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Effectiveness of School-Based Resilience Interventions on Adolescent Tobacco, Alcohol, and Illicit Substance Use: A Meta-Analysis

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ABSTRACT

Background: Resilience is a key protective factor in mitigating substance use behaviors in adolescence, but the effectiveness of school-based resilience interventions remains unclear.

Methods: Randomized and quasi-experimental studies evaluating school-based resilience interventions for tobacco, alcohol, or illicit substance use among students aged 6–18 years were identified. Pooled effect sizes were estimated using random-effects meta-analysis, with subgroup and meta-regression analyses.

Results: From 3504 records, 13 studies on tobacco, 14 on alcohol, and 12 on illicit substances met the inclusion criteria. The pooled results showed significant reductions in tobacco (OR = 0.83, 95% CI = 0.73–0.93, $I^2 = 61.0\%$), alcohol use (OR = 0.81, 95% CI = 0.74–0.90, $I^2 = 57.1\%$), and illicit substance use (OR = 0.80, 95% CI = 0.70–0.92, $I^2 = 45.3\%$). Subgroup analysis revealed that multi-level interventions yielded a greater reduction.

Implications for School Health Policy, Practice, and Equity: School-based resilience interventions reduce adolescent substance use, providing insight into how resilience strategies operate across ecological domains. Embedding sustained, multi-level approaches within whole-school prevention frameworks may strengthen effectiveness and promote equity in school health.

Conclusions: School-based resilience interventions are effective in reducing adolescent substance use, underscoring the need for multi-level intervention strategies.

1 | Introduction

Adolescence is a critical developmental period of rapid physical, psychological, and social changes, providing essential opportunities for health promotion before adulthood [1]. However, a significant number of adolescents worldwide face mental health challenges, including depression, suicidal ideation, and emotional disorders, which can lead to engagement in health-risk behaviors such as smoking, alcohol consumption, and substance abuse [2–4]. Empirical studies suggest that the initiation of alcohol, tobacco, and other drug (ATOD) use predominantly occurs during adolescence [5]. These health-risk behaviors tend to cluster across multiple domains, amplifying the overall burden and highlighting the necessity of comprehensive intervention strategies [6].

The World Health Organization defines adolescence as the developmental period spanning ages 10–19 [1]. From a preventive science perspective, however, interventions targeting adolescent substance use are frequently implemented prior to or during early

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adolescence to modify developmental risk trajectories before substance use behaviors become established [4]. In school-based prevention research, resilience-focused interventions may therefore be initiated in late childhood, while their effectiveness is typically evaluated using substance use outcomes assessed during adolescence [7]. Accordingly, the present study adopts a developmental prevention framework that emphasizes adolescent outcomes, while acknowledging the developmental continuity between late childhood and adolescence.

Resilience, defined as the capacity to adapt positively in the face of adversity and stress, has emerged as a key protective factor that enables individuals to cope effectively with challenges [8, 9]. Increasing attention has been given to the role of resilience in adolescent mental health promotion and the prevention of health-risk behaviors. Systematic reviews on adolescent mental health and risk behavior prevention suggest that psychosocial interventions, including resilience-building strategies, can facilitate behavioral improvements and provide foundational skills for promoting healthy behaviors while preventing smoking, alcohol consumption, and illicit drug use [10]. Furthermore, adolescents with high resilience have been shown to recover quickly from adversity, demonstrating better psychological stability and adaptive coping mechanisms [9, 11].

Resilience interventions are structured programs designed to enhance individuals' capacity to cope with stress and adversity by fostering coping strategies, emotional regulation, and social support [12, 13]. These interventions often incorporate skill-building activities, cognitive-behavioral techniques, and mindfulness practices [14, 15]. Recent studies emphasize the benefits of resilience interventions in improving mental health and overall well-being [15, 16]. Resilience interventions have been found to alleviate symptoms of depression among individuals who have experienced trauma or suffer from severe psychological conditions, suggesting that resilience plays a vital protective role in mitigating the negative effects of stress, adversity, and trauma [8]. Previous Cochrane reviews indicate that school-based interventions focused solely on knowledge dissemination have limited efficacy in reducing adolescent substance use, whereas resilience-based psychosocial approaches demonstrate significant effectiveness [17–19]. Resilience can buffer these adverse effects and promote a healthier lifestyle [20], highlighting the necessity of implementing resilience-based interventions to prevent adolescent engagement in health-risk behaviors.

Accordingly, schools serve as primary settings for adolescent development and provide an optimal environment for delivering resilience-based interventions [21]. Consequently, the importance and necessity of school-based resilience interventions are being increasingly recognized [22, 23]. School-based resilience programs aim to empower adolescents with the skills necessary to overcome stress and adversities.

Although systematic reviews have been conducted on the effectiveness of school-based interventions for reducing adolescent health-risk behaviors [17–19], research synthesizing the effectiveness of resilience-based interventions remains limited [24]. Most existing studies consider resilience as one of multiple intervention components, making it difficult to determine the unique contribution of resilience to reducing health-risk behaviors. Consequently, substantial variation exists in the resilience components incorporated in previous interventions [8, 24]. Furthermore, resilience-based interventions have demonstrated effectiveness in improving psychological and physical health outcomes [25–27], yet the variation in effect sizes across different intervention levels, components, and durations remains an area of uncertainty [8]. Additionally, prior systematic reviews have predominantly focused on single health issues such as depression, alcohol use, or smoking, rather than integrating resilience-based interventions across multiple domains. In real-world settings, single-issue interventions are often deprioritized or replaced based on shifting policy priorities and funding constraints [28, 29].

Therefore, identifying and validating the common features and effectiveness of resilience-based interventions applicable to various health-risk behaviors is essential. To address these gaps, this meta-analysis systematically categorizes resilience factors and settings into individual, interpersonal, and community levels using an ecological framework unlike prior studies. This study also incorporates meta-regression analysis to assess the effectiveness of intervention duration, an aspect largely overlooked in previous reviews. By evaluating the relative effectiveness of various resilience interventions, this study enhances the evidence for optimizing school-based resilience programs aimed at reducing adolescent substance use.

Given this context, there is a growing need for research that expands and enhances the scope and sustainability of resilience-based interventions. This includes investigating the effectiveness of different intervention levels and durations across multiple health domains. This study aims to conduct a comprehensive meta-analysis of school-based resilience interventions to determine their effectiveness in reducing adolescent tobacco, alcohol, and illicit substance use.

2 | Methods

2.1 | Inclusion Criteria

Eligible studies included randomized controlled trials (RCTs) and quasi-experimental study designs that evaluated school-based resilience interventions. Studies published only as abstracts or literature reviews (e.g., systematic and non-systematic reviews, including meta-analysis) were excluded.

The review included studies that implemented a school-based resilience intervention. Resilience interventions were defined as programs targeting one or more resilience protective factors at the individual, interpersonal, and community levels based on previous theoretical frameworks and empirical findings regarding resilience [24, 30, 31]. The individual-level factors included self-regulation (self-control, coping, problem-solving, decision-making, goal setting), interpersonal skills (communication, empathy, cooperation), and positivity (self-efficacy, self-esteem). The interpersonal-level factors encompassed social support, such as family and peer support. The community-level factors included school-based and community-based support.

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School-based interventions were defined as providing a component of the intervention to students within a school environment during school hours. Studies were included if they had a comparison group that received usual care or no intervention. Studies were eligible if they reported quantitative data on tobacco, alcohol, or illicit substance use outcomes, assessed at any time point during adolescence (aged 10–19 years), specifically measuring: (1) Tobacco use (e.g., prevalence of use); or (2) Alcohol use (e.g., prevalence of use); or (3) Illicit substance use (e.g., prevalence of any illicit substance or a specific substance such as cannabis). Studies were included regardless of the age at intervention initiation, provided that substance use outcomes were measured during adolescence.

2.2 | Search Strategy

This meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [32]. A comprehensive search of online databases was performed, including the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, and EMBASE. Peer-reviewed articles published in English and Korean were considered eligible if they met the predefined inclusion criteria. A combination of controlled vocabulary and free-text search terms was used to ensure a thorough retrieval of relevant studies. Various keyword combinations in English were employed using the wildcard symbol (*) to capture different variations of each term. The key search terms included: child, adolescent, student, teen*, youth, school, primary school*, elementary school, secondary school*, middle school*, high school*, school health service, resilience, psychological, intervention*, program*, promot*, enhanc*, smoking, smoking cessation, tobacco, cigarette, nicotine, alcohol, alcohol drinking, alcoholic intoxication, drunk*, alcoholism, alcohol abuse, illicit drug*, drug*, street drug*, drug abuse*, drug addict*, cannabis, marijuana, substance-related disorders, morphine, heroin, hallucinogens, cocaine, and lysergic acid diethylamide (LSD). Citation tracking and manual searches of reference lists from relevant studies were also conducted to identify additional eligible articles. The database searches covered studies published from database inception to 2025.

2.3 | Data Analysis

After removing duplicates, abstracts were screened to identify eligible studies that met the eligibility criteria. Then, full articles were retrieved, screened, and compared against an inclusion criteria checklist. Data were extracted independently by two authors using a standardized extraction coding form. Discrepancies were solved through discussion. Extracted variables included study characteristics (study ID, authors, publication year, country, sample size, study design), participant demographics (age, gender distribution), intervention details (targeted resilience factors, intervention levels, intervention duration), comparison group characteristics, and outcome measures. Effect sizes (odds ratios) were calculated for each study. For each substance-specific meta-analysis, only studies reporting the relevant outcome were included. As a result, the number of studies varied by outcome, although all analyses were based on the same set of studies included in the review. Each binary outcome data were pooled, and effect sizes were calculated as odds ratios using a random-effects model due to expected heterogeneity across studies. Heterogeneity was assessed using Higgins I^2 statistic, with values interpreted as low (< 25%), moderate (25%–75%), or high (> 75%) heterogeneity [33].

When heterogeneity was identified, subgroup analysis was conducted to compare differences in OR between levels of resilience factors and intervention levels. A meta-regression analysis was performed to examine the effect of intervention duration on the odds ratio. In addition, jackknife sensitivity analyses were conducted for each outcome by iteratively excluding one study at a time and recalculating the pooled odds ratio using a random-effects model. This approach was used to assess the robustness of the overall findings and to identify whether any single study exerted undue influence on the pooled estimates.

Publication bias was assessed using funnel plots with Egger's regression test. This test examined the relationship between effect sizes and their standard errors to detect asymmetry in the funnel plot. A significant result from Egger's regression test suggests the presence of small-study effects, which may indicate potential publication bias [34]. The use of Egger's regression test was preferred as it offers a quantitative measure of bias, thereby enhancing the visual inspection of the funnel plot and providing a more objective evaluation of publication bias [34]. All analysis was conducted in May 2024 and updated in February 2025, including the newly identified studies, using Comprehensive Meta-Analysis (CMA) Version 4.0.

2.4 | Quality Assessment

Risk of bias was assessed independently by two reviewers, and disagreements were resolved through discussion. For randomized controlled trials (RCTs), the Cochrane Risk of Bias 2.0 (RoB 2) tool was used. This tool evaluates bias across five domains: (D1) bias arising from the randomization process, (D2) bias due to deviations from intended interventions, (D3) bias due to missing outcome data, (D4) bias in measurement of the outcome, and (D5) bias in selection of the reported result. Each domain was judged as low risk, some concerns, or high risk. For non-randomized studies, risk of bias was assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. ROBINS-I evaluates bias across seven domains, including confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. Overall risk of bias judgments was categorized as low, moderate, serious, or critical.

3 | Results

3.1 | Selected Study Characteristics

Through the preliminary search, 3504 articles were identified. After the removal of duplicates and screening the abstracts, the full text of 86 articles was screened for inclusion. Four additional studies were identified through reference checking of related meta-analysis. After screening the articles, 15 studies consisting

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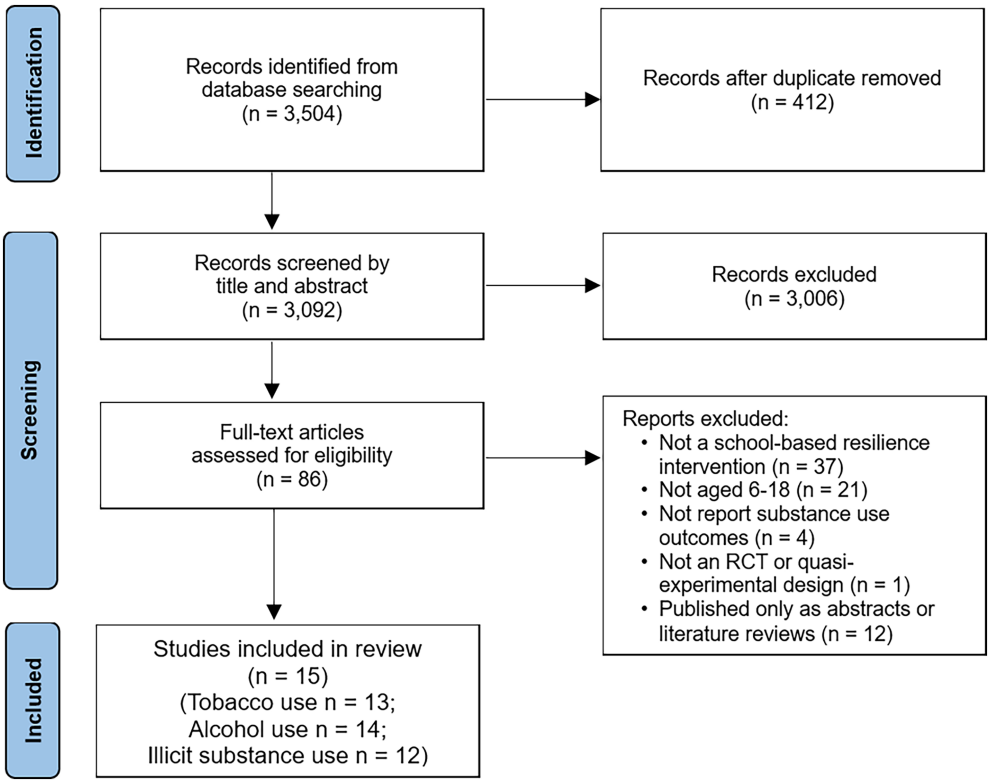


FIGURE 1 | PRISMA flow of studies selection process.

of randomized controlled trials and quasi-experimental designs were selected for analysis (Figure 1).

The characteristics of the included studies are presented in Table 1. Most of the studies were cluster randomized controlled trials (C-RCTs) ($n = 11$), followed by randomized controlled trials (RCTs) ($n = 2$), and a quasi-experimental study ($n = 1$). This meta-analysis included a diverse sample of adolescents aged 6–18 years. The sample size ranged from 86 to 5500 participants. Most of the studies were conducted in the United States ($n = 8$), followed by Australia ($n = 4$), and one each in England, Sweden, and Nigeria.

3.2 | Meta-Analysis

A total of 15 studies were included in the meta-analysis. Due to variations in outcome reporting across substances, substance-specific meta-analyses were conducted using overlapping subsets of studies for tobacco ($n = 13$), alcohol ($n = 14$), and illicit substances ($n = 12$).

3.2.1 | Tobacco Use

The analysis of 13 studies demonstrated a significant effect of school-based resilience interventions on reducing tobacco use (OR = 0.83, 95% CI: 0.73–0.93; Figure 2). The level of heterogeneity was moderate ($I^2 = 61.0\%$).

3.2.2 | Alcohol Use

The analysis of 14 studies demonstrated a significant reduction in alcohol use, which found an overall resilience intervention effect (OR = 0.81, 95% CI: 0.74–0.90; Figure 2), with moderate heterogeneity ($I^2 = 57.1\%$).

3.2.3 | Illicit Substance Use

The analysis of 12 studies demonstrated a significant reduction in illicit substance use (OR = 0.80, 95% CI: 0.70–0.92; Figure 2). The heterogeneity was relatively lower than tobacco and alcohol use ($I^2 = 45.3\%$). The Forest plot analysis revealed that the study by Eisen et al. [38] had a larger effect size compared to other studies.

3.3 | Subgroup Analysis

3.3.1 | Intervention Level

Subgroup analyses were conducted to examine variations in effectiveness based on resilience intervention level (Table 2). Programs that focused solely on individual resilience factors, such as self-regulation, communication, and positivity, showed only in illicit substance use (OR = 0.85, 95% CI: 0.75–0.95). In contrast, interventions integrating interpersonal resilience components, including family and peer support, were found to be more effective in reducing both tobacco use (OR = 0.70, 95%

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TABLE 1 | Characteristics of studies and interventions included in the meta-analysis.

					Intervention		Control				
Study name	**Study design**	**Country**	**Male %**	**Mean age**	***N***	**Intervention description**	***N***	**Intervention description**	**Outcome measure**	**Setting**	**Duration**
Bond et al. (2004) [35]	C-RCT	Australia	46.8	14.0	1335	**The Gatehouse Project** (whole-school intervention enhancing communication, positive school climate, self-regulation, supportive peer relationships, and decision making)	1343	Usual school education	Any drinking, any smoking, any marijuana use in past 6 months	Secondary School	2 years
Bonell et al. (2018) [36]	C-RCT	England	47.5	12.0	2281	**Learning Together** (whole-school intervention using restorative practice, school action groups, and social/emotional skills; self-regulation, communication, peer/school support, and emotional management)	3087	Standard school practices	Alcohol use, Tobacco use, Illicit drug use	School	3 years
Brown et al. (2005) [37]	C-RCT	USA	54.0	7.7	479	**RHC Project** (social development, multi-component intervention (self-regulation, family support, prosocial skills), cooperative learning, parental workshops, social skills training)	479	Standard educational curriculum	Alcohol use, Marijuana use, Cigarette use (past year/month use)	Elementary school	5 years
Eisen et al. (2003) [38]	C-RCT	USA	48.3	11.0	2658	**SFA program** (life skills training on communication, refusal skills, self-efficacy, peer resistance, decision-making, and prosocial skills with peer and teacher activities. 40-session curriculum)	2658	Usual practice	Recent (last 30 days) and lifetime use of alcohol, binge drinking, cigarettes, marijuana	Middle school	2 years
Griffin et al. (2009) [39]	RCT	USA	62.9	NR	92	**BRAVE Program** (self-regulation, communication, community and family support, cognitive-behavioral skills)	86	Usual practice	Tobacco use, Alcohol use, Illicit substance use	Middle School	8 months
Hodder et al. (2017) [24]	C-RCT	Australia	50.0	12.6	1909	**Universal intervention** (self-regulation, decision-making, communication, and community support)	1206	Usual practice	Tobacco use, Alcohol use, Illicit substance use	Secondary School	2 years
Perry et al. (1996) [40]	C-RCT	USA	NR	12.0	951	**Project Northland** (skills training for self-regulation, family and peer support; multi-level intervention (curriculum, peer leadership, parent programs, community task force))	951	Usual health curriculum	Past month alcohol use, Cigarette use, Marijuana use	School	3 years

(Continues)

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TABLE 1 | (Continued)

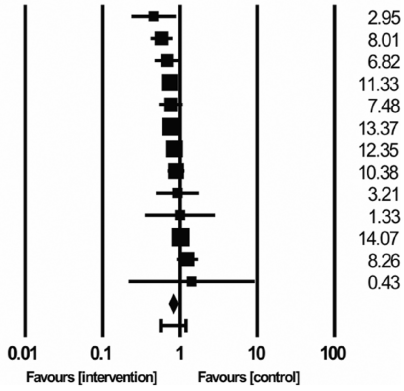
Study name	Study design	Country	Male %	Mean age	Intervention		Control		Outcome measure	Setting	Duration
					N	Intervention description	*N*	Intervention description			
Piper et al. (2000) [41]	C-RCT	USA	48.0	NR	758	**Healthy for Life project** (a multi-component school and family program based on the social influence model and resilience-building by teaching social skills, refusal skills, positive classroom norms, peer leadership, and parent involvement)	898	Regular health education curriculum	Past month tobacco, alcohol, and marijuana use	Middle School	6 months
Roberts et al. (2011) [42]	C-RCT	Australia	52.1	10.9	693	**AOP** (social and optimistic thinking skills, combining family components, interactive lessons on communication, problem-solving, cognitive restructuring, and coping)	297	Standard Health Education curriculum	Smoking and alcohol use in past month	Primary School	3 years
Skarstrand et al. (2014) [43]	C-RCT	Sweden	49.7	12.0	254	**Strengthening Families Program** (family communication, parental monitoring, and adolescent social skills, including joint family sessions)	254	Usual school education	Lifetime and recent smoking, alcohol use, and illicit drug use	Elementary school	3 months
Spoth et al. (2002) [44]	C-RCT	USA	53.0	NR	517	**LST, SFP** (family-focused sessions on parenting skills, monitoring, communication, resistance to peer pressure, and social competency)	463	Standard health education	Tobacco, alcohol, and marijuana use	Middle school	2 years
Spoth et al. (2007) [45]	C-RCT	USA	NR	NR	5500	**PROSPER** (Community–school–university partnerships, family, and school program (resilience, self-efficacy, peer resistance))	5281	Usual practice	Tobacco use, Alcohol use, Illicit substance use	School	2 years
Tebes et al. (2007) [46]	nRT	USA	53.0	14.5	149	**ADM-PYDC curriculum** (18-session decision-making curriculum emphasizing social skills, optimistic cognition, coping, and decision skills, peer support, and family involvement)	155	Usual practice	Past month use of alcohol, marijuana	Secondary School	1 year
Toumbourou et al. (2013) [47]	RCT	Australia	NR	12.3	1108	**Resilient families intervention** (social and emotional skills, parent education, family-community linkage)	1213	Usual practice	Lifetime alcohol use, frequent use (monthly)	Secondary School	1 year
Vigna-Taglianti et al. (2021) [48]	C-RCT	Nigeria	61.5	14.2	1104	**Unplugged curriculum** (social competence and social influence, incorporating teacher and family training)	1539	Standard school curriculum	Past month use of alcohol, tobacco, and marijuana	Secondary School	6 months

Abbreviations: ADM-PYDC = Adolescent Decision-Making Program-Positive Youth Development Program; AOP = aussie optimism program; BRAVE = building resiliency and vocational excellence; C-RCT = cluster-randomized controlled trials; LST = life skills training; NR = not reported; nRT = non-randomized trials (Quasi-experimental study design); PROSPER = PROmoting School–community–university Partnerships to Enhance Resilience; RCT = randomized controlled trials; RHC = raising healthy children; SFA = skills for adolescence; SFP = strengthening families program.

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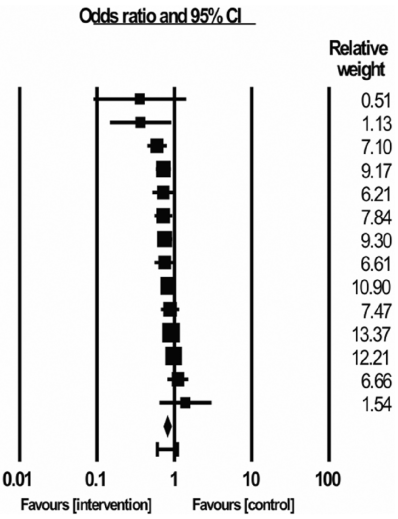
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Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Roberts (2011)	0.460	0.240	0.881	-2.343	0.019	2.95
Bonell (2018)	0.580	0.425	0.791	-3.439	0.001	8.01
Spoth (2002)	0.687	0.479	0.984	-2.048	0.041	6.82
Perry (1996)	0.744	0.609	0.911	-2.869	0.004	11.33
Brown (2005)	0.762	0.547	1.061	-1.609	0.108	7.48
Spoth (2007)	0.770	0.668	0.887	-3.608	0.000	13.37
Bond (2004)	0.844	0.711	1.002	-1.932	0.053	12.35
Piper (2000)	0.893	0.710	1.124	-0.962	0.336	10.38
Vigna-Taglianti (2021)	0.930	0.501	1.725	-0.230	0.818	3.21
Skarstrand (2014)	1.010	0.362	2.822	0.019	0.985	1.33
Eisen (2003)	1.025	0.909	1.156	0.407	0.684	14.07
Hodder (2017)	1.250	0.925	1.689	1.453	0.146	8.26
Griffin (2009)	1.422	0.221	9.152	0.371	0.711	0.43
Pooled	0.825	0.729	0.933	-3.054	0.002	
Prediction Interval	0.825	0.569	1.196			



B

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Griffin (2009)	0.358	0.091	1.406	-1.471	0.141	0.51
Tebes (2007)	0.365	0.149	0.894	-2.205	0.027	1.13
Spoth (2002)	0.597	0.454	0.784	-3.706	0.000	7.10
Toumbourou (2013)	0.720	0.585	0.887	-3.089	0.002	9.17
Vigna-Taglianti (2021)	0.720	0.529	0.979	-2.095	0.036	6.21
Bonell (2018)	0.720	0.562	0.923	-2.594	0.009	7.84
Perry (1996)	0.749	0.610	0.919	-2.766	0.006	9.30
Roberts (2011)	0.752	0.562	1.006	-1.918	0.055	6.61
Bond (2004)	0.835	0.710	0.983	-2.167	0.030	10.90
Brown (2005)	0.881	0.679	1.143	-0.954	0.340	7.47
Spoth (2007)	0.910	0.824	1.005	-1.854	0.064	13.37
Eisen (2003)	0.982	0.862	1.118	-0.281	0.779	12.21
Hodder (2017)	1.110	0.831	1.482	0.707	0.479	6.66
Skarstrand (2014)	1.390	0.651	2.966	0.851	0.394	1.54
Pooled	0.813	0.736	0.897	-4.104	0.000	
Prediction Interval	0.813	0.602	1.098			



C

Study name	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Spoth (2002)	0.498	0.287	0.864	-2.479	0.013	4.74
Spoth (2007)	0.570	0.462	0.703	-5.248	0.000	14.96
Tebes (2007)	0.653	0.343	1.244	-1.295	0.195	3.66
Griffin (2009)	0.672	0.241	1.877	-0.758	0.449	1.59
Bond (2004)	0.824	0.682	0.996	-1.998	0.046	16.06
Vigna-Taglianti (2021)	0.840	0.430	1.640	-0.511	0.610	3.43
Perry (1996)	0.849	0.609	1.184	-0.964	0.335	9.64
Eisen (2003)	0.853	0.757	0.962	-2.598	0.009	19.88
Brown (2005)	0.868	0.619	1.216	-0.824	0.410	9.45
Piper (2000)	1.000	0.642	1.558	-0.000	1.000	6.58
Skarstrand (2014)	1.028	0.412	2.568	0.059	0.953	1.96
Hodder (2017)	1.180	0.805	1.730	0.848	0.397	8.07
Pooled	0.800	0.700	0.915	-3.258	0.001	
Prediction Interval	0.800	0.565	1.134			

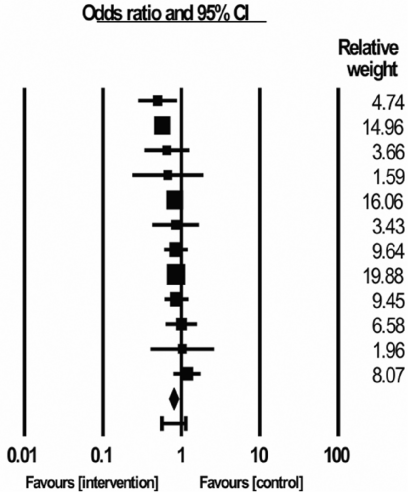


FIGURE 2 | Effect of school-based resilience intervention on tobacco, alcohol and illicit substance use outcomes. (A) tobacco use, (B) alcohol use, (C) illicit substance use.

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TABLE 2 | Subgroup and overall analysis for resilience interventions.

Overall/subgroup	Studies	Effect estimate odds ratio [95% CI]	*p*	I^2
Tobacco use				
Overall	13	0.83 [0.73, 0.93]	< 0.01	61.04
Intervention level				
Individual	2	1.02 [0.91, 1.15]	0.72	0.00
Interpersonal	4	0.70 [0.56, 0.87]	< 0.01	0.00
Community	7	0.82 [0.71, 0.95]	< 0.001	59.60
Alcohol use				
Overall	14	0.81 [0.74, 0.90]	< 0.001	57.15
Intervention level				
Individual	3	0.77 [0.53, 1.11]	0.16	73.29
Interpersonal	5	0.75 [0.63, 0.90]	< 0.01	41.51
Community	6	0.85 [0.75, 0.95]	< 0.01	48.05
Illicit substance use				
Overall	12	0.80 [0.70, 0.92]	< 0.01	45.32
Intervention level				
Individual	3	0.85 [0.75, 0.95]	< 0.01	0.00
Interpersonal	3	0.75 [0.50, 1.11]	0.15	38.69
Community	6	0.82 [0.65, 1.03]	0.10	66.44

Abbreviations: CI, confidence interval; I^2, heterogeneity; *p*, significance level.

CI: 0.56–0.87) and alcohol use (OR = 0.75, 95% CI: 0.63–0.90). Community-level resilience interventions, which emphasized a broader environmental support system, showed effectiveness in reducing tobacco (OR = 0.82, 95% CI: 0.71–0.95) and alcohol use (OR = 0.85, 95% CI: 0.75–0.95). These findings highlight the importance of multi-level resilience interventions that extend beyond the individual level.

3.3.2 | Intervention Duration

Meta-regression analysis was conducted to evaluate the effect of intervention duration on outcomes across different substance uses (Table 3). The results demonstrated a significant negative association between duration of intervention and tobacco use (coefficient = −0.0017, 95% CI: −0.0034 to −0.0000, $p < 0.05$), indicating that longer intervention durations are associated with greater reductions in tobacco use. More specifically, the model suggests that for each additional week of intervention, the log odds of tobacco use decrease by 0.0017. This corresponds to approximately a 1.7% reduction in tobacco use odds per 10 weeks of intervention. Thus, an intervention lasting 12 weeks would be expected to reduce the odds of tobacco use by about 2.0%, compared to a baseline. In contrast, no significant effects of intervention duration were observed for alcohol use or illicit substance use. These findings emphasize that interventions lasting at least 10–12 weeks may be more effective in reducing tobacco use among youth, underscoring the need for sustained, long-term support in school-based resilience programs.

TABLE 3 | Results of univariate random-effects meta-regression analysis.

Variables	Coefficient	SE	95% CI	*p*
Duration of intervention (weeks)				
Tobacco use	−0.0017	0.0009	−0.0034, −0.0000	< 0.05
Alcohol use	−0.0001	0.0009	−0.0019, 0.0016	0.88
Illicit substance use	−0.0002	0.0012	−0.0024, 0.0021	0.89

Abbreviations: CI, confidence interval; *p*, significance level; SE, standard error.

3.3.3 | Sensitivity Analysis

Jackknife sensitivity analyses indicated that the pooled effects of school-based resilience interventions were stable across all outcomes. For tobacco use, exclusion of individual studies resulted in pooled odds ratios ranging from 0.80 to 0.85, all of which remained statistically significant. For alcohol use, pooled odds ratios ranged from 0.79 to 0.84 after removal of each study, with no loss of statistical significance. Similarly, for illicit substance use, pooled odds ratios ranged from 0.77 to 0.85, and the overall intervention effect remained consistent across all iterations. These results suggest that no single study disproportionately influenced the pooled estimates, supporting the robustness of the findings (Figure S1).

3.3.4 | Publication Bias

Publication bias was assessed using funnel plots and Egger's regression test. The funnel plots for tobacco, alcohol, and illicit substance use displayed a symmetrical distribution of studies, suggesting minimal publication bias. Similarly, Egger's regression test yielded non-significant results across all three substance use outcomes, indicating no strong evidence of small-study effects influencing the meta-analysis results. These findings suggest that the results of this study are robust and not substantially affected by selective publication practices.

3.3.5 | Risk of Bias

The RoB 2 assessment indicated that most randomized controlled trials were judged as having low risk of bias across domains related to missing outcome data, outcome measurement, and selective reporting (Figure S2). Some concerns were most frequently identified in the randomization process domain, reflecting insufficient reporting of allocation concealment. Overall, the majority of studies were rated as having low risk of bias or some concerns, with one study judged to be at high risk of bias. The detailed domain-level and overall judgments are presented in Figure S2. The non-randomized study by Tebes et al. [46] was judged to have an overall moderate risk of bias (Figure S2). This assessment was primarily driven by non-random assignment of participants, reliance on self-reported outcomes, and attrition during follow-up. Other domains, including deviations from intended interventions and outcome measurement, were judged as low risk.

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4 | Discussion

This meta-analysis provides substantial evidence supporting the effectiveness of school-based resilience interventions in reducing adolescent tobacco, alcohol, and illicit substance use. These findings align with prior reviews that highlight the protective effects of resilience factors in mitigating health-risk behaviors [17, 19]. Our study builds upon this by specifically demonstrating that resilience-based approaches, particularly those that integrate multiple ecological levels, are highly effective.

A key contribution of this study is its identification of the superior effectiveness of multi-level interventions, particularly those involving both school and family components. Subgroup analysis indicated that although school-based interventions independently resulted in moderate reductions in alcohol and illicit substance use, the addition of family components significantly enhanced their effectiveness across all three substance use categories. These results are consistent with prior studies demonstrating that protective factors at school and family levels contribute to reductions in adolescent substance use [49–52]. This suggests that resilience is not solely an individual trait but is cultivated through supportive environments [20]. Programs incorporating parental engagement likely reinforce protective behaviors at home, providing adolescents with continuous encouragement and modeling of positive coping strategies [3, 22]. Future interventions should further explore structured parent-adolescent engagement methods to optimize program effectiveness.

Another major insight from this study is the role of intervention duration. Meta-regression analysis showed a significant negative association between intervention duration and tobacco use, indicating that longer interventions were more effective in sustaining behavioral change. These findings align with Cleary et al. [53], which suggested that longer interventions with more sessions tend to yield greater improvements in resilience outcomes, whereas short-term interventions may be less effective. Our results indicate that prolonged and frequent intervention may be beneficial for maximizing resilience-based behavior change. Additionally, it remains unclear whether the effects of longer interventions persist beyond adolescence, underscoring the need for longitudinal follow-up studies to determine whether resilience-building efforts translate into sustained substance use prevention into adulthood.

This study also highlights the limitations of community-level interventions. While theoretically beneficial, community-level resilience programs did not demonstrate significantly greater reductions in substance use beyond school-family interventions. This may be attributed to variations in community resource availability, implementation fidelity, or broader sociocultural barriers affecting adolescent engagement with community programs. These findings suggest that while broader environmental support is important, school-family interventions should remain the primary focus of resilience-based substance use prevention strategies. Future research should explore how community-based elements can be effectively integrated without diluting the core protective effects provided by school and family interventions. In particular, hybrid models that blend structured school-family engagement with community partnerships may offer a promising direction for optimizing intervention efficacy.

Overall, this meta-analysis reinforces the importance of resilience-based interventions in adolescent substance use prevention. The findings strongly support a shift from purely individual-focused approaches to multi-level interventions integrating school, family, and, where feasible, community engagement. This study strengthens the theoretical foundation of resilience interventions by identifying key intervention levels that contribute to their effectiveness. The results align with ecological models of health behavior [54], emphasizing the importance of multi-level approaches. From a practical perspective, these findings provide valuable guidance for designing resilience-based programs that foster sustainable, health-promoting school environments. Future research should also investigate whether policy-level support, such as integrating resilience education into school curricula, enhances the effectiveness and sustainability of these programs.

4.1 | Implications for School Health Policy, Practice, and Equity

A key contribution of our research is the direct mapping of these findings onto the Whole School, Whole Community, Whole Child (WSCC) framework, offering a practical roadmap for integrating resilience strategies into school health promotion. Components such as social–emotional climate, family engagement, counseling and psychological services, and community involvement were directly addressed in the included interventions. From an equity perspective, the evidence underscores the importance of adapting these programs for diverse school contexts, including those with low-income, rural, and multicultural populations. These results extend prior research by emphasizing the necessity of integrating multiple ecological levels within intervention strategies rather than solely focusing on individual-level resilience factors.

5 | Limitations

The generalizability of these findings should be interpreted with caution. Most included studies were conducted in Western countries, particularly the United States and Australia, and the overall number of included studies was relatively small. Cultural contexts may influence both adolescent substance use patterns and resilience mechanisms, limiting applicability to non-Western populations. Future research should include more geographically and culturally diverse settings to strengthen external validity. Another limitation involves incomplete reporting of intervention specifics such as intensity, frequency, and delivery mode. This prevented more detailed subgroup analyses and may have contributed to unexplained heterogeneity. Although publication bias appeared minimal, the reliance on published research raises potential concerns about missing null findings.

6 | Conclusions

This meta-analysis provides compelling evidence that school-based resilience interventions are effective in reducing adolescent tobacco, alcohol, and illicit substance use. The findings highlight the importance of multi-level interventions

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that incorporate individual, interpersonal, and community resilience factors. Longer intervention durations were associated with greater reductions in tobacco use, underscoring the need for sustained resilience-building efforts. A significant new insight from this study is that resilience interventions should not be viewed merely as psychological skill-building programs but as broader integrated strategies that require cross-sectoral collaboration among education, public health, and community stakeholders. Integrating these comprehensive frameworks into school curricula offers a scalable and sustainable mechanism for substance use prevention.

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The authors have nothing to report.

Ethics Statement

Preparation of this paper did not involve primary research or data collection involving human subjects, and therefore, no institutional review board examination or approval was required.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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Supporting Information

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