Key personal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | Intrapersonal: lack of knowledge on HIV and testing locations. Institutional: lack of access to transportation and travel locations. Social and cultural stigma. | Non-peer mentor intervention arm | Patients did not receive any intervention and were only asked to complete the baseline and follow-up assessments. | Baseline: 57 vs. 50 Month 4: 10 (12%); vs. 18 (42%) Month 4: 37 (34%); vs. 18 (42%) Month 5: 34 (31%); vs. 18 (42%) Month 6: 37 (34%); vs. 18 (42%) Month 7: 30 (27%); vs. 18 (42%) | HIV screening within the past 12 months | The end is ongoing. | Acceptability: System Usability Scale scores for the intervention arm (4.99 ± 1.05) compared to the control arm (3.60 ± 1.33) | 0.001. Repeat sessions at 4 and 12 months in intervention arm. Repeat sessions at 8 months in control arm. Repeat sessions at 8 months in control arm. |
| Study | Location/setting | Recruitment/ period | Study design | Recruitment strategy | Population characteristics | Intervention components | Theoretical conceptual framework | Theoretical conceptual framework | Control | Simple size and maintenance (intervention vs. control) | Outcome measures | Findings | acceptability, feasibility | cost-effectiveness |
|-------|-----------------|---------------------|-------------|----------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------|----------------------------------|-------------------|----------|--------------------------|----------------|
| Wong et al. | Nationwide | March-August 2015 | RCT | Online registration through the website | MSM aged 18-39 | Mobile app-based intervention | Intervention: lack of self-efficacy for HIV testing | Social cognitive theory, empowerment education and social support | World at controls | Self-reports of HIV testing in the past 12 months | No difference in self-reported HIV testing between intervention and control groups | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) |
| Pelt et al. | New York, NY | July 2016-June 2019 | RCT | Friend pair recruitment (PPR) followed by email recruitment | MSM (n = 412) | “TRUST”: peer-based intervention | Intervention: lack of self-efficacy for HIV testing | Sociocultural, empowerment, social support, and motivational interviewing theories | Self-efficacy, social support, and motivational interviewing theories | Time and attendance control | Self-efficacy and social support | No significant difference in self-reported HIV testing between intervention and control groups | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) |
| Reback et al. | A west coast metropolis | January 2019 | RCT | Friend pair recruitment (PPR) followed by email recruitment | MSM (n = 412) | “Getting Off”: mobile app-based intervention | Intervention: lack of self-efficacy for HIV testing | Stages of change model and cognitive-behavioral therapy model | Self-efficacy and social support | Time and attendance control | No significant difference in self-reported HIV testing between intervention and control groups | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) | 10.3% vs. 6.5% (OR 1.5; 95% CI: 1.0-2.3) |

MSM: men who have sex with men; HIV: human immunodeficiency virus; RCT: randomized controlled trials; MV: many voices; OR: odds ratio; CI: confidence interval; CDC: Centers for Disease Control and Prevention; HOPE: harnessing online peer education; STD: sexually transmitted diseases; PS: partner services; AIDS: acquired immunodeficiency syndrome; TMUS: testing makes us stronger; IO: information only; IP: information plus; SUP: status update project; HMP: HealthMpowerment; SSE: SMART sex ed; TW: transgender women; PEP: primary eligible participant.
Table 2. Quality assessment of controlled intervention studies.

| Study                  | 1. Was the study described as randomized? | 2. Was the method of randomization adequate (i.e., use of randomly generated clinical trial, or assignment)? | 3. Was the treatment allocation concealed (so that assignments could not be predicted)? | 4. Were study participants and providers blinded to treatment group assignment? | 5. Were the people assessing the outcomes blinded to the participants’ group assignments? | 6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)? | 7. Was the overall drop-out rate from the study at endpoint 20% or lower? | 8. Was the differential drop-out rate (between treatment groups at endpoint) 15% or lower? | 9. Was there high adherence to the intervention protocols for each treatment group? | 10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)? | 11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants? | 12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power? | 13. Were outcomes reported or subgroups analyzed prespecified (i.e., identified before analyses were conducted)? | Total score |
|------------------------|------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Fehrs et al. 33        | N                                        | NA                                                                                                               | NA                                                                                   | NA                                                                                 | NA                                                                                 | NA                                                                                  | NA                                                                                  | NA                                                                                 | NA                                                                                  | Y                                                                                | NR                                                                                                   | Y                                                                                                   | NR                                                                                                   | NA                                                                                  | 2                                                                                                      |
| Wilton et al. 20       | Y                                        | CD                                                                                                               | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                  | NR                                                                                 | NR                                                                                 | Y                                                                                | NR                                                                                                   | Y                                                                                                   | NR                                                                                                   | NA                                                                                  | 2                                                                                                      |
| Martínez-Donate et al. 34 | N                                        | NA                                                                                                               | NA                                                                                   | NA                                                                                 | NA                                                                                 | NA                                                                                  | NA                                                                                  | NA                                                                                 | NA                                                                                 | NR                                                                               | NR                                                                                                   | NA                                                                                                   | NA                                                                                                   | NA                                                                                  | 2                                                                                                      |
| Oulaw et al. 35        | Y                                        | Y                                                                                                                 | NR                                                                                   | N                                                                                  | NR                                                                                 | Y                                                                                                   | Y                                                                                  | Y                                                                                  | Y                                                                                  | Y                                                                                                   | Y                                                                                                   | Y                                                                                                   | Y                                                                                  | 10                                                                                                     |
| Hinrichs et al. 36     | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                  | NR                                                                                 | NR                                                                                 | Y                                                                                | NR                                                                                                   | Y                                                                                                   | NR                                                                                                   | NA                                                                                  | 6                                                                                                      |
| Young et al. 37        | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                  | NR                                                                                 | NR                                                                                 | Y                                                                                | Y                                                                                                   | Y                                                                                                   | Y                                                                                  | 11                                                                                                     |
| Bauermeister et al. 38 | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | Y                                                                                  | NR                                                                                  | Y                                                                                  | NR                                                                                 | Y                                                                                  | Y                                                                                | Y                                                                                                   | Y                                                                                                   | Y                                                                                  | Y                                                                                  | 6                                                                                                      |
| Marty et al. 39        | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Foy et al. 32          | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| McCoy et al. 40        | N                                        | NA                                                                                                               | NA                                                                                   | NA                                                                                 | NA                                                                                 | NA                                                                                  | NA                                                                                  | NA                                                                                 | NA                                                                                 | NR                                                                               | NR                                                                                                   | NA                                                                                                   | NA                                                                                                   | NA                                                                                  | 2                                                                                                      |
| Rhodes et al. 41       | Y                                        | CD                                                                                                               | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Bauermeister et al. 42 | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Frye et al. 45         | Y                                        | Y                                                                                                                 | Y                                                                                   | N                                                                                  | N                                                                                  | Y                                                                                                   | Y                                                                                  | Y                                                                                  | Y                                                                                  | Y                                                                                | Y                                                                                                   | Y                                                                                                   | Y                                                                                  | 10                                                                                                     |
| Outlaw et al. 46       | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | Y                                                                                  | 7                                                                                                      |
| Washington et al. 50   | Y                                        | CD                                                                                                               | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 4                                                                                                      |
| Ybarra et al. 51       | Y                                        | Y                                                                                                                 | NR                                                                                   | Y                                                                                  | Y                                                                                  | Y                                                                                                   | Y                                                                                  | Y                                                                                  | Y                                                                                  | N                                                                                | N                                                                                                   | Y                                                                                                   | N                                                                                  | 5                                                                                                      |
| Bauermeister et al. 52 | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 5                                                                                                      |
| Bauermeister et al. 53 | Y                                        | Y                                                                                                                 | CD                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 5                                                                                                      |
| Kahn et al. 54         | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 5                                                                                                      |
| Katz et al. 55         | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 5                                                                                                      |
| Lightfoot et al. 56    | N                                        | NA                                                                                                               | NA                                                                                   | NA                                                                                 | NA                                                                                 | NA                                                                                  | NA                                                                                 | NA                                                                                 | NA                                                                                 | NA                                                                               | NA                                                                                                   | NA                                                                                                   | NA                                                                                                   | NA                                                                                  | 2                                                                                                      |
| McArdle et al. 57      | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 7                                                                                                      |
| Merchant et al. 58     | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 7                                                                                                      |
| Stephenson et al. 59   | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 7                                                                                                      |
| Wray et al. 60         | Y                                        | Y                                                                                                                 | N                                                                                   | Y                                                                                  | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 7                                                                                                      |
| Bice et al. 61         | Y                                        | N                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 7                                                                                                      |
| Gomare et al. 62       | Y                                        | NA                                                                                                               | NA                                                                                   | NA                                                                                 | NA                                                                                 | NA                                                                                  | NA                                                                                 | NA                                                                                 | NA                                                                                 | NA                                                                               | NA                                                                                                   | NA                                                                                                   | NA                                                                                                   | NA                                                                                  | 2                                                                                                      |
| Liu et al. 63          | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Sullivan et al. 64     | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Edwards et al. 65      | Y                                        | Y                                                                                                                 | Y                                                                                   | N                                                                                  | N                                                                                  | Y                                                                                                   | Y                                                                                  | Y                                                                                  | Y                                                                                  | Y                                                                                | Y                                                                                                   | Y                                                                                                   | Y                                                                                  | 9                                                                                                      |
| Harawa et al. 66        | Y                                        | Y                                                                                                                 | N                                                                                   | Y                                                                                  | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Horbach et al. 67       | Y                                        | NR                                                                                                               | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| McSwain et al. 68      | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Mosic et al. 69        | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Mustanski et al. 70     | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Rhodes et al. 71       | Y                                        | Y                                                                                                                 | NR                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Frye et al. 72         | Y                                        | Y                                                                                                                 | Y                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| Reddy et al. 73         | Y                                        | Y                                                                                                                 | N                                                                                   | NR                                                                                 | NR                                                                                 | NR                                                                                  | NR                                                                                 | NR                                                                                 | NR                                                                                 | NR                                                                               | NR                                                                                                   | NR                                                                                                   | NR                                                                                                   | NR                                                                                  | 6                                                                                                      |
| RCT: randomized controlled trials; CD: cannot determine; N: no; NA: not applicable; NR: not reported; Y: yes. |
Table 3. Quality assessment of pretest-posttest studies.

| Study                  | 1. Was the study question or objective clearly stated? | 2. Were eligibility/selection criteria for the study population prespecified and clearly described? | 3. Were the participants in the study representative of those who would be eligible for the test/service/intervention in the general or clinical population of interest? | 4. Were all eligible participants that met the prespecified entry criteria enrolled? | 5. Was the sample size sufficiently large to provide confidence in the findings? | 6. Was the test/service/intervention clearly described and delivered consistently across the study population? | 7. Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants? | 8. Were the people assessing the outcomes blinded to the participants’ exposures/interventions? | 9. Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis? | 10. Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes? | 11. Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design) to determine effects at the group level? | Total score |
|-----------------------|-----------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------|
| Rhodes et al.24        | Y                                                   | N                                                                                               | CD                                                                                                               | CD                                                                                   | NR                                                                                   | Y                                                                                   | N                                                                                   | NR                                                                                   | Y                                                                                   | Y                                                                                   | N                                                                                   | N                                                                                   | 4                        |
| Maksut et al.41        | Y                                                   | Y                                                                                               | CD                                                                                                               | Y                                                                                   | N                                                                                   | Y                                                                                   | N                                                                                   | NR                                                                                   | Y                                                                                   | Y                                                                                   | N                                                                                   | NA                                                                                   | 7                        |
| Newcomb et al.47       | Y                                                   | Y                                                                                               | CD                                                                                                               | Y                                                                                   | NR                                                                                   | Y                                                                                   | N                                                                                   | NR                                                                                   | Y                                                                                   | Y                                                                                   | N                                                                                   | NA                                                                                   | 6                        |
| Shelley et al.25       | Y                                                   | Y                                                                                               | CD                                                                                                               | Y                                                                                   | NR                                                                                   | Y                                                                                   | N                                                                                   | NR                                                                                   | N                                                                                   | Y                                                                                   | Y                                                                                   | Y                                                                                   | 7                        |
| Boudewyns et al.55     | Y                                                   | CD                                                                                               | CD                                                                                                               | CD                                                                                   | N                                                                                   | Y                                                                                   | N                                                                                   | NR                                                                                   | NR                                                                                   | Y                                                                                   | Y                                                                                   | Y                                                                                   | 5                        |

CD: cannot determine; N: no; NA: not applicable; NR: not reported; Y: yes.
tested for HIV. Behavioral outcomes included self-reported HIV testing behavior (yes/no), number of tests and repeat testing (two or more tests over time) during the follow-up. Other less-reported behavioral outcomes included demand for HIV testing, scheduling an appointment to test for HIV, returning or following up for test results and referrals of other MSM to test for HIV. Only one study evaluated the intervention by measuring the structural (e.g., transportation and distance to testing site) and psychosocial barriers (e.g., fear of testing HIV positive and HIV stigma) to HIV testing rated on a 6-point Likert-type scale. For interventions focused on HIV self-testing (HST), self-efficacy toward testing (confidence in ability to test) was reported.

**Theoretical framework**

Key elements of theoretical underpinnings guided most studies to address psychosocial factors (e.g., perception, motivation, stigma, and social support), improve HIV knowledge and deliver risk reduction skills training. Commonly reported theoretical frameworks included social cognitive theory, empowerment education, motivational interviewing principles, self-determination theory, integrated behavioral model, motivational interviewing principles, social learning theory, and social support theory.

**Intervention strategies and findings**

Of 42 interventions reviewed in this study, most common interventions were HST interventions, interpersonal-level interventions, personalized/individualized interventions and technology-delivered interventions. The vast majority of these interventions were developed from 2016 and onward. The types of interventions in this study were not mutually exclusive (e.g., an interpersonal-level intervention might incorporate personalized elements). Hence, the types we presented here were used to provide the readers with examples of various interventions.

**Interventions for HIV self-testing.** Generally, for interventions aimed at promoting HST, participants received information on HST and self-administration of the testing via social media groups, video chat, mobile app, online videos or peer educators. Then they received or requested the test kits from the research teams or ordered the kits online. As an emergent tool for HIV screening, HST was proved to be highly acceptable, feasible, efficacious and cost-effective. In the “HOPE” study, participants who were delivered information on HIV testing had high acceptance across assessment periods and were more likely to request an HIV testing kit compared to those who received general health information (43.9% vs 20.0%).

There were two studies evaluating the effect of testing kits distribution strategies on the uptake of testing, which were network distribution and online purchase by participants. We additionally identified an intervention providing counseling and referral of needed services after participants performed self-testing. All of these interventions exhibited efficacy in promoting HST among MSM.

**Interpersonal-level interventions.** There were two couples-based interventions for MSM, “2GETHER” and ongoing “We Prevent.” Both interventions delivered sessions about communication skills and CHTC. Additional discussions about minority stress, relationship stress and utilization of social and community support. This study demonstrates feasibility, acceptability and preliminary efficacy among young male couples.

Most interpersonal-level interventions were peer-mentored or peer-led. Peers, who shared sociodemographic characteristics with participants, delivered information on HIV testing, provided support or directly distributed HST kits to MSM. Peer-mentored interventions were efficacious in reducing barriers to HIV testing, promoting uptake of testing and returning for testing results. The “HOLA” intervention targeted Latino MSM, and participants who received help from peer leaders had more than eight times the odds of getting the test at 12 months compared to those assigned to the general health education comparison group (OR = 8.3, 95% CI: 3.0–23.0).

We identified two interventions that friends participated in together, “HealthMpowerment 2.0” and “TRUST.” In the “HealthMpowerment 2.0,” participants invited their friends to join the study via the mobile app, but they had no access to detailed information of enrolled friends. In the “TRUST” study, however, friend pairs engaged in HIV testing and intervention sessions together. Evidence suggested that friend pairs were more likely to receive HST during the study period.

**Social campaigns.** We observed two campaigns, “Hombres Sanos” [Healthy Men] and “Testing Makes Us Stronger” (TMUS). The elements of “Hombres Sanos” campaign included print materials, radio advertisements and community-based outreach. Favorable changes in HIV testing among Latino MSM were not observed for “Hombres Sanos.” The TMUS incorporated more Internet-based components such as online advertisements, a dedicated website and social media outreach. The number of HIV testing performed self-testing. All of these interventions exhibited efficacy in promoting HST among MSM.
men by 125%. Another structural intervention was the integration of HIV testing into sexually transmitted diseases (STD) partner services (PS) program in Washington State. This program was highly effective in promoting HIV testing (63% pre-intervention to 91% during) among MSM with an STD and was also cost-effective.

**Personalized/individualized interventions.** Personalized interventions were developed by customizing the content based on participants’ self-reported information (e.g., demographic characteristics, sexual behaviors, psychosocial factors, and prior HIV testing experiences). Most personalized interventions were aimed to improve individual-level information (e.g., HIV prevention information and HIV risk assessment), motivation (e.g., HIV testing reminder, risk reduction and wellness plan, guidance from mentors), and behavioral skills (e.g., safer sex skills). Individualized interventions were found to be acceptable, feasible, and efficacious in enhancing HIV testing among MSM.

At the structural level, two interventions, “Get Connected” and “Get Connected 2.0,” employed tailoring to link participants to the HIV testing sites that were most appropriate to their needs (e.g., privacy, confidentiality and clinic environment). The “All About Me” intervention provided a personalized recommendation of an optimal HIV testing approach (HST, facility-based testing or CHTC) for participants. “All About Me” improved HIV testing among Black MSM during follow-up compared to the non-tailored control (75.9% vs 70.9%), although the difference was non-significant.

**Technology-delivered interventions.** Development and evaluation of technology-delivered interventions exploded from 2010 and onward. Different from venue-based interventions, participants received intervention content including HIV prevention, HIV testing, and sexual risk reduction information through online videos, text messages, websites, and mobile apps. We additionally identified interventions providing online consultation to participants. In these studies, well-trained counselors provided social support and information on HIV testing or assisted participants in setting health goals via chat room, video chat or social media. Technology-delivered interventions for HIV testing were shown to be acceptable, feasible, efficacious, and cost-effective among MSM.

Most interventions delivered via text message, web app, or mobile app provided not only information on HIV and local resources (e.g., HIV testing sites, PrEP clinics and community events), but also interactive activities to boost participants’ engagement. Commonly reported activities were individual risk assessments, setting health goals, using sexual diaries, and engaging in forums, polls, games, and/or quizzes. In addition, participants could directly order prevention commodities (e.g., HST kits, mail-in self-tests or condom variety packages) and follow-up on unreported HIV test results through the apps. For participants who tested positive during the study, information on referral and linkage to HIV services in the local communities were provided. Efficacy of technology-delivered interventions was unclear because most studies were ongoing.

Of note, we observed one intervention, “Stick to it,” incorporating both online and offline activities. Participants were encouraged to earn points through online activities, such as taking quizzes and monitoring their plans for HIV testing. Offline activities occurred at health clinics where participants could receive HIV screening and redeem their points for prizes. The pilot test reported that participants in the intervention group were more likely to repeat an HIV test over the 6 months of follow-up (OR = 2.15, 95% CI: 1.03 - 4.47).

**Comparison of evaluation of interventions**

Evaluation of acceptability and feasibility was mostly conducted in technology-delivered interventions. Participants generally had positive attitudes toward the interventions delivered by website, video or text messages, for example, “I liked the whole goal of the program (Guy2Guy intervention),” and expressed high satisfaction with the program. Mobile app interventions were also shown to be acceptable based on the high System Usability Scale score. In terms of feasibility, these programs were able to recruit and retain diverse participants in their interventions.

All types of interventions demonstrated efficacy to improve HIV testing uptake among MSM, including increased HIV counseling and testing, repeat HIV testing, and less barriers to HIV testing.

Of note, two peer-delivered interventions, “HOLA” and “HOLA en Grupos,” reported more than eight-fold increase in HIV testing among Hispanic/Latino MSM. Few interventions reported non-significant improvement in primary outcomes compared to control groups, including knowledge of testing locations, self-reported HIV testing, motivation to receive testing, and repeat testing.

**Discussion**

There have been an increasing number of RCTs of HST implemented in the United States since 2010. High acceptability of HST and its potential to improve HIV testing uptake among MSM is not surprising given the positive attributes associated with the test (e.g., availability at pharmacies, oral fluid collection and rapid provision of results). In addition, HST may have the ability to decrease the stigma and discrimination associated with HIV, both of which are established barriers to HIV testing among MSM, by providing a confidential and private testing environment. HST interventions also proved to be successful...
The limitations of HST should be noted. First, a rapid self-test is unable to detect early infection due to lower sensitivity of oral fluid HST than whole blood-based test, long window period of the rapid test and poor test performance caused by lack of training or psychological factors. For example, almost 10% of participants were found to wait for less than specified amount of time before opening the test kit and interpreting the results. The findings highlight the importance of provision of training in the performance of HST and technical assistance to help MSM properly conduct the test. With regard to low sensitivity and long window period, a possible solution could be the mail-in self-test. Given the limited evidence and limitations of the mail-in self-test (inability to offer quick results and unavailability at pharmacies), further research is needed to evaluate its efficacy in promoting HIV testing among MSM. Second, linkage to a confirmatory test and HIV primary care after a reactive rapid test remains a challenge due to multi-level barriers. Epidemiological studies have demonstrated that delayed initiation of HIV treatment leads to increased incidence of AIDS or non-AIDS events, decrease in life expectancy and significant number of onward infections. Hence, it is important for future trials to offer follow-up counseling and referral services to participants if needed. Last, efficacy of HST interventions may be overestimated under experimental conditions where test kits were provided free of charge. A study conducted in urban Philadelphia found that although 90% of participants expressed willingness to use HST kits, whereas only 23% were willing to pay for it. Further research regarding public funding of HST programs to maximize HST uptake among MSM is warranted.

At the interpersonal level, we identified two interventions trying to promote HIV testing among male couples, “2GETHER” and “We Prevent.” Couple-based interventions were designed to promote knowledge of HIV risk in couples, peer norms about prevention in relationships and sexual health communication, which were all facilitators of uptake of HIV prevention services. CHTC also facilitates the disclosure of HIV status among couples, based on which they could make sexual risk reduction plan, which is especially important for serodiscordant couples. Secondary analyses of “2GETHER” intervention further revealed the increased motivation to test for HIV with one’s partner for MSM with high internalized stigma. However, given the low coverage of CHTC and multi-level barriers to the implementation but high willingness to use this service among MSM, there remains a need for more research on the development, implementation and promotion of male couple-based interventions.

Another type of interpersonal-level intervention was based on peer mentoring. The strengths of peer-mentored or peer-led interventions lie in efficient peer-based chain recruitment, high acceptance and engagement due to demographic similarity among peers, and provision of peer support. Peer-based intervention would be more useful when they are applied to minority groups, for example, Black and Latino MSM. Peer-based interventions bridge these gaps by providing support and creating an opportunity for minority groups to receive culturally congruent information on HIV from credible sources. Of note, for peer-led interventions, researchers should take caution with selection of peer leaders. Individuals who are both helpful and trusted within their social networks are necessary for the successful implementation of interventions. It is also critical to deliver training programs to peer leaders to ensure that they could deliver high-quality interventions.

We observed one peer-based intervention, “The Passport to Wellness,” that made an effort to improve social determinants of health among Black MSM by using incentives and peer support. This intervention is worth noting because it addressed negative social determinants of health including poverty, access to healthy food, stigma and discrimination, all of which were thought to be the root cause of health and barriers to seeking HIV prevention services. There remains a need for more research to integrate and address social determinants of health into HIV prevention and testing programs.

At the structural level, the only intervention implemented in recent years was the STD PS program in Washington State which ensured HIV testing for MSM with an STD and their partners. We observed a pronounced increase in HIV testing among MSM who received the diagnosis of STD from healthcare providers that were not specializing in HIV or STD care. This finding highlights the great potential of the healthcare system, especially non-speciality providers, in promoting HIV testing and the importance of collaboration across health departments. However, the generalizability of a similar program in other states are uncertain given the disparity in public health infrastructure across the United States.

We found an increasing number of interventions incorporating personalized elements in recent years. Three novel interventions seeking to connect participants with the most appropriate HIV testing approach were identified. Compared to common interventions to promote community- or facility-based testing, these interventions not only addressed institutional barriers to HIV testing (e.g. healthcare providers’ stigmatizing behaviors toward patients) by filtering testing sites based on participants’ past experiences and expectations, they also took into account local testing resources (e.g. geographic coverage of testing sites). However, it is important to note that the development of tailored intervention remains challenging.
For instance, in the “All About Me” study, development of an algorithm to match individuals to an optimal testing method involved the identification of barriers to testing and consideration of institutional conditions. Formative studies to fully understand participants’ needs and exploration of local HIV testing resources are warranted for the successful implementation of personalized interventions.

With the increasing use of the Internet and mobile technology by MSM to find HIV-related information, connect to the gay communities and seek sexual partners, technology has become an effective tool for researchers to conduct HIV prevention interventions among MSM. The technology-delivered interventions are no doubt time-saving and convenient and thereby are cost-effective. With online recruitment, researchers could reach MSM who may be hard to reach through traditional outreach in a cost-efficient means. Flexibility in delivery enables this type of intervention to hold more promise in promoting HIV testing in the context of COVID-19 where reduction of interpersonal contact is required. Nascent technologies (e.g. virtual reality, crowdsourcing and chatbot) were reported to be used in HIV prevention in recent years. More studies to determine their effect on MSM are required since the application of technology to HIV interventions is still at its infancy.

We identified three limitations associated with the technology-delivered interventions. First, given the ethnic/racial disparities in the use of technology for health-related purposes, Black and Latino MSM may be less likely to participate in online HIV prevention interventions and use Internet for HIV information. The second is the moderate level of engagement probably due to the lack of direct contact with research team. For example, a mobile app-based study found that almost 20% of participants never downloaded/opened the app. Potential strategies to improve participants’ engagement may include adoption of existing popular platforms, incorporation of individualized and interactive activities, and reminders sent from research team via text message or email. Last, development of the website or app remains a barrier. Commonly reported issues included insufficient guidance, technical problems (e.g. app crashing or slow responsiveness) and problems with user control and freedom.

When pilot testing the Status Update Project mobile app, some participants appreciated its simplicity and reminders while others thought that it was too simple and repetitive. Formative studies and pilot tests are required to learn participants’ preference and test the usability of the online interventions.

There are several common limitations to current HIV testing interventions regardless of their intervention modalities. First, there might be a mismatch between the complexity of HIV information content and participants’ health literacy. For example, participants with high health literacy thought that the health information was “simplistic” and they “did not fully get the opportunity to learn anything new.” Possible solution could be the development of intervention content tailored to participants’ educational level and health literacy. Second, we observed diminished effect of the intervention across study periods. Attention should be paid to participants who did not have established HIV testing patterns before joining the study, given the evidence that these people were less likely to follow the intervention. Furthermore, incorporation of personalized elements and booster sessions might be effective in extending the effect of intervention.

Third, some people did not return or follow-up for test results while knowledge of HIV status is the first step in the initiation of treatment for HIV. Reminder to follow-up on and provision of testing results via text message, email or mobile app could be useful in promoting knowledge and acceptance of HIV status among MSM. Last, condomless sex may be comitant with increased HIV testing due to mutual knowledge of HIV-negative serostatus among couples. Therefore, integration of sexual health education into interventions for HIV testing are necessary to reinforce the importance of sexual health while promoting HIV testing among MSM.

Compared to previous reviews of HIV testing interventions among MSM, our study extends the literature by aggregating up-to-date intervention strategies (e.g. gamification, personalization and couple-based intervention), comprehensively evaluating existing interventions in terms of acceptability, feasibility, efficacy and cost-effectiveness, and summarizing gaps/limitations in those interventions. Some limitations are also worth noting. First, the search terms used in this systematic review may not be comprehensive and therefore we were unable to include all relevant studies. Second, in addition to poor or fair methodological quality, some studies reported small sample size and short follow-up period, which might lead to low statistical power. High-quality RCTs with a large sample size and a long follow-up period are warranted to replicate their results. Finally, most studies evaluated the efficacy of the interventions by measuring self-reported binary HIV testing, which was prone to recall bias and social desirability bias.

Objective measures of HIV testing behavior are further required. In addition, future studies should take into account more aspects of HIV testing such as knowledge, attitudes, barriers and repeat HIV testing when evaluating their interventions.

**Conclusion**

MSM continue to be disproportionately affected by HIV in the United States. Low uptake of HIV testing in general, and of repeat testing among MSM is concerning. Not testing and infrequently testing may exacerbate negative health outcomes, late initiation of HIV treatment, further engagement in condomless sex, and potential onward transmission of HIV. Development of interventions to improve MSM’s HIV testing rates and frequency has proliferated in recent years. Most common interventions were those focused on HST,
interpersonal, level, personalized, and technology delivered. These interventions hold promise in expanding the coverage of HIV testing among MSM in the United States given their acceptability, feasibility and efficacy. Researchers are presented with opportunities to overcome the limitations we identified in this review and provide more evidence to demonstrate the effect of interventions to improve HIV testing uptake and frequency among MSM in the United States.

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Y.L. designed the research study. Y.W. led the systematic review and drafted the first version of this manuscript. Y.W. and Y.L. conducted title and abstract screening. Y.W. conducted full-text review and extracted data which were cross-checked by Y.L. J.M. reviewed and revised the manuscript. All authors critically interpreted the results and revised the manuscript. All authors have read and approved the final manuscript.

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