

Effectiveness of Behavior Change Theory-Based Interventions for Reducing Secondhand Smoke Exposure in the Home: A Meta-Analysis

Ercan ASİ^{1*} , Sebahat GÖZÜM² 

¹ Burdur Mehmet Akif University, Faculty of Health Science, Department of Nursing, Burdur, Türkiye

² Akdeniz University, Faculty of Nursing, Department of Public Health Nursing, Antalya, Türkiye

*Corresponding author: ercanasi@mehmetakif.edu.tr

Abstract

This meta-analysis aims to evaluate the effectiveness of interventions based on behavior change theories in reducing secondhand smoke (SHS) exposure in the home environment. The meta-analysis based on PRISMA 2020. A meta-analysis was conducted by searching Cochrane Library, CINAHL Complete, PubMed, Scopus, and Web of Science for randomized controlled trials published in English between January 2015 and October 2025. Studies implementing behavior-change-based interventions to reduce SHS exposure at home were included. Exposure to SHS in the home was assessed using data from biomarker tests, environmental measurements, and participant self-reports. Eleven trials with a total of 4.026 participants were included. Most of the included interventions were based on the Health Belief Model. Interventions demonstrated a significant medium effect in reducing SHS exposure (Hedges' $g = -0.274$; 95% CI = -0.342 to -0.206; $p < 0.001$), with low heterogeneity ($\tau^2 = 0.000$; $\chi^2 = 7.523$, $df = 10$, $p = 0.675$; $I^2 = 0.0\%$). No publication bias was identified. Theory-based interventions are effective in reducing SHS exposure. Therefore, integrating the structured behavior change strategies used in these interventions into public health programs may contribute to the development of smoke-free home environments. Future research should include longer follow-up periods to evaluate the sustainability of outcomes.

Keywords

Secondhand smoke,
Smoke free-home,
Behavior change,
Meta-analysis

Davranış Değişikliği Teorilerine Dayalı Müdahalelerin Ev Ortamında İkinci El Sigara Dumanı Maruziyetini Azaltmadaki Etkililiği: Bir Meta-Analiz

Ercan ASİ^{1*}, Sebahat GÖZÜM²

¹ Burdur Mehmet Akif Ersoy Üniversitesi, Sağlık Bilimler Fakültesi, Hemşirelik Bölümü, Burdur, Türkiye

² Akdeniz Üniversitesi, Hemşirelik Fakültesi, Halk Sağlığı Hemşireliği Anabilim Dalı, Antalya, Türkiye

*Sorumlu yazar: ercanasi@mehmetakif.edu.tr

Öz

Bu meta-analiz, ev ortamında ikinci el sigara dumanı (İESD) maruziyetini azaltmaya yönelik davranış değişikliği teorilerine dayanan müdahalelerin etkililiğini değerlendirmeyi amaçlamaktadır. Çalışma, PRISMA 2020 rehberine uygun şekilde yürütülmüştür. Ocak 2015 ile Ekim 2025 tarihleri arasında yayımlanan İngilizce randomize kontrollü çalışmaları belirlemek amacıyla Cochrane Library, CINAHL Complete, PubMed, Scopus ve Web of Science veri tabanlarında sistematik bir literatür taraması yapılmıştır. Ev ortamında İESD maruziyetini azaltmaya yönelik davranış değişikliği temelli müdahaleleri içeren çalışmalar dahil edilmiştir. İESD maruziyetine ilişkin sonuçları değerlendirmek için biyobelirteçlerden, çevresel ölçümlerden ve katılımcıların öz-bildirimlerinden elde edilen veriler kullanılmıştır. Toplam 4.026 katılımcının yer aldığı 11 çalışma meta-analize dahil edilmiştir. Müdahalelerin çoğu Sağlık İnanç Modeli'ne dayanmaktadır. Müdahaleler, İESD maruziyetini azaltmada anlamlı ve orta düzeyde bir etki göstermiştir (Hedges' $g = -0.274$; %95 GA = -0.342 ila -0.206; $p < 0.001$) ve heterojenite düşüktür ($\tau^2 = 0.000$; $\chi^2 = 7.523$, $sd = 10$, $p = 0.675$; $I^2 = 0.0\%$). Yayın yanlılığı saptanmamıştır. Teori temelli müdahaleler, İESD maruziyetini azaltmada etkilidir. Bu nedenle, bu müdahalelerde kullanılan yapılandırılmış davranış değişikliği stratejilerinin halk sağlığı programlarına entegre edilmesi, dumansız ev ortamlarının geliştirilmesine katkı sağlayabilir. Gelecekteki araştırmalarda, elde edilen sonuçların sürdürülebilirliğini değerlendirmek amacıyla daha uzun takip sürelerinin kullanılması önerilmektedir.

Anahtar kelimeler

İkinci el sigara dumanı,
Dumansız ev,
Davranış değişikliği,
Meta-analiz

1. INTRODUCTION

Due to the implementation of smoking bans in public places and private vehicles, the home has become the primary setting for secondhand smoke (SHS) exposure [1, 2]. SHS exposure contributes significantly to the global burden of disease [3]. There is no safe level of SHS exposure; even brief contact can result in serious and potentially fatal health consequences [4]. As exposure increasingly shifts to the home, understanding its health consequences has become more important than ever.

SHS exposure has serious and widely recognized health consequences for both adults and children. Studies have shown that it is associated with lung and breast cancer, ischemic heart disease, and stroke in adults, as well as lower respiratory tract infections, otitis media, and sudden infant death syndrome in children [3, 5]. One study estimated that 52.3 smokers are associated with the death of one nonsmoking individual. Lower risk was observed in regions with strong tobacco control policies, such as North America, compared to areas with weaker regulations like the Middle East and North Africa [6]. Given these risks and policy limitations, promoting individual behavior change has become essential in reducing SHS exposure, particularly in private settings like the home.

Despite existing regulations, SHS exposure at home remains a persistent issue. Minimizing indoor smoking, particularly in enclosed spaces, is the most effective way to protect nonsmokers in the home environment [7]. Evidence suggests that various programs and interventions have shown moderate success in reducing SHS exposure [8, 9, 10, 11, 12]. As SHS exposure is a preventable health risk [13], both smokers and nonsmokers must adopt sustainable behaviors: smokers should avoid indoor smoking, and nonsmokers should take steps to reduce their exposure. Sustainable reduction of SHS exposure in the home relies on the consistent application of protective behaviors.

Personal efforts and self-regulation play a critical role in protecting individuals from SHS exposure in the home. This requires strong awareness, a clear understanding of the risks, a sense of importance, motivation to act, and the adoption of protective behaviors. To promote sustained behavioral change, interventions targeting SHS exposure should be grounded in established behavior-change theories such as the Health Belief Model [14], Transtheoretical Model [15], Health Promotion Model [16], or the Theory of Planned Behavior [17]. Using theory-based frameworks may help structure interventions in a way that supports meaningful and sustainable changes in SHS-related behaviors at home.

Previous research has evaluated the effectiveness of interventions aimed at reducing SHS exposure in the home. However, the extent to which these interventions are based on behavior change theories remains unclear. Two earlier meta-analyses did not specify whether the programs they assessed were based on any theoretical framework [10, 11]. Similarly, three subsequent

systematic reviews did not report whether the included studies incorporated a behavior-change model [8, 9, 18]. Clarifying their theoretical foundations may be important for improving the design of future intervention programs. To address this gap, the present meta-analysis systematically reviews and synthesizes studies published between January 2015 and October 2025 that implemented theory-based interventions aimed at reducing SHS exposure in the home environment.

1.1. Aim

This meta-analysis aims to evaluate the effectiveness of interventions based on behavior change theories in reducing SHS exposure in the home environment.

2. MATERIAL AND METHOD

This study has been registered in the International Prospective Register of Systematic Reviews (PROSPERO). PROSPERO ID: CRD420251196812. PROSPERO registration link:

This meta-analysis prepared according to the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) guideline [19].

2.1. Data Sources and Strategy

Searches were conducted in the Cochrane Library, CINAHL Complete, PubMed, Scopus, and Web of Science databases for studies published in English within the last 10 years (January 2015 - October 2025). Keywords were developed according to Medical Subject Headings (MeSH), and the search strategy was structured as follows: "(secondhand smoke OR environmental tobacco smoke OR involuntary smoke OR passive smoke) AND (model OR theory) AND (RCT OR randomized controlled trial OR randomized control study OR cluster randomized controlled trial)." A randomized controlled trial (RCT) filter was applied. Case-control, cross-sectional, meta-analysis, systematic review, protocol, and observational studies, as well as guidelines, were excluded. In addition, studies that did not specify the source of SHS exposure and those that evaluated exposure in a combined manner across home, private vehicles, or public settings were excluded from the analysis.

2.2. Data Extraction

Data were independently extracted and cross-checked by two authors; discrepancies were resolved through discussion.

2.3. Study Eligibility

Studies meeting the following criteria were included: (1) Study design: RCTs or controlled trials (CTs). (2) Participants: there were no restrictions regarding the study population; individuals such as children, parents, guardians, mothers, and fathers were all eligible for inclusion. (3) Types of intervention: any intervention based on a behavioral theory or model. The statement in

the study that the intervention was developed based on a specific theory or model was considered sufficient for inclusion in the meta-analysis. (4) Comparison: at least a control and an intervention group. (5) Outcomes: measurement of nicotine or particulate matter in the air, biological laboratory results, or self-reports.

2.4. Outcomes

Our outcome was in change in SHS exposure from baseline to longest follow-up.

2.5. Meta-Analytic Approach

Data was entered and analyzed using Comprehensive Meta-Analysis (CMA) software (Version 3.0, Biostat Inc.). Studies reporting exposure to SHS in the home as measured by air nicotine (raw values, log values, or geometric mean), particular matter (raw values, log values, geometric mean), biomarkers (urine nicotine, blood nicotine, saliva nicotine, hair nicotine), or self-report was included. Hedges' g (small: $d \leq 0.20$, medium: $0.20 < d < 0.80$, and large: $d \geq 0.80$ [20]) was used to estimate effect size. Cochran's Q statistics were used to test for heterogeneity. The I^2 coefficient was used and centered around the rate of change in estimates as heterogeneity rather than sampling errors [21]. According to previous guidelines, the interpretations of 25%, 50%, and 75% correspond to low, medium, and high heterogeneity, respectively [22]. A random-effects model was used to determine the overall effect of interventions on reducing SHS exposure [23]. Publication bias was assessed using Egger's regression test on the funnel plot [24].

2.6. Risk of Bias

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool [22]. This tool evaluates the risk of bias across five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported result. In addition to these domains, an overall risk of bias judgment is also generated for each study.

The signaling questions within the RoB 2 tool were independently answered by two researchers for each study, and the risk of bias for each domain was determined based on these responses. The tool's algorithm automatically produced a risk judgment for each domain and an overall assessment for each study. In cases where initial assessments differed between reviewers, discrepancies were discussed and resolved through consensus prior to finalizing the ratings. All assessments were conducted in accordance with the official RoB 2 guidance and decision rules outlined in the Cochrane Handbook for Systematic Reviews of Interventions.

3. RESULTS

3.1. Study Characteristics

A total of 606 records were identified through database searches conducted between January 2015 and October 2025. After removing duplicates, 441 records remained. Title and abstract screening resulted in the exclusion of 412 studies. The full texts of 29 studies were reviewed, and 18 were excluded for not meeting the eligibility criteria. A total of 11 studies were included in the final analysis (Figure 1).

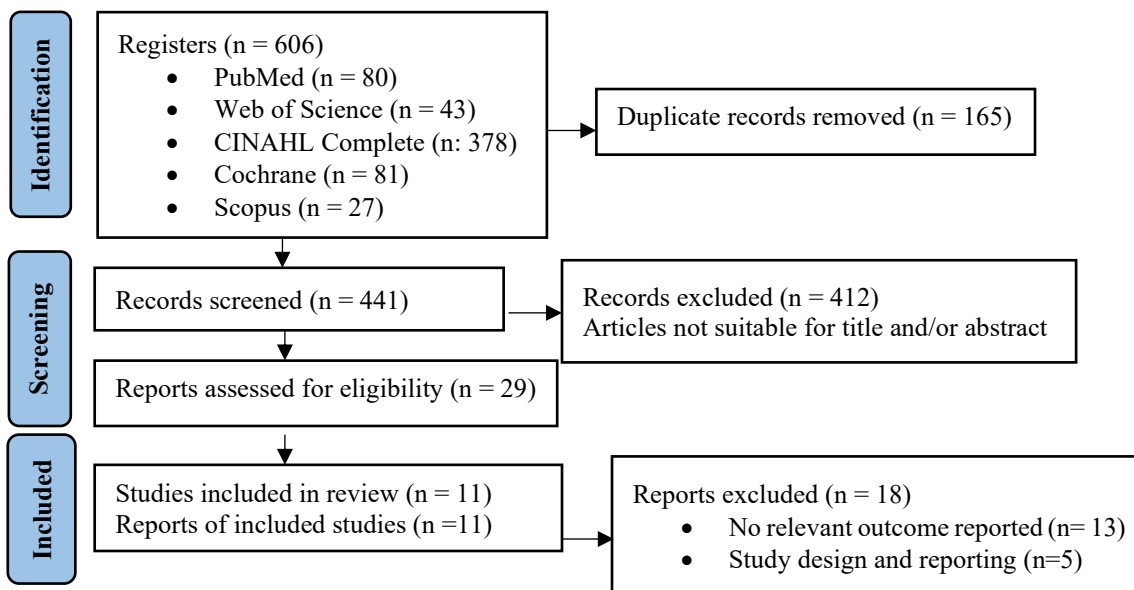


Figure 1. Flowchart for identification of studies

Table 1. Characteristics of the studies included in the meta-analysis

Author Country	Participant	Theory or Model	Types of Intervention	Observation of outcomes	Outcomes measures
[25] China	Parents, caregivers Intervention n:164 Control n:154	Protection motivation theory	Individual counselling, Telephone counselling, Self-help materials	0, 2, 6 months	Urine cotinine
[26] USA	Smoker or nonsmoker Intervention n:246 Control n:252	Social Cognitive Theory Transtheoretical model	Mailings, coaching call	0, 3,6-months	Self-reported
[27] Taiwan	Nonsmoking pregnant women Intervention n:50 Control n:50	Health Belief Model	Direct teaching	Baseline, 1 month	Exhaled carbon monoxide concentration
[28] Taiwan	Nonsmoking pregnant women Intervention n:50 Control n:50	Health Belief Model Self-efficacy theory	Direct teaching	Baseline, 1, 2 months	Exhaled carbon monoxide concentration
[29] USA	Smoker or nonsmoker Intervention n:260 Control n:240	Social Cognitive Theory Transtheoretical model	Mailings, coaching call	0, 3, 6 months	Self-reported
[30] China	Nonsmoking pregnant women Intervention n:526 Control n:655	Health Belief Model	Health education	Baseline, postintervention, 3 months after birth	Questionnaire
[31] Sri Lanka	Nonsmoker women Intervention n:375 Control n:375	The health belief model Social cognitive theory	Health education	1 week, 1 month	Questionnaire
[32] USA	Parent or guardian Intervention n:149 Control n:149	Behavioral Ecological Model	Coaching Real-time feedback	Days (Mean±SD) Baseline: 37.5 ±16.3 Post-baseline: 61.8 ± 24.3	Air particle monitors
[34] Iranian	Pregnant women and their smoker spouses Intervention n:53 Control n:53	Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis and Evaluation (PRECEDE) Theory of Reasoned Action	Counseling, educational brochures	0, 8 weeks	Questionnaire
[35] Iranian	Smoking men (Nonsmoker pregnant women) Intervention n:37 Control n:38	Health Belief Model	Training, educational tips	0,6 weeks	Questionnaire
[36] Saudi Arabia	Nonsmoker pregnant women Intervention n:50 Control n:50	Health Belief Model	Counselling, Pamphlet	0, 4 weeks	Questionnaire

The included studies were conducted in the United States (n = 3), Sri Lanka (n = 1), China (n = 2), Iran (n = 2), Taiwan (n = 2), and Saudi Arabia (n = 1). Sample sizes ranged from 75 to 1.181 participants, comprising a total of 4.026 individuals. Follow-up periods varied from

3.2. Risk of Bias

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool. Based on this structured evaluation, all 11 studies were judged to have low risk of bias across all five domains: bias arising from

baseline to 12 months post-intervention. Most studies assessed SHS exposure using self-reported questionnaires. Objective measures (urine cotinine) and environmental indicators (carbon monoxide concentration) were also used in some studies (Table 1). the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported result. No concerns were identified in any of these domains for any of the included studies. These findings are visually summarized in Figure 2.

Study ID	D1	D2	D3	D4	D5	Overall	
Abdullah et al., 2015	+	+	+	+	+	+	Low risk
Kegler et al., 2015	+	+	+	+	+	+	Some concerns
Chi et al., 2015	+	+	+	+	+	+	High risk
Chi et al., 2016	+	+	+	+	+	+	
Williams et al., 2016	+	+	+	+	+	+	D1 Randomisation process
Yang et al., 2016	+	+	+	+	+	+	D2 Deviations from the intended interventions
Alagiyawanna et al., 2017	+	+	+	+	+	+	D3 Missing outcome data
Hughes et al., 2018	+	+	+	+	+	+	D4 Measurement of the outcome
Soltani et al., 2019	+	+	+	+	+	+	D5 Selection of the reported result
Sahebi et al., 2019	+	+	+	+	+	+	
Wahabi et al., 2020	+	+	+	+	+	+	

Figure 2. Risk of bias summary

3.3. Effect of Interventions on SHS Exposure

The meta-analysis revealed a statistically significant effect of theory-based interventions in reducing SHS exposure at home (Hedges' $g = -0.274$; 95% CI: -0.342 to -0.206; $p < 0.001$). No significant heterogeneity was observed ($\tau^2 = 0.000$; $\chi^2 = 7.523$, $df = 10$, $p = 0.675$; $I^2 =$

0.0%), indicating high consistency across studies (Figure 3). Orwin's fail-safe N indicated that 50 additional studies with null results would be needed to reduce the observed effect size to a trivial level ($p < 0.05$), supporting the robustness of the findings. Funnel plot symmetry (Figure 4) and Egger's regression test ($t = 1.655$, $p = 0.132$) showed no evidence of publication bias.

Meta Analysis

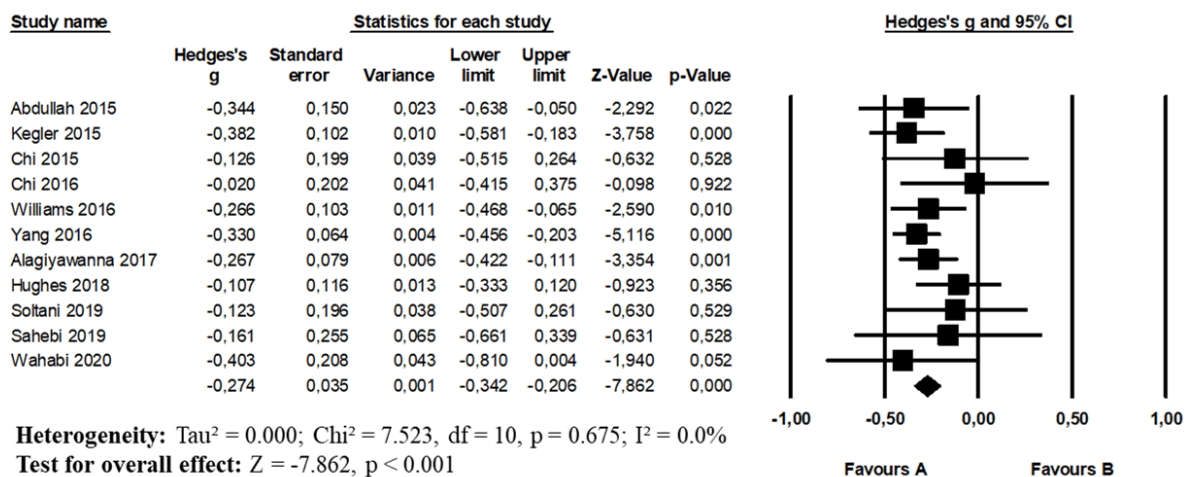


Figure 3. The overall effect of theory-based interventions on SHS exposure

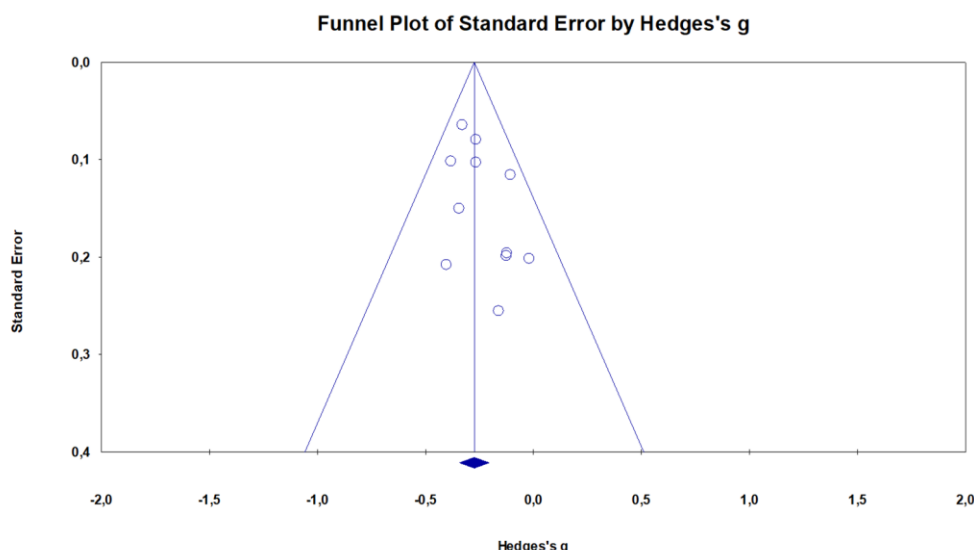


Figure 4. The effect of theory-based interventions on SHS exposure: Funnel Plot

4. DISCUSSION

This meta-analysis demonstrates that interventions grounded in behavior change theories have a medium-sized effect in reducing SHS exposure in the home environment. The findings suggest that interventions integrating behavioral change components tend to be more effective in reducing SHS exposure than those based solely on educational strategies. Theoretical frameworks such as the Health Belief Model posit that perceived susceptibility, perceived threat, self-efficacy, and social support are critical determinants of behavior change [37]. Consistent with this assumption, the included studies revealed that interventions targeting these mechanisms successfully reduced SHS exposure [27, 28, 29, 30, 35]. Notably, self-efficacy played an essential role in supporting smoke-free practices among parents who smoke. Family-based interventions strengthened individuals' belief in their ability to maintain smoke-free environments, thereby enhancing SHS avoidance behaviors [25, 38]. These findings underscore the importance of incorporating theory-based elements such as self-efficacy and perceived threat into interventions aimed at reducing SHS exposure.

According to Social Cognitive Theory, social reinforcement accelerates behavior change [39]. In line with this theoretical perspective, interventions that combined environmental feedback, such as particulate matter monitoring [32], with social support mechanisms, such as family involvement [34], were associated with more favorable outcomes. Conversely, interventions based solely on information provision demonstrated limited impact on behavior change. Communication-focused strategies, including motivational interviewing and behavioral planning, strengthened parents' willingness to change and helped bridge the intention-behavior gap [31, 36]. These findings underscore the importance of supporting educational components with behavior change theories to achieve sustained behavioral outcomes.

The effectiveness of theory-driven interventions observed in this review aligns with the broader health behavior literature. Contemporary evidence suggests that programs explicitly grounded in theory foster long-term behavior change by targeting psychological processes such as risk perception, self-efficacy, action planning, and social support [40]. Furthermore, theoretical constructs should not be incorporated as background references; rather, they should be systematically integrated into intervention components and operationalized through evidence-based behavior change techniques [41]. In this context, family-based SHS-reduction interventions should employ structured strategies such as goal-setting, self-efficacy enhancement, feedback provision, and mobilization of social support [40, 41]. Therefore, it is evident that theory-based interventions play a critical role in supporting sustainable behavior change.

In this meta-analysis, no significant heterogeneity or publication bias was detected among the included studies. The lack of statistical heterogeneity suggests that the interventions had a relatively uniform effect despite variations in population characteristics, settings, and implementation strategies. This consistency strengthens the internal validity of the findings and enhances their applicability across different contexts. Additionally, the absence of publication bias further supports the reliability of the pooled effect estimate. Minimizing heterogeneity and reporting bias is essential for ensuring that meta-analytic conclusions are both trustworthy and generalizable [22]. The combined absence of these biases in the present review increases confidence in the observed effectiveness of theory-based interventions. Taken together, these findings suggest that theory-based approaches to reducing SHS exposure are not only effective but also consistently applicable across diverse home environments, making them a promising foundation for future public health strategies.

Overall, interventions designed with explicit theoretical frameworks, incorporating family engagement, strengthening self-efficacy, targeting social norms, and providing measurable environmental feedback appear to

be more successful in reducing SHS exposure in the home. These findings highlight the importance of conceptualizing behavior change as a multidimensional process shaped by cognitive, social, and environmental influences, rather than as a singular educational task.

4.1. Strengths and Limitations

This meta-analysis has several notable strengths, including the exclusive inclusion of studies with experimental designs and the focus on interventions explicitly grounded in behavior change theories. Another important methodological strength is the consistency observed across the included studies. The lack of statistical heterogeneity suggests that the interventions had a relatively uniform effect across diverse contexts. Moreover, the absence of publication bias supports the reliability of the findings. Together, these factors enhance the internal validity of the results and reduce the likelihood of biased or overstated conclusions.

However, some limitations should be acknowledged. In many included studies, SHS exposure was primarily assessed through self-reported measures, which may introduce reporting bias. In addition, variations in intervention content and duration, along with relatively short follow-up periods, may limit the generalizability and long-term interpretation of the results.

4.2. Implications for Practice and Policy

The findings suggest that theory-based behavior change strategies can be a feasible and effective approach for reducing SHS exposure in home environments. Brief structured behavioral support and risk-communication strategies could be integrated into routine primary care services. Moreover, existing tobacco-control initiatives may benefit from incorporating evidence-based, low-cost interventions aimed at promoting SHS awareness and protective practices. Developing user-friendly educational materials, brief counselling protocols, and behavior change support tools for frontline health personnel is essential to enhance implementation and sustainability in real world settings.

5. CONCLUSION

This meta-analysis indicates that theory-based interventions may be effective in reducing SHS exposure in home environments. Interventions targeting behavior change and incorporating structured components appear to yield more favorable outcomes than information-only strategies. However, the magnitude of intervention effects varied across studies depending on design, duration, and measurement methods. Overall, the findings highlight the importance of integrating theory-driven, feasible, and sustainable approaches into public health programs aimed at reducing SHS exposure. Future research should employ longer follow-up periods to evaluate the durability of intervention effects and better understand mechanisms that support sustained behavior change.

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