



Review article

The effectiveness of protective behavioral strategies for reducing alcohol use and alcohol-related harms among adults: A systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

Objectives: Excessive alcohol consumption is a major public health concern. Protective behavioral strategies (PBS) are widely incorporated into alcohol interventions, but their effectiveness and role as mechanisms of behavior change remain unclear. This systematic review and meta-analysis evaluated the effects of PBS-based interventions on alcohol consumption, alcohol-related harms, and PBS use.

Methods: PubMed, Embase, Scopus, CINAHL, and ProQuest were searched from inception to December 2025 for randomized controlled trials (RCTs) of adults (≥ 18 years) delivering PBS as an active intervention component. Random-effects meta-analyses using Hedges' g examined alcohol quantity, drinking frequency, alcohol-related problems, and PBS use.

Results: Fifteen RCTs were included, predominantly involving young adults attending U.S. universities. PBS interventions increased protective strategy use ($g=0.23$, $p=0.005$ after outlier removal), but alcohol effects were modest: no change in quantity ($g=-0.05$, $p=0.162$), small reduction in frequency ($g=-0.09$, $p=0.014$), and marginal reduction in problems ($g=-0.07$, $p=0.052$; significant in sensitivity analysis). Subgroup findings suggested greater effects at longer follow-up and when PBS was incorporated into multi-component interventions. Evidence supporting PBS as a mechanism of change was limited and inconsistent.

Conclusions: PBS-based interventions produce modest, context-dependent effects on alcohol outcomes. Most evidence comes from young U.S. university students, underscoring the need for studies in more diverse adult populations and further mechanistic research.

1. Introduction

Excessive alcohol consumption remains a major contributor to preventable morbidity and mortality worldwide (WHO, 2024). Although alcohol prevention efforts have expanded, heavy episodic drinking and alcohol-related harms remain common, particularly among young adults (Danpanichkul et al., 2025). Therefore, identifying scalable, theory-driven strategies that can effectively reduce risky drinking remains a public health priority.

Brief behavioral interventions, particularly motivational interviewing and personalized normative feedback, have consistently demonstrated small reductions in alcohol consumption and related harms (Pueyo-Garrigues et al., 2024; Schwenker et al., 2023). Nevertheless,

intervention effects remain modest and vary across populations, highlighting the need to identify the active intervention components responsible for behavior change. One such component that has received increasing attention is protective behavioral strategies (PBS).

PBS are self-regulatory behaviors intended to reduce alcohol consumption and related harms, such as setting drink limits, pacing alcohol intake, and ensuring safe transportation (Martens et al., 2005). Greater PBS use is consistently associated with lower alcohol consumption and fewer alcohol-related consequences (Greń and Ostaszewski, 2023). However, most intervention studies deliver PBS alongside motivational or normative components, making it difficult to determine the unique contribution of PBS to intervention effectiveness (Greń and Ostaszewski, 2023; Pearson, 2013; Peterson et al., 2021). Furthermore, PBS are

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frequently examined as correlates or mediators of drinking behavior rather than as actively delivered intervention components, limiting understanding of their causal role in reducing alcohol consumption and related harms (Cox et al., 2024).

PBS have also been proposed as proximal mechanisms through which alcohol interventions influence drinking behavior (Cox et al., 2024; Greń and Ostaszewski, 2023; Pearson, 2013). Consistent with this perspective, recent event-level research found that use of manner-of-drinking PBS was associated with lower odds of same-day alcohol-related consequences among both college and non-college young adults (Shoemaker et al., 2026). Nevertheless, whether changes in PBS use consistently mediate intervention effects remains uncertain because relatively few randomized trials have formally evaluated mediation.

Early narrative and systematic reviews primarily synthesized observational studies examining associations between PBS use and alcohol-related outcomes, whereas more recent reviews expanded the evidence base to include intervention studies (Cox et al., 2024; Greń and Ostaszewski, 2023; Pearson, 2013). Although these reviews generally concluded that PBS are associated with lower alcohol-related risk and modest improvements in drinking outcomes, they also highlighted substantial uncertainty regarding the specific contribution of PBS to intervention effectiveness.

Importantly, previous reviews have largely treated PBS interventions as a relatively homogeneous group (Cox et al., 2024; Greń and Ostaszewski, 2023). Across intervention studies, PBS have been incorporated as the core therapeutic component (Kenney et al., 2014), the primary focus of a brief intervention (Arazan et al., 2023), an embedded component of a broader multicomponent intervention (Andersson, 2015), or reinforcement of previously delivered intervention content (Braitman and Henson, 2016). These functional differences may influence the extent to which observed effects can be attributed to PBS rather than accompanying intervention components. Distinguishing these roles may therefore improve interpretation of intervention effectiveness and inform how PBS can be incorporated into future alcohol interventions.

Likewise, implementation characteristics, such as intervention intensity and delivery format, and the level of human support, may influence participant engagement and intervention effectiveness (Lewis et al., 2026; Tan et al., 2023). Emerging intervention development research has emphasized repeated reinforcement, tailored messaging, and support for sustained PBS use, suggesting that how PBS are delivered may be as important as which strategies are taught (Lewis et al., 2026). However, these implementation characteristics have not been systematically synthesized across randomized controlled trials (RCTs), leaving limited evidence regarding which delivery approaches are associated with greater intervention effectiveness. In addition, the existing evidence base is largely derived from university student samples in Western countries, limiting the generalizability of findings to broader adult and community populations (Cox et al., 2024; Greń and Ostaszewski, 2023; Peterson et al., 2021).

To our knowledge, no previous systematic review and meta-analysis has specifically synthesized RCTs evaluating interventions in which PBS were explicitly delivered as active intervention components. Nor has any review systematically examined how PBS are operationalized and implemented, the functional roles they serve within interventions, or whether evidence supports PBS as mechanisms of change. Accordingly, this review aimed to (1) characterize PBS operationalization and delivery; (2) classify interventions according to the functional role and intensity of PBS; (3) quantify the effects of PBS-based interventions on alcohol use and related harms; and (4) summarize the preliminary evidence evaluating PBS as a potential mechanism of change.

2. Methods

2.1. Protocol and registration

This systematic review and meta-analysis followed PRISMA 2020 guidelines (Page et al., 2021). The protocol was prospectively registered on PROSPERO (CRD420251148669).

2.2. Eligibility criteria

2.2.1. Inclusion criteria

Population

Studies were eligible if participants were adults (aged ≥ 18 years) who reported alcohol use. No restrictions were placed on participant characteristics (e.g., student, community, or clinical populations) or alcohol risk level. Studies including both adolescents and adults were eligible only if outcome data for adult participants were reported separately or could be extracted independently.

Interventions

PBS interventions were defined as behavioral interventions in which individuals were explicitly taught, prompted, or reinforced to use intentional behaviors before, during, or after alcohol consumption to reduce intake or harms. Consistent with established frameworks (Cox et al., 2024; Martens et al., 2005), PBS were categorized into three domains: limiting or stopping drinking (e.g., setting drink limits), manner of drinking (e.g., pacing drinks), and harm reduction (e.g., using a designated driver). These PBS content domains were extracted descriptively to characterize intervention content. Because most interventions incorporated multiple domains, these categories were not analyzed quantitatively.

Studies were eligible if PBS was a primary or clearly identifiable intervention component and was directly delivered through instruction, skills training, practice, or other activities designed to promote PBS use. Eligible interventions could be delivered as standalone PBS programs or as part of broader multi-component interventions delivered in digital, in-person, or hybrid formats. PBS had to function as an active intervention component rather than merely being measured or analyzed within the study. Therefore, studies in which PBS served only as an outcome, correlate, mediator, or moderator, or in which the intervention primarily targeted other psychological mechanisms (e.g., social norms, attitudes, motivation, or identity) without directly delivering PBS, were excluded.

Comparators

Eligible comparators included no intervention, waitlist, standard care, education, or alternative behavioral interventions.

Outcomes

Studies were required to report at least one quantitative alcohol-related outcome using validated or clearly defined measures. Primary outcomes included alcohol consumption (quantity and/or frequency) and alcohol-related harms (physical, social, or psychological). Secondary outcomes included PBS use, self-efficacy, readiness to change, adherence, and satisfaction. The secondary outcomes may reflect proximal behavioral, cognitive, or implementation processes through which PBS interventions are expected to influence alcohol-related outcomes. However, except for PBS use, these secondary outcomes were infrequently and inconsistently reported across studies and were therefore not synthesized.

Study design

Randomized controlled trials (RCTs), including both individual and cluster designs, were included.

Publication restrictions

Peer-reviewed English articles from database inception to December 2025.

2.2.2. Exclusion criteria

Studies were excluded if they included participants younger than 18

years without separately reportable adult data; did not meet the pre-defined eligibility criteria for PBS interventions; used non-randomized study designs (e.g., quasi-experimental or observational studies); or were reviews, editorials, protocols, conference abstracts, or other non-peer-reviewed publications.

2.3. Search strategy

Comprehensive literature searches were conducted in PubMed, Embase, Scopus, CINAHL, and ProQuest using MeSH, Emtree, and free-text terms (adapted for each) for PBS, alcohol use, consequences, and RCTs (Appendix 1). No population filters were applied; population eligibility was assessed during screening. Additional studies were identified through citation tracking, reference list screening, and review of relevant systematic reviews.

2.4. Study selection process

Duplicates were removed using EndNote. Two reviewers independently screened titles/abstracts and full texts, with disagreements resolved by consensus or a third reviewer. Reasons for exclusion were documented (Appendix 2). The study selection process is presented in a PRISMA flow diagram (Fig. 1).

2.5. Risk of bias assessment

Two reviewers independently assessed methodological quality using the Cochrane RoB 2 tool (Sterne et al., 2019). Discrepancies were resolved through discussion or a third reviewer. Overall ratings (low/some concerns/high) visualized via robvis (McGuinness and Higgins, 2020), see Fig. 2. Because only one study was judged to have low overall risk of bias, sensitivity analyses based on study quality were not feasible. All eligible studies were therefore included in the primary analyses, and risk of bias was considered when interpreting the findings.

2.6. Data extraction

Data were extracted independently by two reviewers using a pre-piloted, standardized extraction form. Extracted data included study characteristics (e.g., setting, design, sample, attrition), intervention details (e.g., PBS content focus, delivery mode, intensity, mechanism), comparators, outcomes (e.g., types, follow-up duration, main conclusion).

Classification of the role of PBS

The role of PBS within each included intervention was systematically classified during data extraction. Two reviewers independently examined published intervention descriptions, manuals, supplementary materials, and protocols to determine the theoretical emphasis, delivery structure, and functional role of PBS in each study.

Interventions were categorized a priori into four mutually exclusive groups according to the functional role of PBS within the intervention: a) Core (only PBS): PBS constituted the sole active intervention component and the primary theoretical framework; b) Primary: PBS was the main intervention target but was delivered in a brief or low-intensity format; c) Booster: PBS was delivered to reinforce or extend a separate core intervention; d) Adjunct: PBS was incorporated as one component within a broader multi-component intervention. This classification was developed for this review to organize heterogeneous PBS interventions and should not be interpreted as a definitive taxonomy.

Intervention intensity was extracted descriptively according to the reported frequency and duration of PBS exposure. Single-session interventions involved one discrete PBS session, whereas repeated interventions involved multiple contacts, prompts, or sessions over time. Because intervention schedules varied substantially across studies, intensity was described but was not used as a subgroup classification. Additionally, data were extracted on whether PBS was evaluated as a

mechanism of change (no analysis, mediation, moderation, or both). Discrepancies were resolved through discussion, with third-reviewer adjudication if needed. Calibration meetings were conducted throughout the process to ensure consistency. Data were managed in Excel.

2.7. Data synthesis

This review employed both narrative synthesis and quantitative meta-analysis. Narrative synthesis was used to summarize study characteristics and intervention features, characterize PBS operationalization and delivery, classify interventions according to the functional role and intensity of PBS, and synthesize evidence regarding PBS as a potential mechanism of change. Findings were organized according to intervention characteristics and the direction of effects.

Meta-analysis was conducted when sufficient studies reported compatible effect sizes for alcohol outcomes and PBS use. Because mediation and moderation analyses used diverse statistical methods and outcome measures, evidence regarding PBS as a mechanism of change was synthesized narratively. Prespecified subgroup analyses were conducted according to follow-up duration (≤ 3 months vs. > 3 months) and the functional role of PBS within the intervention (core/primary vs. adjunct/booster). Other intervention characteristics (e.g., delivery mode, intervention intensity, and human support) were not examined because they were highly heterogeneous and could not be classified consistently across studies.

Continuous outcomes were pooled using group-level means, standard deviations (SDs), and sample sizes for intervention and control groups. When standard errors were reported, they were converted to SDs using standard formulas. Given the heterogeneity in outcome measures (e.g., drinks per week, total consumption), effect sizes were calculated as standardized mean differences (Hedges' g) with 95% confidence intervals (CIs), allowing comparability across scales and correcting for small-sample bias. All effect sizes were based on post-intervention data.

Random-effects meta-analyses were performed using Jamovi (version 2.6.44) with the MAJOR module to account for clinical and methodological heterogeneity. Separate random-effects meta-analyses were performed for alcohol quantity, drinking frequency, alcohol-related harms, and PBS use. To ensure independence, only one effect size per study was included in each model. When multiple follow-up points were available, the longest follow-up was used for the primary analysis. Studies could contribute one effect size to each follow-up subgroup.

Heterogeneity was assessed using Cochran's Q ($p < 0.10$) and the I^2 statistic (25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively) (Higgins and Thompson, 2002). Influence diagnostics (studentized residuals, Cook's distance) were used to identify outliers, with sensitivity analyses conducted by excluding influential studies. Publication bias was assessed, when feasible, using funnel plots, rank correlation tests, and Egger's regression. Where asymmetry was detected, additional sensitivity analyses were performed. All tests were two-tailed, with statistical significance set at $p < 0.05$.

3. Results

3.1. Study selection and overview

A total of 15 RCTs met inclusion criteria (Fig. 1). Published between 2007 and 2023, studies were conducted primarily in university settings, with most in the United States ($n = 13$, 86.7%) and one each in Sweden and Australia. Sample sizes ranged from 45 to 9,277, with analyzed samples varying due to attrition.

Participants were predominantly undergraduate students aged 18–24 years, with one study including individuals up to 35 years (O'Donnell et al., 2019). Alcohol risk profiles ranged from universal prevention samples to heavy episodic drinkers and event-specific

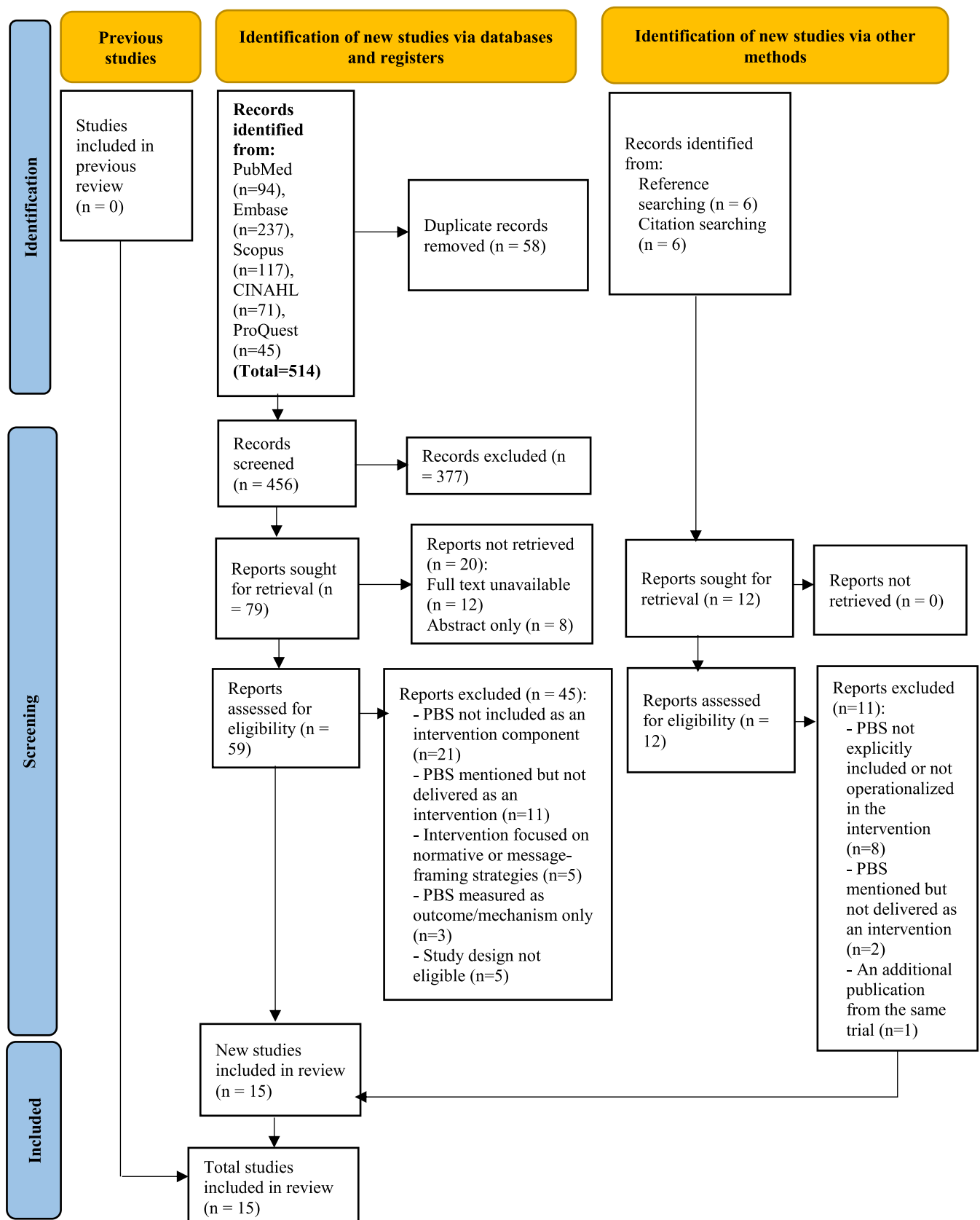


Fig. 1. The PRISMA flow chart.

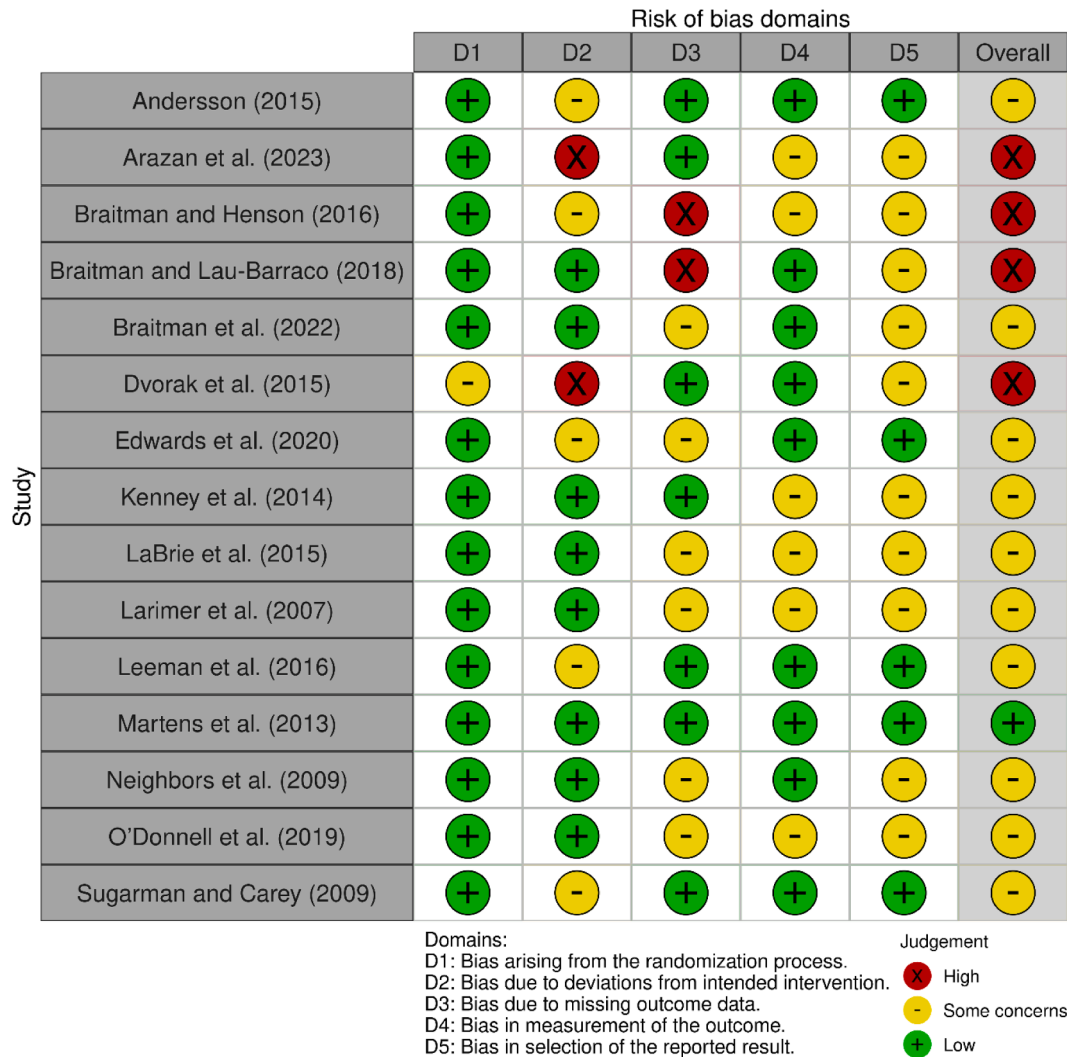


Fig. 2. Risk of bias assessment.

high-risk groups (e.g., 21st birthday celebrations). Attrition varied widely (0%–95%), with the highest rates observed in large-scale digital or web-based interventions (Table 1).

Overall risk of bias was low to moderate (Fig. 2). Almost all studies showed low risk for randomization; however, some concerns arose in several trials due to deviations from intended interventions and missing outcome data, largely reflecting high attrition and limited adherence monitoring. Outcome measurement and selective reporting were generally rated as low risk or some concerns. Only one study was rated low risk across all domains, three were high risk, and the remainder had some concerns.

3.2. Characteristics of interventions

Substantial heterogeneity was observed in how PBS were operationalized and delivered across interventions (Table 2). Most interventions incorporated multiple PBS domains rather than focusing on a single category. Eleven interventions included limiting, manner-of-drinking, and harm-reduction strategies concurrently, whereas four emphasized selective avoidance and alternative strategies. No study evaluated individual PBS domains in isolation; therefore, subgroup analyses according to PBS domain were not possible.

Based on the predefined classification framework, four studies (26.7%) evaluated core (only PBS) interventions, four (26.7%) evaluated primary PBS-focused interventions, three (20.0%) delivered PBS as

booster interventions, and four (26.7%) incorporated PBS as an adjunct component within broader multi-component interventions. Overall, nearly half of the trials (46.7%) incorporated PBS as a secondary intervention component (adjunct or booster) rather than as the principal intervention component (core or primary).

Intervention intensity was generally low to moderate, with most studies using single-session or brief formats. Delivery was predominantly digital or automated (e.g., web-based feedback, email, SMS, smartphone applications), whereas human facilitation was largely limited to core PBS interventions. Only four interventions included a face-to-face component (three individual or group sessions and one group-based intervention with subsequent diary monitoring), whereas the remaining studies were delivered entirely through digital or remote formats. No clear differences in effectiveness were observed between face-to-face and digitally delivered interventions; however, formal comparisons were not possible because of substantial heterogeneity in intervention content, intensity, and study design.

Reporting of fidelity and adherence was inconsistent, particularly in digital interventions where engagement could not be objectively verified. Only a small number of studies explicitly evaluated PBS as a mechanism of change through mediation or moderation analyses.

3.3. Integrated summary of effects

Across studies, PBS-based interventions were generally effective in

Table 1

Characteristics of included studies and participants (n=15).

First Author (Year)	Country	Setting	Study Design	Sample Size (Randomized / Analyzed)	Participant Characteristics	Mean Age (SD) / Range	Alcohol Risk Profile	Attrition (%)
Andersson (2015)	Sweden	University	5-arm automated RCT	1,678 / 1,422	Students; 41% female	23.2 (2.9)	Hazardous drinkers (AUDIT $\geq 6/8$)	15
Arazan et al. (2023)	USA	University	2-arm posttest-only RCT	9,277 / 658	Students; ~59% female	Turning 21	High-risk celebratory drinkers	88–95
Braitman and Henson (2016)	USA	University	2-arm RCT	353 / 213	Students; 65.7% female	18–24	≥ 4 drinks in past 2 weeks	40–67
Braitman and Lau-Barraco (2018)	USA	University	3-arm RCT	537 / 537	Students; 67.4% female	19.7 (1.7)	≥ 1 drink in past 2 weeks	70–79
Braitman et al. (2022)	USA	University	3-arm RCT	528 / 528	Students; 71.6% female	19.9 (1.8)	≥ 1 drink in past 2 weeks	31–45
Dvorak et al. (2015)	USA	University	2-arm web-based RCT	104/76	Students; 53.9% female	19.3 (1.4)	Current college student drinkers	27
Edwards et al. (2020)	USA	University	2-arm RCT	161 / 143	Students; 80.1% female	20.0 (1.7)	≥ 1 drinking occasion in past month	11
Kenney et al. (2014)	USA	University	2-arm RCT	247 / 226	Students; 100% female	18.1 (0.5)	Heavy episodic drinkers	9
LaBrie et al. (2015)	USA	University counseling center	2-arm RCT	251 / 251	Students; 70% female	20.0 (1.2)	Heavy drinkers in treatment	NR
Larimer et al. (2007)	USA	University	2-arm RCT	1,488 / 1,488	Students; 70.4% female	20.6 (3.0)	Universal sample	33
Leeman et al. (2016)	USA	University	4-arm RCT	208 / 183	Students; 62.5% female	19.9 (1.4)	Heavy drinkers	8–10
Martens et al. (2013)	USA	University	3-arm RCT	365 / 365	Students; 65.2% female	20.1 (1.4)	≥ 1 binge episode in past month	5–6
Neighbors et al. (2009)	USA	University	2-arm RCT	295 / 282	Students; 58.3% female	Turning 21	Intended celebratory drinkers	4
O'Donnell et al. (2019)	Australia	University campus and social media	2-arm pilot RCT	45 / 38	Young adults; 80% female	21.3–23.0	Weekly drinkers	16
Sugarman and Carey (2009)	USA	University	3-arm RCT	177 / 177	Students; 65% female	18.8 (1.0)	Recent drinkers (past 2 weeks)	0

Notes: RCT = Randomized controlled trial; AUDIT = Alcohol Use Disorders Identification Test; NR = Not reported; Ranges of attrition indicate different follow-up time points or study arms.

increasing protective strategy use but showed less consistent effects on alcohol outcomes (Table 3). Eleven studies (73.3%) reported increases, maintenance, or mixed improvements in PBS use, including eight with clear increases.

In contrast, only six studies demonstrated clear reductions in alcohol consumption, with one reporting partial effects and one mixed finding. Reductions in alcohol-related harms were observed in only three studies. Several trials reported increases in PBS use without corresponding reductions in alcohol consumption or harms (Arazan et al., 2023; Martens et al., 2013; O'Donnell et al., 2019; Sugarman and Carey, 2009).

Evidence evaluating PBS as a mechanism of change was limited. Six studies conducted mediation analyses, of which three identified significant indirect effects through PBS. Three studies examined moderation, with one indicating stronger intervention effects among individuals with lower baseline PBS use. Findings relating to mediation and moderation are summarized narratively because of methodological heterogeneity.

3.4. Meta-analysis results

Random-effects meta-analyses were conducted for alcohol quantity ($k = 9$), drinking frequency ($k = 6$), alcohol-related problems ($k = 7$), and PBS use ($k = 6$).

3.4.1. Quantity of alcohol consumption

Nine studies were included (Fig. 3). The pooled effect was small and non-significant (Hedges' $g = -0.05$, 95% CI: -0.13 to 0.02 , $p = 0.162$), indicating no meaningful reduction. Heterogeneity was low ($I^2 = 22.0\%$). The 95% prediction interval (-0.18 to 0.07) indicates that true effects are likely to range from small reductions to negligible. No

influential outliers or publication bias were detected (Supplementary Fig. S1).

3.4.2. Frequency of alcohol consumption

Six studies were included (Fig. 4). The pooled effect indicated a small but statistically significant reduction (Hedges' $g = -0.09$, 95% CI: -0.17 to -0.02 , $p = 0.014$), with low heterogeneity ($I^2 = 11.85\%$). The 95% prediction interval (-0.19 to 0.001) indicates effects may vary from small reductions to negligible. No influential studies or publication bias were identified (Supplementary Fig. S2).

3.4.3. Alcohol-related problems

Seven studies were included (Fig. 5). The pooled effect indicated a small, non-significant reduction (Hedges' $g = -0.07$, 95% CI: -0.14 to 0.0007 , $p = 0.052$), with no heterogeneity ($I^2 = 0\%$). Influence diagnostics identified Larimer et al. (2007) as an influential study. Excluding this study yielded a statistically significant effect ($g = -0.10$, 95% CI: -0.19 to -0.01 , $p = 0.034$), with unchanged heterogeneity. No evidence of publication bias was detected (Supplementary Fig. S3).

3.4.4. Protective behavioral strategy use

Six studies were included (Fig. 6). The pooled effect was positive but non-significant (Hedges' $g = 0.58$, 95% CI: -0.21 to 1.37 , $p = 0.152$), with substantial heterogeneity ($I^2 = 97.8\%$). The 95% prediction interval (-1.47 to 2.63) indicates high variability across contexts. No evidence of publication bias was observed (Supplementary Fig. S4). One influential outlier (O'Donnell, 2019) was identified. After its removal, the effect was small but statistically significant ($g = 0.23$, 95% CI: 0.07 to 0.40 , $p = 0.005$), and heterogeneity was substantially reduced ($I^2 =$

Table 2

Characteristics of Interventions and Role of Protective Behavioral Strategies in Included Studies (n = 15).

First Author (Year)	PBS Content Focus	Delivery Mode	Intervention Type	Role of PBS	Intensity	Human Support	Mechanism Tested	Comparator
Andersson (2015)	Limiting; manner of drinking	Web / IVR	PNF + PBS	Adjunct (embedded PBS)	Single or repeated	None	None	Assessment only
Arazan et al. (2023)	Limiting, harm-reduction strategies	Email e-card message	Brief digital PBS	Primary (PBS-focused)	Single session	None	None	No intervention
Braitman and Henson (2016)	Selective avoidance, manner of drinking, and alternative strategies	Email booster	CDI + PBS	Booster (PBS reinforcement)	Single session	None	Moderation	CDI only
Braitman and Lau-Barraco (2018)	Selective avoidance, manner of drinking, and alternative strategies	Email booster	CDI + PBS	Booster (PBS reinforcement)	Single session	Minimal	None	CDI only
Braitman et al. (2022)	Selective avoidance, manner of drinking, and alternative strategies	Email booster	CDI + PNF + PBS	Booster (PBS reinforcement)	Single session	Minimal	None	CDI only
Dvorak et al. (2015)	Limiting, manner of drinking, harm-reduction strategies	Web-based weekly messages	DRT + PBS prompting	Primary (PBS-focused)	Repeated (6 weeks)	None	Mediation and moderation	Positive-frame vs negative-frame DRT messages
Edwards et al. (2020)	Limiting, manner of drinking, harm-reduction strategies	SMS	PBS prompting	Primary (PBS-focused)	Repeated (3 days)	None	None	Assessment only
Kenney et al. (2014)	Limiting, manner of drinking, harm-reduction strategies	Group sessions (face-to-face)	PBS skills training	Core (only PBS)	Single session	Trained facilitators	Mediation	Study skills
LaBrie et al. (2015)	Limiting, manner of drinking, harm-reduction strategies	Individual session (face-to-face)	MI + PBS	Core (only PBS)	Single session	Trained facilitators	Mediation	Health education
Larimer et al. (2007)	Limiting, manner of drinking, harm-reduction strategies	Mailed postcards	PNF + PBS	Adjunct (embedded PBS)	Repeated (10 weeks)	None	Mediation	Assessment only
Leeman et al. (2016)	Limiting, manner of drinking, harm-reduction strategies	Web feedback	US-THRIVE + PBS	Adjunct (embedded PBS)	Single session	None	None	Electronic brochure
Martens et al. (2013)	Limiting, manner of drinking, harm-reduction strategies	Individual session (face to face)	PBSF	Core (only PBS)	Single session	Trained facilitators	Mediation	Alcohol education
Neighbors et al. (2009)	Limiting, manner of drinking, harm-reduction strategies	Web feedback	PNF + PBS + BAC feedback	Adjunct (embedded PBS)	Single session	None	Mediation	Assessment only
O'Donnell et al. (2019)	Limiting, manner of drinking, harm-reduction strategies	Smartphone app	PBS-based digital intervention	Core (only PBS)	Repeated (28 days)	None	None	Control app
Sugarman and Carey (2009)	Selective avoidance, strategy while drinking, alternatives	In-person (group) + diary	Self-monitoring + behavioral instruction	Primary (PBS-focused)	Repeated (2 weeks)	Research staff instruction at baseline	None	Self-monitoring

Note. Core = PBS constitutes the primary therapeutic content of the intervention; Primary = PBS is the dominant intervention focus; Adjunct = PBS is embedded within broader interventions; Booster = PBS delivered as reinforcement following an initial intervention; CDI = Computer-delivered interventions; DRT = Deviance Regulation Theory; IVR = Interactive Voice Response; MI = motivational interviewing techniques; PNF = personalized normative feedback.

49.9%, Supplementary Fig. S5).

3.4.5. Subgroup analyses by follow-up duration

Effects were more evident at longer follow-up. No significant effects were observed at ≤ 3 months. At > 3 months, small but significant reductions were observed for alcohol quantity ($g = -0.12$, $p = 0.004$) and frequency ($g = -0.13$, $p = 0.003$), with negligible heterogeneity (Supplementary Figs. S6–S7). No significant differences by follow-up duration were found for alcohol-related problems or PBS use (Supplementary Figs. S8–S11).

3.4.6. Subgroup analyses by the role of PBS within interventions

Effects varied by the role of PBS. When delivered as adjunct components within multi-component interventions, PBS were associated with small but significant reductions in alcohol quantity ($g = -0.10$, $p = 0.040$) and frequency ($g = -0.13$, $p < 0.001$), with low heterogeneity (Supplementary Figs. S12, S13).

In contrast, core or primary PBS interventions showed no significant

effects on alcohol quantity and only non-significant effects on alcohol-related problems ($g = -0.11$, $p = 0.091$) and PBS use ($g = 0.91$, $p = 0.128$), with substantial heterogeneity for the latter (Supplementary S14–S16). These subgroup findings should be interpreted cautiously given the small number of studies.

4. Discussion

This systematic review and meta-analysis synthesized evidence from RCTs evaluating PBS as active components of alcohol interventions. Although all included studies involved adults aged ≥ 18 years, the evidence base was dominated by young adults recruited from universities in the United States. Consistent with previous reviews, PBS-focused interventions generally increased PBS use but produced small and inconsistent effects on alcohol consumption and related harms. Importantly, this review extends previous literature by demonstrating that, although increases in PBS may contribute to improved alcohol outcomes in some interventions, current RCT evidence does not support PBS as a sufficient

Table 3

Study-level effects of PBS-based interventions on alcohol outcomes and mechanisms (n = 15).

First author (Year)	Primary outcomes	PBS change	Alcohol reduction	Alcohol-related harm reduction	PBS Mechanism	Follow-up	Main conclusion
Andersson (2015)	Alcohol consumption (quantity, frequency, BAC)	Not assessed	Yes	Not assessed	Not tested	6 weeks	The combined intervention significantly reduced drinking outcomes
Arazan et al. (2023)	Alcohol-related harms	Yes	No	No	Not tested	Post-event	PBS increased but did not reduce alcohol-related harms
Braitman and Henson (2016)	Alcohol consumption (quantity, frequency, heavy drinking, peak BAC); Alcohol-related harms	Mixed	Yes	No	Moderation	4 weeks	Intervention reduced drinking but not alcohol-related harms; effects moderated by baseline PBS
Braitman and Lau-Barraco (2018)	Alcohol consumption (quantity, frequency, BAC); Alcohol-related harms	Not assessed	Mixed	No	Not tested	9 months	Booster emails produced short-term reductions in drinking but no sustained long-term effects
Braitman et al. (2022)	Alcohol consumption (quantity, frequency, peak drinks); Alcohol-related harms	Maintained	No	No	Moderation (ns)	3 months	Drinking declined over time with no added benefit of PBS boosters
Dvorak et al. (2015)	PBS use; alcohol quantity; alcohol-related consequences	Yes	Yes	Yes	Mediation and moderation	6 weeks	DRT-framed PBS messages increased PBS use and indirectly reduced alcohol use and alcohol-related consequences among participants who strongly believed the intervention message.
Edwards et al. (2020)	Alcohol-related harms	Yes	No	Yes*	Not tested	3 days	PBS prompting increased PBS use and reduced alcohol-related harms after controlling for alcohol consumption
Kenney et al. (2014)	Alcohol consumption (drinks per week, heavy drinking); Alcohol-related harms	Yes	Partial	Yes	Mediation	6 months	PBS mediated reductions in alcohol-related harms and short-term heavy drinking
LaBrie et al. (2015)	Alcohol consumption (drinks per week, heavy drinking); Alcohol-related harms	Yes	No	No	Mediation	6 months	Intervention increased PBS use and indirectly reduced drinking via PBS
Larimer et al. (2007)	Alcohol consumption (frequency, drinks per week, heavy episodic drinking); Alcohol-related harms	Not assessed	Yes	No	Mediation	12 months	Personalized feedback reduced drinking; effects mediated by increased PBS use
Leeman et al. (2016)	Alcohol consumption (frequency, quantity, peak drinking); Alcohol-related harms	No	Yes	No	Not tested	6 months	Intervention reduced weekly and peak drinking without changes in PBS use
Martens et al. (2013)	Alcohol use; Alcohol-related harms	Yes	No	No	Mediation (ns)	6 months	PBS intervention increased PBS use but did not reduce drinking or alcohol-related harms
Neighbors et al. (2009)	BAC; alcohol quantity	Yes	Yes	NA	Mediation (ns)	1 week	Intervention reduced 21st-birthday BAC; effects were not mediated by PBS
O'Donnell et al. (2019)	Risky single-occasion drinking; alcohol-related harms	Yes	No	No	Not tested	Post-intervention	Intervention increased PBS use but did not change drinking or harms
Sugarman and Carey (2009)	Alcohol consumption (drinks per week, BAC)	Yes	No	No	Not tested	2 weeks	PBS use increased but was not associated with reductions in alcohol consumption

Note. Alcohol reduction and alcohol-related harm reduction indicate statistically significant improvements favoring the intervention group; “Mixed” indicates inconsistent effects across outcomes or follow-up periods; “Partial” indicates improvements in some but not all alcohol outcomes

* Adjusted for alcohol consumption. BAC = blood alcohol concentration; NA = not applicable.

or universal mechanism of alcohol behavior change.

Previous systematic reviews have reported small but significant associations between PBS and reduced alcohol consumption and related harms (Cox et al., 2024; Gren et al., 2021; Pearson, 2013), but these findings are largely based on observational evidence. By synthesizing RCTs, the current review provides a more rigorous test of PBS as both an intervention target and a hypothesized mechanism. A recurring pattern across trials was an inconsistency between proximal increases in PBS use and distal alcohol outcomes. Several studies reported that increased PBS use did not result in reductions in alcohol consumption or related harms (Arazan et al., 2023; Martens et al., 2013; O'Donnell et al., 2019; Sugarman and Carey, 2009), whereas others identified indirect effects through PBS (Dvorak et al., 2015; Kenney et al., 2014; LaBrie et al., 2015; Larimer et al., 2007). Conversely, some interventions reduced alcohol outcomes without measurable changes in PBS (Braitman et al., 2022; Leeman et al., 2016). Collectively, these findings suggest that

PBS may contribute to intervention effects under certain conditions but are unlikely to represent a universal pathway through which alcohol interventions produce behavioral change.

Although mechanistic evidence remains limited, the available findings suggest that PBS may operate as context-dependent behavioral tools rather than standalone determinants of alcohol outcomes. PBS are likely embedded within broader processes involving motivation, self-regulation, and situational opportunity. Supporting this interpretation, emerging longitudinal evidence from cannabis research suggests a bidirectional relationship between PBS and substance use: greater PBS use predicted subsequent reductions in cannabis use frequency, whereas greater cannabis-related consequences predicted subsequent increases in PBS use (Romero-Pérez et al., 2026). Although observational, these findings suggest that PBS may represent adaptive behavioral responses that both influence and respond to substance-related risk.

Building on these findings, we propose a preliminary

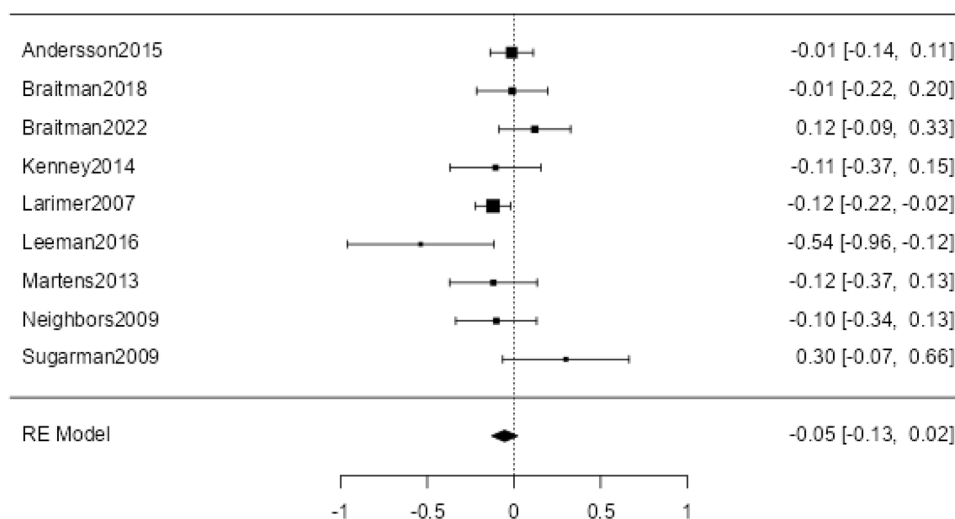


Fig. 3. Forest plot of intervention effects on quantity of alcohol consumption.

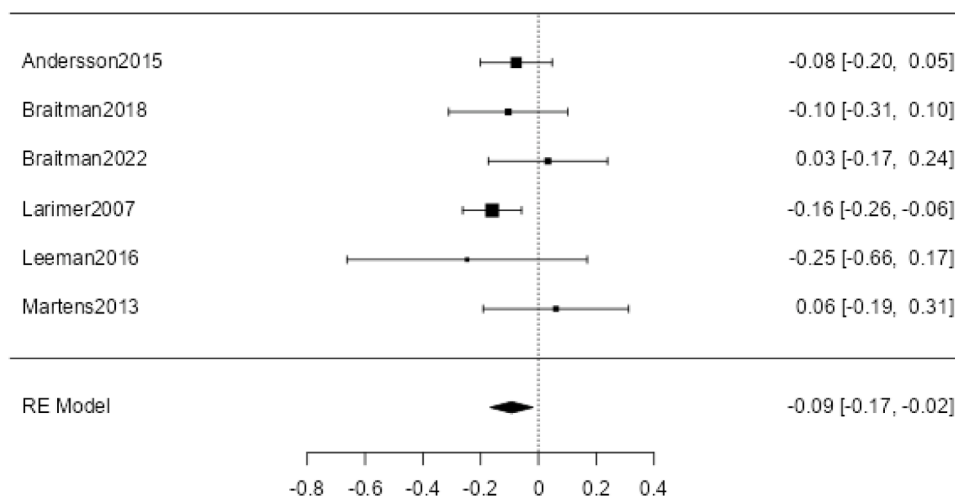


Fig. 4. Forest plot of intervention effects on frequency of alcohol consumption.

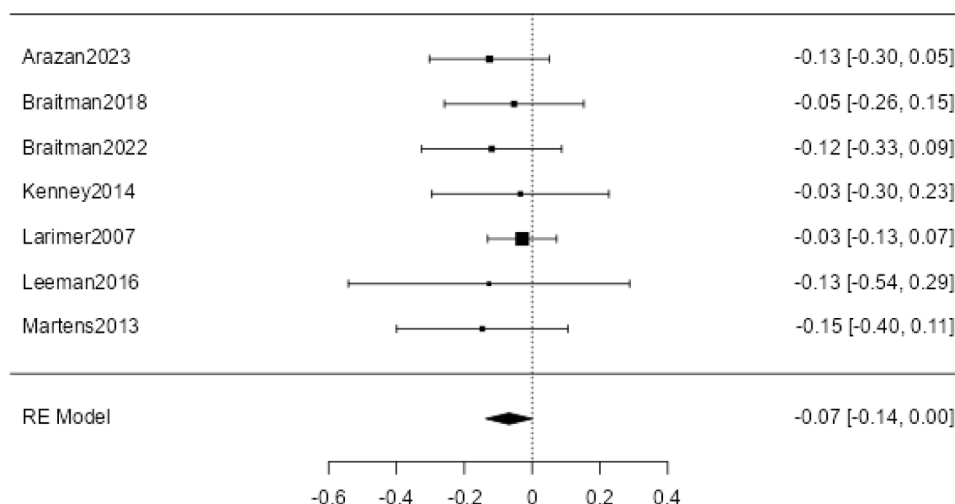


Fig. 5. Forest plot of intervention effects on alcohol-related problems.

initiation–execution–context framework to explain why increases in PBS do not consistently translate into improved alcohol outcomes. Initiation

refers to motivation, readiness, and intention to adopt PBS before drinking (Bravo et al., 2015; González-Ponce et al., 2024). Execution

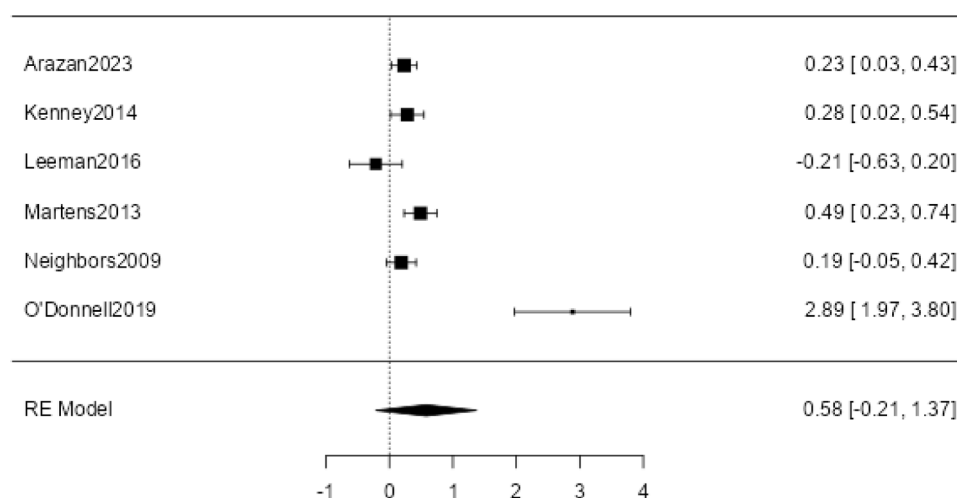


Fig. 6. Forest plot of intervention effects on protective behavioral strategy use.

reflects the ability to implement these strategies during drinking episodes, which depends on self-regulatory capacity and behavioral skills (Sanchez-Garcia et al., 2024). Context represents situational factors, including peer drinking norms, social pressure, and drinking environments, that may facilitate or constrain PBS implementation (Arterberry et al., 2014). Thus, PBS may function less as independent causal drivers and more as behavioral tools whose effectiveness depends on whether individuals are motivated to use them, able to implement them, and supported by their surrounding context. Accordingly, individuals may endorse intentions to use PBS but fail to implement them during high-risk drinking situations. However, this framework should be considered hypothesis-generating rather than confirmatory.

These findings have important implications for intervention development. Rather than assuming that increasing PBS use alone will reduce alcohol consumption, future interventions should also target processes that support successful strategy enactment, including motivation, self-regulatory skills, and contextual barriers (Braitman et al., 2017; González-Ponce et al., 2024; Pearson et al., 2013). Although several trials suggested indirect effects through PBS, relatively few formally evaluated mediation, and findings were inconsistent across intervention designs. Future studies should therefore examine whether changes in PBS temporally precede improvements in alcohol outcomes using longitudinal mediation models, ecological momentary assessment, and event-level analyses. Preliminary evidence from a pilot cannabis intervention, in which episode-level PBS use mediated reductions in cannabis use, further supports the value of investigating PBS mechanisms at the behavioral episode level (Prince et al., 2020).

The meta-analytic findings summarized in this review further support the interpretation that PBS may influence different aspects of alcohol-related behavior to varying degrees (Cox et al., 2024). Although pooled effects appeared more evident for some alcohol outcomes than others, these findings should be interpreted cautiously because individual meta-analyses included relatively few studies. One possible explanation is that reductions in drinking frequency may be more closely related to pre-drinking decision-making, whereas reductions in drinking quantity may require successful implementation of PBS during drinking episodes (Pearson, 2013). Consistent with the intention-behavior gap, individuals may intend to use PBS but fail to implement these strategies consistently in real-world drinking contexts (Gius et al., 2026). Recent ecological momentary evidence further suggests that PBS may reduce event-level alcohol-related harms even when changes in overall consumption are modest (Shoemaker et al., 2026). These patterns suggest that PBS may differentially affect components of drinking behavior rather than exert uniform effects across all alcohol outcomes. However, this interpretation remains tentative because

existing evidence has primarily focused on intervention effects rather than directly testing the behavioral mechanisms underlying PBS use.

Subgroup analyses provide preliminary insight into conditions under which PBS may be more effective. Effects appeared more evident at longer follow-up, suggesting that PBS-related behavior change may require repeated practice and contextual adaptation rather than occur immediately after intervention exposure (Braitman et al., 2017; Pearson, 2013). Adjunct PBS interventions also showed potentially greater effects than interventions primarily focused on PBS; however, this finding should be interpreted cautiously because subgroup classifications were developed specifically for this review, included relatively few studies, and could not fully account for differences in intervention intensity, delivery format, or other intervention components. Therefore, these findings should be considered exploratory rather than evidence that one intervention approach is superior to another.

Nevertheless, these observations suggest that PBS may be most effective when integrated with complementary intervention components that strengthen motivation and self-regulatory execution. Recent intervention research has similarly emphasized repeated reinforcement, personalized feedback, and sustained support rather than one-time exposure to PBS content (Lewis et al., 2026). In addition, because most interventions combined multiple PBS domains, this review could not determine whether specific strategies contributed differently to intervention effectiveness. This distinction is important because different PBS target different behavioral pathways. For example, strategies that limit or pace drinking may be more directly related to reducing alcohol consumption, whereas harm-reduction strategies, such as arranging transportation, may primarily reduce alcohol-related consequences (Martens et al., 2005). Future trials using factorial or dismantling designs are needed to determine which PBS strategies are most effective, for whom, and under which drinking contexts.

The predominance of brief, low-intensity, and digitally delivered interventions may also contribute to the modest effects observed. These approaches may provide limited opportunities for participants to acquire, practice, and sustain the self-regulatory skills required for consistent implementation of PBS, particularly because maintaining health behavior change typically requires repeated enactment, feedback, and ongoing self-regulation rather than one-time exposure (Hennessy et al., 2020; Kwasnicka et al., 2016). This interpretation is consistent with evidence that brief alcohol interventions generally produce small effects that may attenuate over time compared with more intensive approaches (Tanner-Smith and Lipsey, 2015). In addition, no clear pattern indicated that delivery mode alone explained differences in effectiveness; rather, intervention intensity, reinforcement, engagement, and content likely interact to influence outcomes.

High attrition rates and inconsistent reporting of adherence further complicate interpretation. These issues were particularly evident in large-scale digital interventions and may reflect both methodological limitations and reduced intervention exposure (Wang et al., 2024). Limited engagement may reduce opportunities to develop and apply PBS, meaning that modest or null effects could reflect insufficient uptake rather than true ineffectiveness (Gan et al., 2021). Distinguishing between intervention failure and engagement failure is therefore critical for interpreting effectiveness.

The generalizability of current evidence is limited by the predominance of Western university-based samples, particularly young adults in the United States. PBS are grounded in individual-level self-regulation and assume some degree of personal control over drinking decisions, which may vary across sociocultural contexts (Ayala Guzman et al., 2024). Evidence from cannabis research suggests that PBS use and its relationship with substance-related outcomes may differ across countries, highlighting the potential influence of cultural context (Richards et al., 2021). In collectivist or resource-constrained settings, drinking behaviors may be more strongly shaped by social norms and structural factors (Lincoln, 2016), potentially requiring cultural adaptation rather than direct transfer of existing PBS models. Future RCTs should therefore prioritize community-based and culturally diverse adult populations to determine whether findings from predominantly young U.S. university samples extend to broader populations.

4.1. Strengths and limitations

This review has several strengths. First, it focused exclusively on RCTs, providing a more rigorous assessment of PBS as intervention components and potential mechanisms of change than previous reviews based largely on observational evidence. Second, the review integrated meta-analysis with narrative synthesis and explicitly examined whether changes in PBS use were associated with improvements in alcohol outcomes. Third, the proposed initiation–execution–context framework provides a theoretically informed interpretation of why PBS increases may not consistently translate into reductions in alcohol consumption or related harms.

Several limitations should be considered when interpreting these findings. First, the evidence base was dominated by young adults attending universities in the United States, limiting generalizability to older adults, community populations, and culturally diverse settings. Second, although 15 RCTs were included, individual meta-analyses and subgroup analyses were based on relatively few studies, resulting in limited statistical power and exploratory subgroup findings. Third, few trials formally evaluated mediation, and heterogeneous analytical approaches prevented quantitative synthesis of mechanistic pathways. In addition, most studies did not establish the temporal sequence between changes in PBS use and subsequent alcohol outcomes, limiting causal inference regarding PBS as mechanisms of change.

Finally, reliance on self-reported outcomes, heterogeneous outcome definitions, inconsistent reporting of intervention fidelity and adherence, and interventions combining multiple PBS domains limited the ability to determine which strategies were most effective. In addition, studies at high risk of bias were retained because of the limited evidence base, and no risk-of-bias sensitivity analyses were performed; therefore, the pooled estimates should be interpreted cautiously. Although the classification of PBS roles was conducted systematically using predefined criteria, this framework was developed specifically for this review and may not fully capture differences in intervention intensity, delivery format, or theoretical emphasis. Therefore, conclusions regarding specific PBS components and their mechanisms should be interpreted cautiously.

4.2. Implications

The findings have important implications for the conceptualization

and design of alcohol interventions. PBS should not be viewed as standalone techniques expected to directly reduce alcohol consumption, but rather as behavioral tools operating within broader intervention systems. Interventions may achieve greater effectiveness when PBS are combined with components that strengthen motivation, self-regulation, and context-sensitive planning rather than relying solely on brief exposure to PBS content.

Future research should move beyond treating PBS as a uniform mechanism and determine which strategies are effective, for whom, and under what conditions. Adequately powered RCTs involving community-based, non-student adult populations and culturally diverse settings are needed to improve generalizability. Future studies should also incorporate longer intervention periods with repeated reinforcement and evaluate mechanisms of change using longitudinal mediation, moderation, and event-level designs. Improved assessment of intervention fidelity, participant engagement, and adherence will be essential for distinguishing ineffective interventions from interventions that were insufficiently implemented. Developing and testing theoretical models that situate PBS within broader behavioral systems may further advance intervention optimization.

5. Conclusion

PBS-based interventions represent a promising but context-dependent approach to alcohol harm reduction. Although PBS interventions generally increase protective behaviors, their effects on alcohol consumption and related harms are modest and not consistently explained by increases in PBS use alone. The current evidence suggests that PBS function most effectively as complementary behavioral tools embedded within broader motivational, self-regulatory, and contextual processes rather than as standalone mechanisms of change. However, this interpretation remains preliminary. Future mechanistic research using longitudinal and event-level approaches is needed to clarify when, how, and for whom PBS contribute to reductions in alcohol use and related harms.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT 5.3 in order to improve clarity and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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CRediT authorship contribution statement

Trieu Van Nhat: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Penpaktr Uthis:** Writing – review & editing, Supervision, Methodology, Data curation. **Russunan Jantarapakdee:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Patcharin Krongtham:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

All authors have completed the manuscript independently of any commercial or financial relationships that could be construed as a

potential conflict of interest. The authors declare that they have no conflicts of interest related to this work.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.psychres.2026.117430](https://doi.org/10.1016/j.psychres.2026.117430).

Data availability

No primary datasets were generated or analyzed for this study. All data are derived from published studies included in the systematic review.

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