Effectiveness of family-based behavioral intervention for smoking cessation in low-income households: a systematic review and meta-analysis

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Summary

Background Smoking-attributable harms are substantial in low-income households. The effectiveness of family-based behavioral interventions for smoking cessation in this population remains uncertain. This review aims to assess the effectiveness of family-based behavioral interventions on smoking cessation in low-income households.

Methods This systematic review and meta-analysis were conducted by searching six databases and one clinical trial registry for studies published from inception to 30 January 2024 (with an updated search conducted until 1st January 2025). Randomized controlled trials of family-based behavioral interventions for smoking parents from low-income households, co-living children aged ≤18 years, were included. Data extraction and analysis were independently performed by two investigators following the Preferred Reporting Items for Systematic reviews and Meta-Analysis guidelines. Primary outcomes were self-reported 7-day point prevalence abstinence (PPA) or biochemically validated abstinence at 3 months or longer. The Mantel-Haenszel method was used to calculate the relative risk (RR) with random-effect model. The study was registered on PROSPERO (CRD42023466096).

Findings Among 22 trials (N = 5292) included in the review, 12 (N = 2782) were analyzed in the meta-analysis. Most of trials (17/22) were of moderate or high quality. Family-based behavioral interventions significantly increased self-reported 7-day PPA (RR:1.70, 95%CI: 1.16–2.48) compared with usual care at follow-ups of 3 months or longer. Behavioral counseling combined with nicotine replacement therapy (NRT) was most effective (RR: 2.45, 95% CI: 1.28–4.68) and for 12-month follow-up (RR: 1.96, 95% CI: 1.44–2.66). Further significant effects were observed in parents of non-asthmatic children (RR: 1.88, 95% CI: 1.39–2.53), parents both smoked (RR: 1.79, 95% CI: 1.23–2.60), and interventions including NRT provision (RR: 1.78, 95% CI: 1.15–2.74).

Interpretation Family-based behavioral interventions significantly increased abstinence in low-income households where both parents smoked and pharmacotherapy was included. Interventions that incorporated behavioral counseling with NRT and implemented with a long-term follow-up tended to be more effective.

Funding None.

Keywords: Family-based behavioral intervention; Smoking cessation; Low-income; Systematic review; Meta-analysis

Introduction

Individual-based smoking cessation programs, including pharmacotherapy (e.g., nicotine replacement therapy [NRT][1]) and behavioral interventions (e.g., brief advice,[2] counseling,[3] and instant messaging[4]) were proven effective. Within behavioral strategies, both

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Research in context

Evidence before this study

Low-income families experience a disproportionately high burden of smoking-related morbidity and mortality given the disadvantages of financial constraints, access to healthcare, and psychosocial stress. Children in these households are intensively exposed to secondhand smoke, increasing risks of asthma, infections, and other chronic conditions. Although many trials have been conducted specifically for this group, few systematic reviews have evaluated family-based behavioural interventions for smoking cessation among parents in low-income settings. We searched PubMed, Cochrane Library, and the PROSPERO from inception to Jan 30, 2024, for systematic reviews of family-based behavioural interventions on smoking cessation. Two narrative summaries and three meta-analyses published between 2012 and 2021 were identified. Four focused on interventions to prevent adolescents from starting smoking, and one meta-analysis published in 2021 highlighted the importance of familial support for parents' smoking cessation but had not comprehensively examined the impact of such interventions within low-income populations.

Added value of this study

To the best of our knowledge, this is the first systematic review and meta-analysis to focus on family-based behavioral interventions for smoking cessation in low-income households. We found that family-based behavioral counseling combined with nicotine replacement therapy and extended follow-up significantly improves cessation outcomes. Specifically, family-based behavioral interventions significantly increased self-reported 7-day point prevalence abstinence and biochemically validated abstinence rates among smoking parents in low-income households. Parents receiving family-based behavioral interventions showed greater reductions in daily cigarette consumption, increased quit attempts, improved indoor air quality, and enhanced adherence to smoke-free home practices.

Implications of all the available evidence

To promote the reduction of tobacco use, researchers have developed comprehensive cessation strategies to assist tobacco users in quitting. In this context, our findings highlight the potential of family-based behavioral interventions in increasing abstinence rates in low-income households. Further work should optimize the intervention components, provide more personalized intervention, and rigorously evaluate the cost-effectiveness to inform prioritization of the interventions in resource-limited settings. Additionally, implementation strategies need to be integrated with existing community health organizations and actively engage local stakeholders to facilitate sustainable, wide-scale adoption of family-based interventions.

brief interventions (e.g., advice) and structured psychological treatments (e.g., cognitive-behavioral therapy) have showed robust efficacy in improving quit rates across income groups.[5] Structured treatments consisted with more intensive and theory-driven treatment session, outperform brief advice, self-help materials, or counselling without formal protocol.[6] Family-based behavioral interventions include a comprehensive approach to support smoking cessation, which includes offering brief advice to both smokers and their family members,[7] engaging both in individual and group counseling,[8] and creating a supervised environment by making smoke-free home bans.[9] Family members play a critical role in facilitating smokers to quit with tangible resources (e.g., medication reminders), informational support (e.g., how to cope with withdrawal) and emotional support (e.g., encouragement to persist in the cessation process).[10,11] A meta-analysis of family-based behavioral interventions conducted in middle- and high-income populations reported an increase in abstinence rate at 6-month follow-up (13.1% vs. 8.4%; $P < 0.001$).[12]

Low-income households, defined as those with income below a threshold relative to the median income of the general population,[13] faced higher prevalence of smoking (18.3% vs. 6.7%),[14] secondhand smoke (SHS) exposure (47.9% vs. 21.2%)[15] and SHS-attributed hospitalizations (45.0% vs. 21.4%),[16] compared to wealthier households. Such disparities were attributed to factors including higher stress levels, poorer ventilation in rental and multi-unit housing, lower health awareness among smoking parents and less access to health resources.[1,14,17] Two systematic reviews and meta-analyses have synthesized evidence on family-based interventions for smoking cessation, one focusing on preventing smoking in both children and adolescents,[18] and the 2021 meta-analysis concluded the effectiveness of these interventions without considering specific challenges faced by low-income families.[12] The effectiveness of these interventions remains uncertain due to the different levels of nicotine dependence and smoking profiles among low-income parents,[19,20] and variations in intervention contents,[9] intensity[21] and delivery modes.[8] No study has reported the overall effect of family-based behavioral interventions on smoking cessation in low-income parents, particularly for different subgroups. Considering the effectiveness of intervention may vary among subgroups, it is essential to conduct a rigorous and comprehensive assessment for evaluating the effectiveness.

This systematic review and meta-analysis assessed the effectiveness of family-based behavioral

interventions in promoting smoking cessation and reducing SHS exposure in low-income households of smoking parents co-living with children under 18 years. The pooled intervention effects by types of abstinence measurement, intervention contents, durations of follow-up, pharmacotherapy treatments, types of participants, and health status of the children were analyzed.

Methods

Search strategy

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement[22] and was registered in the PROSPERO database (CRD42023466096). Any amendments made between the protocol and the review have been documented in Supplemental Table S1. We conducted systematic searches in six databases and one clinical registry (Pubmed, MEDLINE, Embase, CINAHL, PsycINFO, CENTRAL and Cochrane TAG Specialised Register) and Google Scholar for grey literature from inception to 30 January 2024, with an updated search conducted until 1st January 2025. Backward citation searching was used to scrutinize the bibliographic of relevant reviews and studies. The search items was structured according to the PICOS framework (Supplemental Table S2), incorporating MeSH terms and keywords related to parent, cessation, intervention, smoking and low-income, combined using Boolean operators. Supplemental Table S3 shows the search strategy adapted for each database. Two reviewers independently scrutinized each trial using pre-established criteria. Any disagreements on the inclusion of a trial were resolved by discussion and consultation with an experienced third reviewer.

Eligibility criteria

Randomized controlled trials (RCTs) were included based on the following criteria: (a) interventions targeting smokers and their family members that using behavioral counseling with or without additional interventions (e.g., incentive, indoor air detectors, nicotine replacement therapy [NRT]) for either the smoking father, mother or both, co-living with children aged ≤ 18 years; (b) outcomes included but were not limit to smoking abstinence rate (e.g., self-reported 7-day point prevalence abstinence [PPA]; validated abstinence [VQ]) assessed at least three months follow-up[23]; (c) smoking parents as participants recruited from low-income communities, including multi-unit and rental housing, or household monthly income lower than the median income level in corresponding countries; and (d) full-text original articles in English.

Exclusion criteria were: (a) interventions focused primarily on relapse prevention rather than smoking cessation; (b) cessation interventions for pregnant women; and (c) studies relying solely on pharmacological treatments.

Data extraction

Two reviewers independently extracted key information of included trials using pre-established criteria. For each trial, sample size and abstinence rates (including self-reported 7-day PPA and validated quitting) were extracted to calculate the effect size. We contacted the authors when relevant data were not clearly reported. Discrepancies in data extraction were resolved by discussions with the third reviewer. Additional information regarding participant and trial characteristics was collected, including the first author's name, year of publication, country, participant demographics, intervention details, main study results, and follow-up time.

Risk-of-bias assessment

Risk of bias was assessed by two reviewers using the Cochrane risk-of-bias tool version 2 (ROB2) for randomized trials.[24] Each study was evaluated across five domains, with judgments categorized as "low risk", "some concern", or "high risk". Any disagreements were resolved through discussion involving a third reviewer.

Evaluation of the certainty of evidence

Following Cochrane methodology, the quality of the evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework based on the five considerations (risk of bias, inconsistency of effect, imprecision, indirectness and publication bias) by two reviewers.[25] According to GRADE, we judged the certainty of the evidence for the outcomes to be "high", "moderate", "low", or "very low" quality. Methodological quality of the review was further evaluated using A MeaSurement Tool to Assess Systematic Reviews (AMSTAR) 2 tool.[26,27]

Data analysis

A random-effect meta-analysis was conducted to generate relative risks (RR) for overall using an intention-to-treat analysis.[28] Consistent with previous studies,[12,29,30] the primary outcome was the abstinence rate at latest reported follow-up (e.g., 12-month) when multiple assessment points were available. Abstinence rates at end-of-treatment were also reported. Other outcomes without statistical testing (e.g., parental smoking behaviors, changes in indoor air quality and children's SHS exposure) were synthesized narratively. Subgroup analyses was conducted to investigate potential difference in abstinence rate due to the pre-defined subgroups of: (1) type of abstinence measurement (self-reported 7-day PPA vs. biochemically validated abstinence), (2) intervention contents (face-to-face and telephone behavioral counseling only vs.

behavioral counseling with NRT vs. behavioral counseling with indoor air quality feedback), (3) follow-up duration (3-month vs. 6-month vs. 12-month), (4) inclusion of pharmacotherapy treatments (NRT provision vs. non-provision), (5) types of participants (parents both smoked vs. maternal smokers), and (6) children's health status (asthmatic vs. non-asthmatic). Evidence of significant subgroup effects was assessed by using test for subgroup differences from meta-analysis.

We assessed heterogeneity between trials using the Cochrane Q test and calculated the I^2 statistic. To explore potential inter-trial heterogeneity, we conducted meta-regression with number of counseling sessions and intervention duration, using a random-effect model and restricted maximum likelihood (REML) estimation (transformed to logRR). Publication bias was evaluated by inspecting funnel plot symmetry and performing Egger's regression test. An asymmetrical plot with significant test ($P < 0.05$) was deemed as having publication bias. We used trim-and-fill method to estimate and adjust for potentially missing studies and to derive corrected pooled effect sizes. The fail-safe number of negative studies that would be required to nullify (i.e., make $P > 0.05$) the effect size was also calculated. All statistical tests were two-sided with statistical significance set at $P < 0.05$. STATA/SE (version 16.1) was used for all analyses.

Ethics statement

No formal ethics approval and informed consent is required for this review, as it involved secondary analysis of data from previously published trials and did not involve the collection of new data from human participants.

Role of the funding source

There was no funding source for this study.

Results

Search process

Searches in seven electronic databases yielded 421 trials, supplemented by 8 trials identified from reference lists. After removing 188 duplicates, 241 trials underwent screening of titles, abstracts, and keywords, leading to the exclusions of 144. Full-text review of the remaining 97 trials resulted in the exclusion of 75, and 22 trials were included in the systematic review, as shown in the PRISMA Flowchart in Fig. 1. Full-text exclusion reasons are summarized in Supplemental Table S4.

Description of included studies

Twenty-two trials published in 2000–2022, comprised 19 RCTs and three pilot RCTs. Twelve trials included in the meta-analysis. Most trials were conducted in the USA (k = 18) and the UK (k = 4), as summarized in Table 1.

Description of included participants

A total of 5392 smoking parents co-living with children under 18 years were included, with sample size ranged from 48[31] to 500.[32] The age of children and parents varied from 14.1 ± 7.0 months[33] to 64.5 ± 31.6 months[34] and 21.4 (17–38) years[9] to 39.9 ± 11.3 years, respectively.[32] Most trials involved families in which both parents smoked (k = 12), with the rest being mothers smoked only (k = 10). Twenty trials involved smoking parents with non-asthmatic children, two with asthmatic children.[21,35]

Interventions and comparators

The 22 trials reported six types of behavioral interventions. These included: telephone behavioral counseling (k = 6),[8,32,35–38] face-to-face and telephone behavioral counseling (k = 5),[19,34,39,40] behavioral counseling with NRT (k = 4),[20,41–43] behavioral counseling with indoor air quality feedback (k = 3),[9,31,44] behavioral counseling with indoor air quality feedback and NRT (k = 3),[45–47] and behavioral counseling with NRT and financial incentives (k = 1).[48] Control groups included brief advice, education alone, and nutrition education attention control. Intervention duration ranged from 4[35] to 26 weeks,[9] with the number of counseling sessions varying from 2[35] to 14.[42,43] Most interventions (k = 16) were theoretically-based but 6 trials (27.3%) did not report theoretical basis. Details of the interventions are summarized in Supplemental Table S5.

Risks of bias

Overall, we rated seven trials to be at low risk of bias (31.8% rated as "low risk" across all domains), and five trials to be at high risk of bias (22.7% rated as "high risk" at least one domain), with the rest at unclear risk (45.5% rated as "some concern" at least one domain). Risk of bias assessment for each study are shown in Fig. 2, with detailed evaluations summarized in Supplemental Table S6.

Intervention effects and subgroup analyses

Fig. 3 shows that the pooled risk ratio for smoking abstinence at the latest follow-up was 1.70 (12.5% vs. 7.2%; 95%CI 1.25–2.31) in a meta-analysis of 12 RCTs involving 2782 smoking parents. Heterogeneity among trials was low to moderate, with a Cochrane Q of 15.36 ($P = 0.17$) and I^2 of 28.4% ($P = 0.001$). The pooled risk ratios at end of treatment was 2.19 (12 trials; 95%CI 1.41–3.40) (Supplemental Fig. S1). Meta-regression (Supplemental Table S7) showed that abstinence rates tended to increase with a greater number of counseling sessions (LogRR = 0.03, $P = 0.56$) and with a shorter intervention duration (LogRR = –0.03, $P = 0.39$), albeit non-statistically significant.

Table 2 shows that the intervention was associated with significant increases in self-reported 7-day PPA (RR = 1.70; 95%CI 1.16–2.48). Higher abstinence rate

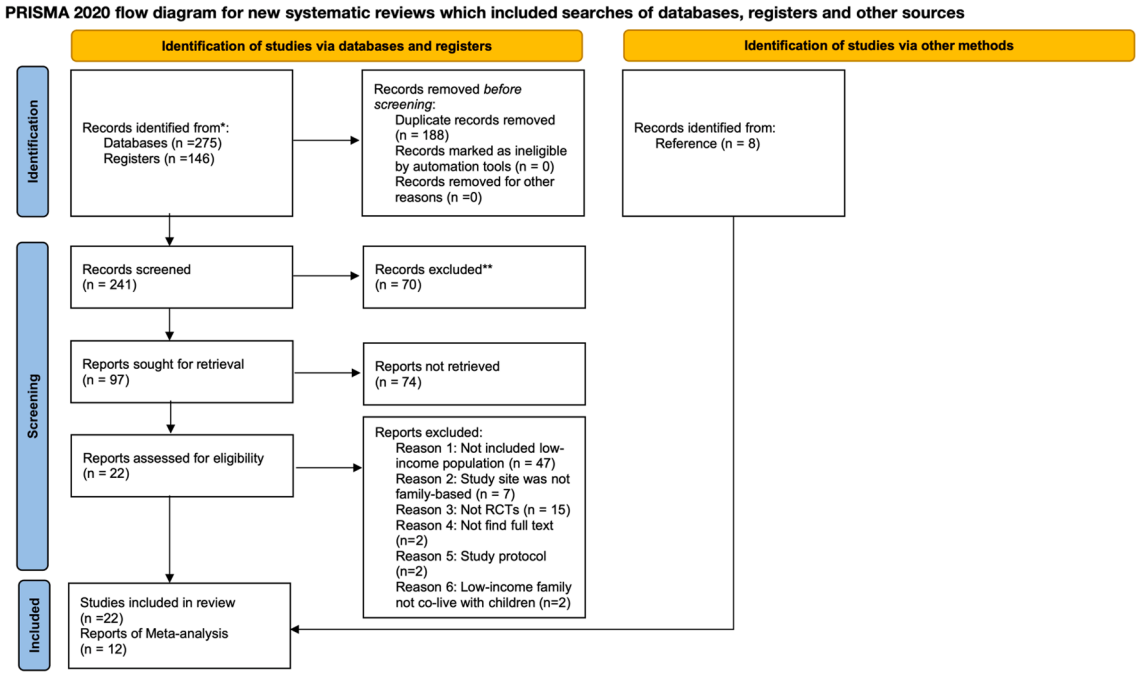

Fig. 1: Preferred reporting items for systematic reviews and meta-analyses flow chart.

were observed in groups receiving only face-to-face and telephone behavioral counseling (RR = 1.66; 95%CI 1.06–2.59) and in those receiving behavioral counseling with NRT (RR = 2.45; 95%CI 1.28–4.68). No statistically significant effect on smoking abstinence was observed in the group receiving behavioral counseling with indoor air-quality feedback (RR = 1.22; 95%CI 0.70–2.12). A significant higher abstinence rate was noted in subgroups provided with NRT (RR = 1.78; 95%CI 1.15–2.74) and at the 12-month follow-up (RR = 1.96; 95%CI 1.44–2.66). Parents who both smoked receiving family-based behavioral interventions had higher abstinence rates than maternal smokers (16.39% vs. 9.44%; RR = 1.79; 95%CI 1.23–2.60). A statistically significant effect on smoking abstinence was also observed only among parents with non-asthmatic children (RR = 1.88; 95%CI 1.39–2.53).

Publication bias

The funnel plot (Fig. 4) showed asymmetry, with a relative paucity of small studies reporting negative or null results. This observation was aligned with Egger's regression test (Supplemental Fig. S2), which showed significant small-study effects (β = 1.63, SE = 0.66, P = 0.03), indicating potential publication bias. Trim-and-fill analysis (Supplemental Fig. S3) identified one potentially missing study on the right side of the funnel plot, and the imputed study slightly increased the overall effect size (LogRR) from 0.59 (95% CI 0.35–0.82) to 0.60 (95% CI 0.36–0.84). The fail-safe number of additional negative studies required to nullify the significance of the main analysis was of 20 studies with negative results (Supplemental Table S8).

Quality of the evidence

The certainty of evidence for the effect of family-based behavioral interventions on abstinence rates (both at the end of treatment and at the latest follow-up) was rated as moderate (Supplemental Table S9). The evidence was downgraded by one level due to suspected publication bias, supported by visual asymmetry in the funnel plot and a statistically significant Egger's test. No downgrading was applied for risk of bias, inconsistency, imprecision, or indirectness, as the findings were robust to sensitivity analyses and the confidence interval did not include the null value. The methodological quality of the review was rated as high across 16 items, including the seven critical domains (Supplemental Table S10).

Narrative summary

A detailed summary of the effectiveness of family-based behavioral interventions on improving parental smoking behaviors, reducing children's SHS exposure, and enhancing indoor air quality is shown in Supplemental Table S11. The summary included 22 trials, 10 of which examined biomarkers of SHS exposure in children. Eight trials[19,32–34,36,40,42,43] reported reductions in children's urine cotinine levels and two trials[31,39] in salivary cotinine levels from baseline to the 6-month or

Author (year)/ country	Sample size	Mean age at baseline (children) (Y/Mo)	Mean age at baseline (parent) (Years)	Participants included in the trial	Group		Intervention			
					Intervention group	Control group	Duration	Frequency	Form	Provision of NRT
Bradley N. Collins (2022)/USA	T:396 I:199/C:197	I:31.3 (20.8) C:29.2 (19.1) (Mo)	I:29.8 (6.4) C:30.4 (6.6)	Maternal smoker	AAR + MBI	AAR + brief advice	12 weeks	Five counseling sessions	Behavioral counseling combined with NRT	Yes
Mandeep S. Jassal (2021)/USA	T:135 I:63/C:72	Not reported	Not reported	Maternal smoker	TSE education, quitline referrals, and financial incentives	TSE education and quitline referrals	6 months	Once per month	Behavioral counseling combined with NRT and incentives	Yes
Bradley N. Collins (2020)/USA	T:300 I:145/C:155	I:19.7 (14.9) C:18.2 (14.1) (Mo)	Not reported	Maternal smoker	FRESH Behavioral counseling	Brief advice	16 weeks	Two onsite sessions and seven online sessions	Behavioral counseling by face to face interview and telephone	No
Bradley N. Collins (2020)/USA	T:327 I:163/C:164	I:64.5 (31.6) C:64.0 (33.9) (Mo)	I:32.7 (7.9) C:33.9 (9.2)	Parents both smoked	AAR + individualized telephone counseling	AAR + brief advice	16 weeks	Two onsite sessions and seven online sessions	Behavioral counseling by face to face interview and telephone	No
Sean Semple (2018)/UK	T:117 I:58/C:59	Not reported	I:21.7 (17–43) C:21.4 (17–38)	Parents both smoked	Standard advice + personalised air-quality feedback	Standard health service advice on SHS	26 weeks	Nine home visits and behavioral counseling	Behavioral counseling combined with indoor air quality feedback	No
Charlotte Renwick (2018)/ UK	T:204 I:102/C:102	I:3.6 (2.6) C:3.3 (2.3) (Y)	I:28.1 (1.2) C:27.9 (6.6)	Parents both smoked	Behavioral support, personalised feedback on air quality, and nicotine replacement therapy	Brief advice	12 weeks	Four sessions and two phone calls or SMS support	Behavioral counseling combined with indoor air quality feedback and NRT	Yes
Elena Ratschen (2018)/UK	T:205 I:103/C:102	I:3.6 (2.6) C:3.3 (2.3) (Y)	I:28.1 (6.2) C:27.9 (6.6)	Parents both smoked	Behavioral support, personalised feedback on air quality, and nicotine replacement therapy	Brief advice	12 weeks	Four sessions and two phone calls or SMS support	Behavioral counseling combined with indoor air quality feedback and NRT	Yes
Stephen J. Lepore (2018)/USA	T:327 I:163/C:164	I:64.5 (31.6) C:64.0 (33.9) (Mo)	I:32.7 (7.9) C:33.9 (9.2)	Parents both smoked	AAR and telephone counseling	AAR + nutrition education attention control	12 weeks	Five counselling sessions	Behavioral counseling by telephone	No
Bradley N. Collins (2018)/USA	T:327 I:163/C:164	I:64.5 (31.6) C:64.0 (33.9) (Mo)	I:32.7 (7.9) C:33.9 (9.2)	Parents both smoked	AAR and telephone counseling	AAR + nutrition education attention control	12 weeks	Five counselling sessions	Behavioral counseling by telephone	No
Rebecca S. Williams (2016)/ USA	T:500 I:260/C:240	Not reported	I:39.9 (11.3) C:39.6 (12.1)	Parents both smoked	2-1-1 callers intervention	Printed material	6 weeks	Three mailings and three coaching calls	Behavioral counseling by telephone	No
Michelle N. Eakin (2014)/USA	T:330 I:165/C:165	I:3.8 (0.8) C:3.7 (0.8) (Y)	I:32.1 (8.6) C:32.1 (9.2)	Parents both smoked	MI and education	Education alone	12 weeks	Four counselling sessions and one booster session	Behavioral counseling by face to face and telephone	No
Bradley N. Collins (2015)/USA	T:300 I:145/C:155	I:19.7 (14.9) C:18.2 (14.1) (Mo)	Not reported	Maternal smoker	Behavior counseling	Enhanced standard care	16 weeks	Two home visits and seven phone calls	Behavioral counseling combined with NRT	Yes
Inga Wilson (2012)/UK	T:48 I:21/C:27	T:3.5 (1.2–5.7) (Y)	T:30.0 (19.7–45.7)	Maternal smoker	MI and feedback on air quality	Brief advice	4 weeks	Four home visits	Behavioral counseling combined with indoor air quality feedback	No
Bradley N. Collins (2012)/USA	T:327 I:163/C:164	I:64.5 (31.6) C:64.0 (33.9) (Mo)	I:32.7 (7.9) C:33.9 (9.2)	Parents both smoked	Clinic Quality Improvement and Behavioral Counseling	Clinic Quality Improvement and Attention Control	12 weeks	Five counselling sessions	Behavioral counseling by telephone	No

(Table 1 continues on next page)

Author (year)/ country	Sample size	Mean age at baseline (children) (Y/Mo)	Mean age at baseline (parent) (Years)	Participants included in the trial	Group		Intervention			
					Intervention group	Control group	Duration	Frequency	Form	Provision of NRT
(Continued from previous page)										
Belinda Borrelli (2010)/USA	T:133 I:68/C:65	I:6.9 (5.1) C:7.3 (4.6) (Y)	I:36.6 (9.2) C:37.1 (10.0)	Parents both smoked with asthma children	Precaution adoption model (PAM)	Behavioral action model (BAM)	12 weeks	Three home visit and one call	Behavioral counseling combined with indoor air quality feedback and NRT	Yes
Sandy Liles (2009)/USA	T:150 I:76/C:74	Not reported	I:30.2 (6.9) C:30.0 (7.4)	Maternal smoker	14 counseling sessions	Brief advice	6 months	Ten onsite counseling sessions and four by telephone	Behavioral counseling with NRT	Yes
Melbourne F. Hovell (2009)/ USA	T:150 I:76/C:74	I:22.7 (13.9) C:23.8 (12.3) (Mo)	I:30.2 (6.9) C:30.0 (7.4)	Maternal smoker	14 counseling sessions	Brief advice	6 months	Ten onsite counseling sessions and four by telephone	Behavioral counseling with NRT	Yes
Joy M. Zakarian (2004)/USA	T:150 I:76/C:74	I:17.6 (10.0) C:16.7 (10.4) (Mo)	I:29.1 (6.3) C:28.4 (6.7)	Maternal smoker	Seven behavioral counseling session	Measures-only control condition	6 months	Seven behavioral counselling	Behavioral counseling by face to face and telephone	No
Susan J. Curry (2003)/USA	T:303 I:156/C:147	Not reported	I:34.2 (8.8) C:33.6 (9.5)	Maternal smoker	Brief motivational message, self-help materials, nurse or interventionist clinic visit and telephone counseling	Brief advice	12 weeks	Three telephone counselling calls	Behavioral counseling by telephone	No
Melanie Wakefield (2002)/USA	T:264 I:128/C:136	I:5.5 (2.8) C:5.2 (3.0) (Y)	I:31.3 (6.3) (mother) 34.4 (7.6) (father) C:35.2 (6.6) (mother) 35.3 (6.6) (father)	Parents both smoked with asthma children	Written and verbal feedback, information booklets, and two telephone calls	Brief advice	4 weeks	Two telephone counselling sessions	Behavioral counseling by telephone	No
Karen M. Emmons (2001)/USA	T:291 I:150/C:141	Not reported	Not reported	Parents both smoked	MI	Brief advice	6 months	One MI session and four telephone calls	Behavioral counseling combined with indoor air quality feedback	No
Melbourne F. Hovell (2000)/ USA	T:108 I:53/C:55	I:14.1 (7.0) C:14.3 (6.9) (Mo)	I:28.5 (6.6) C:29.0 (6.9)	Maternal smoker	Seven individualized counseling sessions	Usual nutritional counseling and brief advice	12 weeks	Three onsite counselling sessions and four by telephone	Behavioral counseling by face to face interview plus telephone	No

T, Total; I, Intervention; C, Control; Mo, Month; NRT:Nicotine Replacement Therapy; AAR, Ask, Advise, Refer; MBI, Muti-model behavioral intervention; TSE, Tobacco smoke exposure; SHS, Second-hand smoke; MI, Motivational Interviewing.

Table 1: **Basic details of included studies (k = 22).**

Fig. 2: Risk of bias of the included trials.

12-month follow-up. Sixteen trials assessed improvements in parental smoking behaviors, six[32,40,41,43,46,47] reported a decrease in cigarettes smoked per day, nine[8,19,32,33,35,37,43–45] reported a reduction in children's exposure to SHS from parents or other sources, five[32,38,42,46,47] found an increase in quit attempts, with additional findings highlighting lower nicotine dependence,[34,47] increased engagement with quitline and NRT usage,[8] and heightened confidence and planning to quit.[32] One trial[34] also showed increased self-efficacy in parents to protect children from SHS. Nine trials reported improvements in indoor air quality, with one-third[8,32,35] implemented smoking bans in homes or cars, and six trials[9,31,39,44,46,47] noted enhancements in indoor Particulate Matter ($PM_{2.5}$) levels.

Discussion

This review found significant effects of family-based behavioral interventions on smoking cessation among low-income parents living with children under 18 years, highlighting the value of incorporating family-based strategies to enhance the effectiveness of behavioral interventions. We found a 73% higher abstinence rate in the intervention group compared to the control group, with effectiveness varying across different subgroups (RR range: 0.23–2.46), and the results were

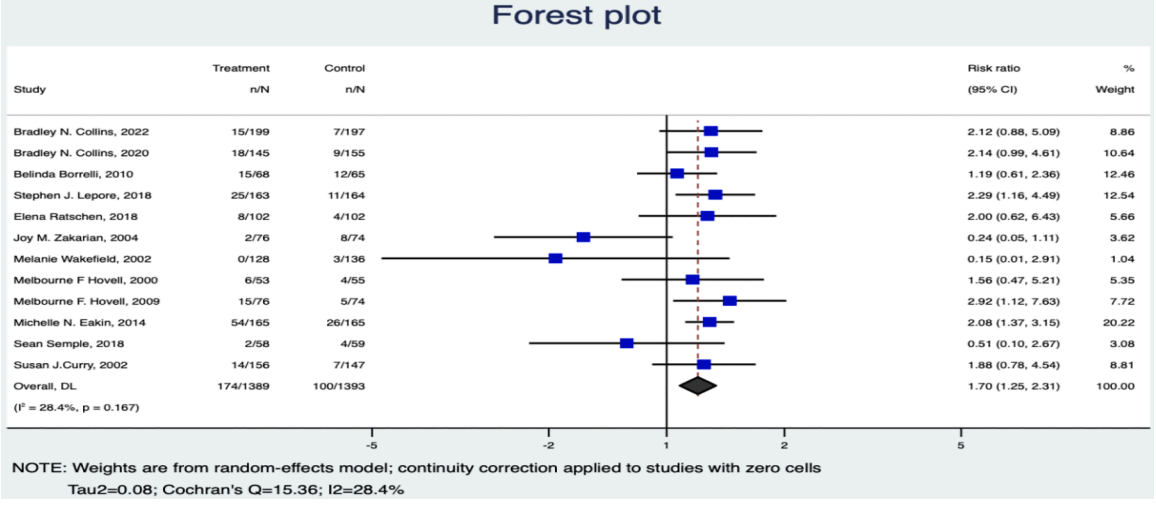

Fig. 3: Meta-analysis of RRs of the effect of behavioral smoking cessation program at the latest follow-up.

Study or subgroup	Heterogeneity					Test for overall effect		Test for subgroup differences	
	Included trial	Sample size	Tau^2	*P* value	I^2	RR (95%CI)	*P* value	*P* value	I^2
Smoking abstinence rate								0.92	0.0%
Self-reported 7-day PPA	7	1501	0.06	0.25	23.0%	1.70 (1.16, 2.48)	0.007		
Validated abstinence rate	5	1281	0.20	0.11	48.0%	1.63 (0.92, 2.92)	0.10		
Intervention contents								0.27	22.8%
Face-to-face and telephone behavioral counseling	7	1782	0.14	0.10	44.0%	1.66 (1.06, 2.59)	0.03		
Behavioral counseling combined with NRT	2	546	0.00	0.63	0.0%	2.45 (1.28, 4.68)	0.007		
Behavioral counseling combined with indoor air quality feedback	3	454	0.00	0.41	0.0%	1.22 (0.70, 2.12)	0.48		
Participants								0.68	0.0%
Maternal smokers	7	1524	0.20	0.11	42.0%	1.56 (0.93, 2.62)	0.09		
Parents both smoked	5	1258	0.04	0.28	21.0%	1.79 (1.23, 2.60)	0.002		
Children's health status								0.29	9.0%
Non-asthmatic children	10	2385	0.04	0.27	18.0%	1.88 (1.39, 2.53)	<0.001		
Asthmatic children	2	397	1.05	0.17	47.0%	0.70 (0.11, 4.33)	0.70		
Latest Follow-up timepoint									
Short-term (3 months)	2	337	0.00	0.45	0.0%	1.36 (0.76, 2.45)	0.30	0.06	63.5%
Mid-term (6 months)	2	381	0.00	0.48	0.0%	0.38 (0.09, 1.62)	0.19		
Long-term (12 months)	8	2064	0.03	0.29	17.0%	1.96 (1.44, 2.66)	<0.001		
Pharmacological treatments								0.62	0.0%
Combined with NRT	4	883	0.00	0.46	0.0%	1.78 (1.15, 2.74)	0.01		
Not combined with NRT	8	1899	0.17	0.07	46.0%	1.52 (0.96, 2.39)	0.07		

Table 2: **Subgroup analysis of RRs of the effect of intervention by using random-effect model.**

consistent with previous studies that showed increases in abstinence rates (OR = 2.10, $P < 0.001$; F = 14.71, $P < 0.001$).[49,50] The overall effect size in our study was larger than that reported in another systematic review involving middle- and high-income families (RR = 1.62).[12] Compared to other smoking cessation interventions targeting low-income populations at the individual-level, family-based behavioral interventions were more effective than short-message-services (SMS) (12.5% vs. 9.3%)[51] and motivational interviewing (MI) (12.5% vs. 6.4%).[52] In low-income settings with limited professional cessation service and constrained external assistance, family-based behavioral interventions delivered by local healthcare workers provide a cost-efficient and sustained strategy. By using existing family ties, these interventions target the household smoking environments and embed ongoing support within daily routines. Family members can provide accessible emotional and instrumental assistance, including praise, reminders, and stress alleviation, which compensates for limited resources and enhances both the feasibility and effectiveness of cessation efforts.[11]

In addition to conventional smoking cessation strategies, behavioral counseling sessions in our included trials were designed to help families establish mutual support, encourage effective discussions, and set cessation goals. The intervention may be useful for low-income households, where smoking parents often had lower education levels and limited health resources. We observed a significant improvement in abstinence at the end of treatment (RR = 2.19, 12.1% vs. 5.2%). This may be attributed to key counselling components, including motivational interviewing techniques,[45] individualized quit plans,[20] and frequent counselor contact,[8] which improved the short-term cessation outcomes. Such counseling might strengthen the communication of smoking parents, partner support and family relationships, leading to a longer term smoking cessation.[16,30] Our subgroup analyses supported this explanation as family-based behavioral interventions were particularly effective for parents both smoked and during the

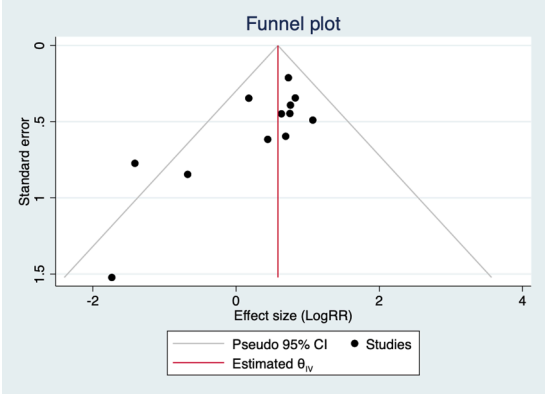

Fig. 4: Observed funnel plot of the Included Studies.

12-month follow-up period. Integrating structured home visits or community-based group sessions that include skill-building exercises, such as conflict resolution training and motivational interviewing tailored to both smokers and their non-smoking relatives should be considered in future research. To enhance accessibility and scalability, especially in the context of inflexible work schedules and limited access to in-person cessation services, the integration of digital tools, including shared progress-tracking applications, tailored SMS reminders, and virtual family support groups, may offer a alternative solution to extend support and sustain engagement in these underserved populations.

Combining behavioral counseling with other interventions has been shown to enhance abstinence rates. Our subgroup results using random-effect model suggested that behavioral counseling was particularly effective when combined with NRT, which addresses both behavioral and physiological aspects of nicotine dependence.[20] Behavioral counseling with indoor air quality feedback functions as an education tool, increasing awareness of the harms of SHS and the benefits of a smoke-free environment.[9] Combined behavioral counseling with NRT produced the largest effect size of abstinence rates, consistent with the United States Preventive Services Task Force (USPSTF) recommendations[53] and other reviews (k = 41; N = 15,021; RR = 1.82; 95% CI 1.66–2.00)[54] that highlighted the combination of behavior therapy with pharmacotherapy treatments as the most effective strategy. However, the small between-group differences and the limited number of trials (n = 4) in the NRT subgroup warrant to be evaluated in trials under the similar context. Additionally, our narrative synthesis found the improvements in indoor air quality, more action to implement home smoking bans, and higher awareness of reducing children's exposure to SHS from different sources when using behavioral counseling combined with indoor air quality feedback, which were in line with a comprehensive review finding[55] showing that indoor air quality monitoring systems are effective for enhancing public health, although the effect in the subgroup analysis was not statistically significant. Future trials should consider incorporating accessible cessation services information into home visits or counselling sessions for low-income smoking parents, such as providing information on local, free NRT distribution points. Integrating one-to-one air quality feedback into educational tools may further elevate low-income parents' understanding of second-hand smoke risks and facilitate the successful adoption of smoke-free home policies.

Family-based behavioral interventions were not effective in increasing abstinence rates among parents with asthmatic children because of only two trials included in the meta-analysis without sufficient intensity of their interventions (one home visit/month[21]; two telephone counselling sessions/month[35]) to generate effects. A supporting trial conducted in the US focused on smoking parents with asthmatic children showed that those receiving intensive behavioral interventions (two home visits and two MI calls/month) were 3–4 times more likely to quit smoking at 6 months compared to those receiving usual care (7-day PPA: OR = 3.71; 30-day PPA: OR = 4.15).[56] Our meta-regression also supported a positive association between number of counseling sessions and abstinence rate despite with non-significance. Although no significant effect on abstinence rates of subgroups was observed, our narrative summary showed a higher adherence level to implementing home and car smoking bans, reduced cigarette consumption and lower children's urinary cotinine levels. This suggested that parental concern over their child's well-being may prompt cessation actions regardless of the child's health condition. Future studies should focus on improving the intervention intensity and duration, particularly among low-income smoking parents, and on providing tailored support based on individual smoking patterns, readiness to quit, and family smoke-free policies. In addition, motivational interviewing should emphasise the health risks of parental smoking on children's respiratory function and development. Emerging digital platforms, including chat-based instant messaging,[4] mobile applications,[57] and large language model (LLM)-based chatbot,[58] warrant exploration to reinforce cessation efforts during intersession intervals in low-income households, which may have the potential to enhance participant engagement by providing real-time support and delivering personalized feedback based on individual and family-level progress.

This review has several limitations. First, several subgroups (e.g., behavioral counseling combined with NRT; behavioral counseling combined with indoor air quality feedback; smoking parents with asthmatic children; trials with follow-up limited to three or six months) in the meta-analysis included only two to three trials. Moderate heterogeneity was also observed between some subgroups, which may limit statistical power and the robustness of individual estimates. These findings should therefore be considered exploratory and interpreted with caution. Second, the funnel plot showed potential publication bias, and the imputed study analyzed by the trim-and-filled method slightly increased the overall effect size, indicating that publication bias may have resulted in modest underestimation of the original effect size. Although the family-based behavioral intervention showed effectiveness in increasing abstinence rate in low-income households, generalization of the findings should be made carefully. Thirdly, several trials had no data on the "dose" of behavioral counseling (i.e., duration of each session and delivered frequency), limiting the precisely

comparison of the effects across different trials. Finally, the populations included in our review were primarily from low-income families residing in the USA and UK, and may not reflect the broader diversity of socioeconomic or cultural experiences across other regions. Although ethnicity was not a primary variable of analysis, structural factors, including income inequality, housing conditions, and access to cessation support, may influence outcomes. Our results may inform scalable family-based interventions that leverage existing social support within households to promote long-term cessation.

In conclusion, family-based behavioral interventions significantly increased cessation among low-income households, particularly when combined with NRT, implemented in both parents smoked settings, and supported by long-term follow-up. These interventions were effective in enhancing measures to prevent children from secondhand smoke exposure among parents.

Contributors

Miss Li and Dr Zhao directly accessed and verified the underlying data in all research articles, and had full access to all data included in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

All authors were responsible for the decision to submit the manuscript.

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Data sharing statement

This meta-analysis did not require the collection of new data, but rather the analysis of previously published data. Details of our meta-analysis process are available on request to the corresponding author.

Declaration of interests

We declare no competing interests.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2025.103420.

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