REVIEW

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Effectiveness of Smoke-Free Home-based Interventions in Reducing Second-Hand Smoke Exposure in Children and Adults: A Systematic Review

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Abstract

Background: Second-hand smoke (SHS) exposure is a major health risk that causes thousands of deaths every year. Most countries have laws banning smoking in public places, but not in homes, where non-smoking children and women, are exposed to SHS. A comprehensive review on effectiveness of smoke free home interventions in reducing SHS is limited. **Objective:** To evaluate the effectiveness of home-based interventions to reduce SHS exposure among non-smoking household members of any age group. **Methods:** The following sources were searched for this systematic review: MEDLINE, CINAHL, Scopus, Proquest, Embase, and Google scholar. **Interventions:** Randomized controlled trials that compared home-based interventions with usual or standard care intervention were included. Studies that measured SHS exposure using biochemical or environmental indicators, such as cotinine in urine, saliva and hair were considered and the risk of bias was assessed using standardized criteria. **Results:** We included 34 studies with a total of 10,727 participants from various countries and settings. The interventions varied in type, intensity, duration, method of education, counselling, feedback, incentives, and support. As far as urinary outcomes were considered 4 studies showed a significant decrease among infants and children whereas two others showed no change. Whereas, atmospheric 2.5 particulate matter seemed to be a more sensitive objective measure with all studies demonstrating either a decrease or significant decrease. Smoking ban policies at home were found to be more effective in the intervention groups compared to control group. **Conclusions:** Home-based educational and behavioural interventions show considerable promise in reducing secondhand smoke exposure. These interventions offer a practical, scalable approach to addressing SHS exposure, particularly in vulnerable populations such as children. Future research should focus on evaluating long- term outcomes. **Protocol registration number:** The review was prospectively registered in PROSPERO CRD42023398093.

Keywords: Second hand smoking- Home-based Interventions study- Cotinine- 2.5 pm

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Introduction

Tobacco smoke constitutes a significant risk factor for various health conditions, including heart diseases, respiratory illnesses, various forms of cancer, and other adverse health outcomes. An estimated eight million people succumb to tobacco-related diseases annually, with 15% of these deaths attributed to second-hand smoke (SHS) exposure [1]. New-borns of mothers who smoke face elevated risks of sudden infant death syndrome and birth defects. Additionally, exposure to second-hand smoke during pregnancy is linked to a 23% increased risk of stillbirth and a 13% increased risk of congenital defects. Second-hand smoke, also known as passive smoking, results from the combined inhalation of smoke emitted from burning tobacco products such as cigarettes, cigars, hookahs, or pipes, as well as smoke exhaled by active smokers. Even minimal exposure to SHS, regardless of duration, can lead to severe and fatal health consequences. Complete elimination of tobacco smoke exposure is the sole means of protecting non-smokers from the hazards of SHS [2].

Children from underprivileged family are vulnerable, as caregivers in these households are more likely to smoke heavily. This will lead to tobacco dependence across generations. The negative health impacts of SHS exposure in children are well-established, including increased risks of lower respiratory infections, asthma, wheezing, middle

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ear disease, meningitis, and sudden infant death syndrome (SIDS) [3].

Many countries have enacted legislation prohibiting smoking in indoor public spaces, including government buildings, hospitals, workplaces, public transportation, and shopping malls [4]. However, private home environments, where non-smoking children and adults cohabit with smokers for extended periods, are not covered by these laws. This leaves children and non-smoking women particularly vulnerable to SHS. The economic burden associated with second-hand smoke is another pressing issue. In 2017, India incurred an annual direct economic expense of INR 566.7 billion (USD 8.7 billion) due to SHS-related diseases. This translates to INR 705 (9 USD) per non-smoking adult. Younger age groups, particularly those aged 20 to 24 years, bore a higher burden, with women accounting for 71% of the direct medical costs linked to SHS [5].

Evaluating the effectiveness of interventions aimed at reducing home-based SHS exposure is crucial for formulating policies promoting smoke-free homes. Smoke-free home interventions have demonstrated positive results in decreasing SHS exposure among non-smoking household members [6]. Significant reduction in daily smoking frequency has been reported among smokers in the intervention group compared to the control group, although the daily frequency and duration of SHS exposure among other household members did not decline over time [7]. The intervention group exhibited an increased perception of susceptibility and severity, along with reduced perception scores of barriers to avoid SHS exposure compared to the control group. However, there was no change in SHS exposure for both groups, as women in both the intervention and control groups continued to be exposed to SHS [8]. A reduction in PM2.5 (particulate matter with a diameter of 2.5 micrometres) was achieved in a trial of home-based intervention of SHS. The incremental cost-effectiveness ratio was $164.26 per additional 10μg/m3 reduction in PM2.5 and $ 89.02 per additional quitter [9].

A review among children in China describes various interventions using self-help materials, warnings against smoking at home, individual counselling, text messages via phone, group counselling, biochemical feedback, and health education [10]. Another review focussed on children, assessed interventions involving counselling, phone support, nicotine replacement therapy (NRT), biochemical feedback, air purifiers, self-help materials, and tobacco smoke air pollution feedback (measured by air nicotine or PM) in a single study [11]. However, no systematic review has comprehensively covered all age groups and genders, particularly women who are more vulnerable as they are largely home bound.

While the most effective way to prevent children's exposure to SFHs, at home is for caregivers to quit smoking, this is not always feasible or sustainable. When quitting is not an option, the next best approach is to support caregivers in making their homes entirely smoke-free. Several strategies based on behavior change theories and educational interventions have been suggested to help protect children from SHS exposure and encourage the creation of smoke-free homes.

The present study aims to conduct a systematic review of home-based intervention trials designed to reduce SHS exposure among non-smoking household members of all age groups.

The objective of this Systematic review was to evaluate the effectiveness of home-based interventions to reduce SHS exposure among non-smoking household members of any age group.

Materials and Methods

This systematic review was conducted according to the Joanna Briggs Institute (JBI) methodology for systematic reviews of effectiveness evidence and reported according to PRISMA guidelines. The review was registered in PROSPERO (registration no: CRD42023398093)

Inclusion criteria

Participants

Studies that focused on non-smokers in the home of tobacco smokers were included. These non-smokers included parents (mother, father, or both), women, children, older adults, grandparents, and any other person living in the same home as the smoker. Studies that focussed on caretakers were also included, when done in a home-based setting. There was no restriction based on the age, gender, education level, or socio-economic status of participants for study selection. However, studies involving assessment among guests were excluded.

Intervention(s)

Studies containing home-based interventions among non-smokers were eligible to be included. These included educational or counselling sessions, motivation, booklet or pamphlet distribution, home visits by healthcare workers, or demonstration of level of second-hand smoking at the participants' homes. Educational or counselling sessions that were delivered through methods such as, in-person, telephone calls, post, emails, short message services, compact discs (CDs), or booklets. Additionally, home-based activities such as moving the non-smoker away from source, opening windows when a family member smoked, asking the smoker to smoke outside, and partial or complete smoking ban regulations at home were considered as home-based interventions.

Comparator

Studies with control groups given standard of care (usual levels of education or counselling), minimal levels of education or counselling than the intervention group, no education or counselling, absence of home-based smoking regulations, or distribution of only printed instructions were included.

Outcomes

Outcomes included were biochemical validation of reduced SHS (urine cotinine level or urine 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL) level or saliva cotinine level or biomonitoring of hair to assess cotinine levels), air quality monitoring using aerosol or air monitors or air nicotine level or PM2·5 concentration or geometric mean particle count or percentage change in time >15,000 particle counts and smoking ban (complete or partial) at home.

Types of studies

This systematic review included only randomized controlled trials.

Study selection

Studies published in the English language were included and there was no time specified for the search. In this review, a three-step search strategy was used. First, an initial limited search of MEDLINE (EBSCOHost) was done which provided 174 articles (Supplementary file Table 1.). In the second step, a detailed search via MEDLINE(EBSCO Host), CINAHL (EBSCO Host), Scopus (Elsevier), ProQuest, Embase, and Google scholar was done which yielded 782 articles (Figure 1). The search strategy, including all identified keywords and index terms, was adapted for each database and/or information source. The reference list of all included sources of evidence were screened for additional studies.

The key words searched for under population were; second hand smokers or second hand smoke or Non-smokers or Non smokers or second hand tobacco smoking or second hand tobacco smoker or Tobacco smoke exposure and family or kinor family home or household or home based or home. Similarly keywords were used for Intervention, Comparison and outcome (Supplementary File 1).

Following the search, all identified citations were collated and uploaded into Zotero, and duplicates were removed. Titles and abstracts were then screened by two independent reviewers (MN and PB) for assessment against the inclusion criteria. Conflicts in selection resolved through discussion with a third reviewer (CJ). Potentially relevant studies were retrieved in full, and their citation details were imported into the JBI System for the Unified Management, Assessment, and Review of Information (JBI SUMARI) (JBI, Adelaide, Australia).

The full text of selected records was assessed in detail against the inclusion criteria by two independent reviewers (MN and PB). Reasons for the exclusion of papers in full text were recorded and reported in the systematic review. Any disagreements that arose between the reviewers at each stage of the selection process were resolved through discussion with an additional reviewer (CJ). The results of the search and the study inclusion process have been reported in full in the final systematic review and presented in a Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram (Figure 1).

Assessment of methodological quality

Eligible studies were critically appraised by two independent reviewers (MN and CJ) at the study level for methodological quality in the review using standardized critical appraisal instruments from JBI for experimental studies. Any disagreements that arose were resolved through discussion to reach a consensus. The results of the critical appraisal are reported in narrative form. All studies, regardless of the results of their methodological quality, underwent data extraction and synthesis.

Data extraction

Data were extracted from studies included in the review by two independent reviewers (MN and PB) using the Microsoft Excel. Initial ten studies underwent pilot data extraction and were checked for reliability. The data extracted included specific details about the participants, study methods, interventions, and outcomes. Any disagreements that arose between the reviewers were resolved through discussion with other reviewers (CJ, KRT, AS). The data extraction tool is provided in Appendix 2.

Data synthesis

The findings were synthesized by a summary approach and presented in a narrative form with tables and figures to aid in data presentation, where appropriate. The Summary of Findings (SoF)comprised absolute risks for the treatment and control groups, estimates of relative risk, and a ranking of the quality of the evidence based on the risk of bias, and risk of publication bias of the results. The outcomes reported in the SoF were urine cotinine, salivary cotinine or hair cotinine levels, hair nicotine level, health of participants, country of study, smoking ban achieved, urine NNAL, and air particulate matter.

Results

A comprehensive search was carried out in April 2023, across six electronic databases: PubMed, Scopus, ProQuest, CINAHL, Embase, and Google Scholar. The initial retrieval yielded 782 studies from the databases and an additional 62 through citation searching. We did not find any grey literature. Among these, 239 duplicate studies were removed. The titles and abstracts of the remaining 605 studies were screened, leading to the exclusion of 479 studies that did not align with the inclusion criteria. The eligibility of 126 studies was assessed based on their full-text articles of which 87 articles were excluded. The reasons for exclusion are given in Figure 1. Finally, our systematic review included 34 studies.

Characteristics of included studies

The studies included in this systematic review were conducted in various countries around the world. The majority of the studies (n=18) were from USA [7, 12-28]. There were three studies from Thailand [29-31], followed by UK [9, 32], China [33, 34], Iran [35, 36], and Turkey [37, 38] each having two studies included. The remaining studies were from Armenia [39], Australia [40], New Zealand [40], Bangladesh [41], Germany [42], and Israel [11]. These 34 studies were published between 1994 [17, 23, 24] and 2021 [31, 41] and included 8,759 participants.

The current review focussed exclusively on outcome measures among non-smokers. The majority of studies, measured outcomes on healthy non-smokers (n=29), while four studies focussed on asthmatic children [17, 20, 22, 24] and one study involved premature babies [13]. Hospitals

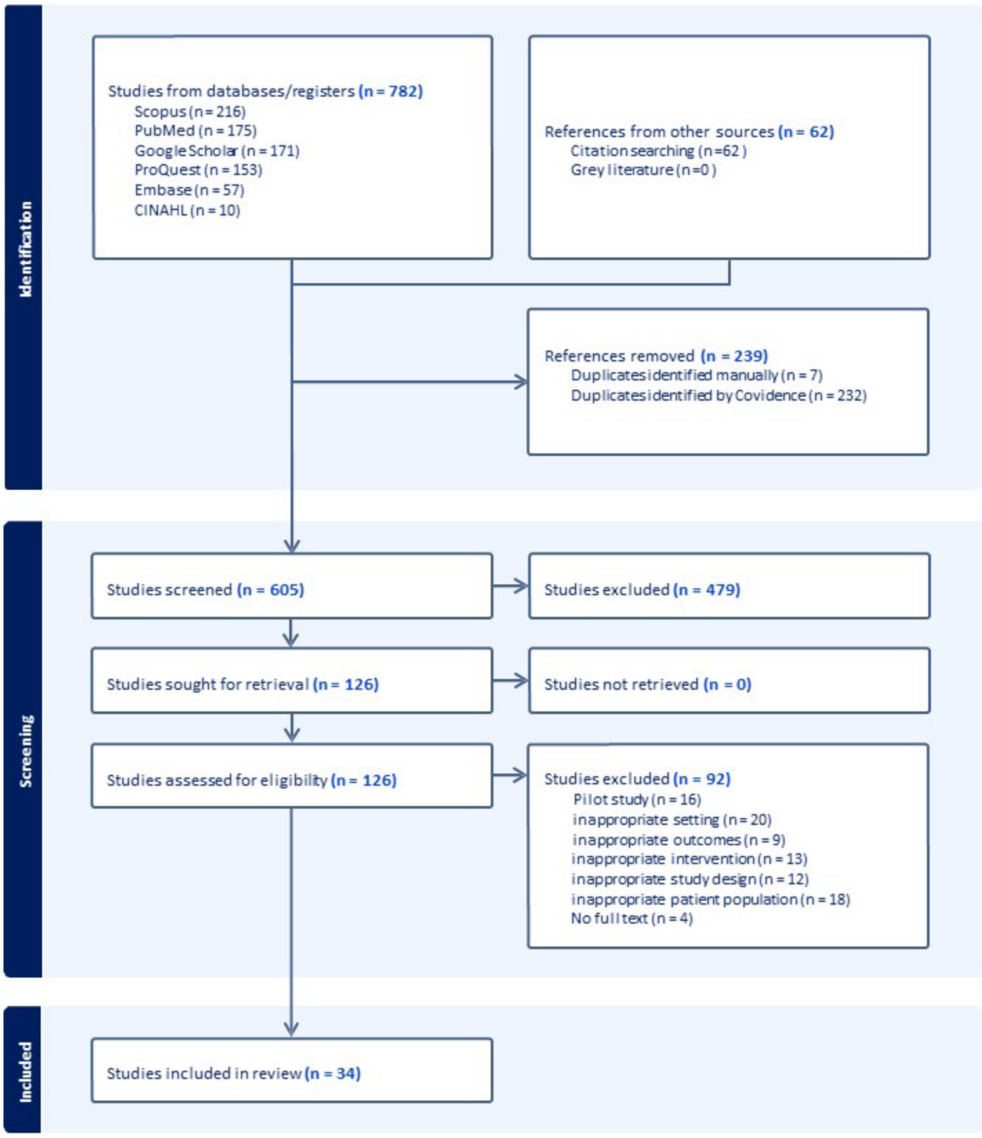

Figure 1. Effectiveness of Tobacco Smoke Free Homebased Interventions in Reducing Second Hand Smoking Exposures

served as the primary recruitment setting for majority of studies. Few studies had schools [22, 29], day care centres [43], neighbourhood [42], ongoing public health programs [10, 14, 16, 18], supermarkets [16], social media [16, 43], mosques [41], 2-1-1 contact centres [7, 28], and homes as intervention areas [27]. The source of exposure (smoker) were mainly, family members such as a parent, spouse while some studies focussed on caregivers [19, 20, 34].

Intervention Details

Table 1 shows the characteristics of included studies. Among the included studies, many studies used educational interventions [7, 12, 18, 20, 21, 24, 26, 29-32, 34-36, 38] which involved providing the participants with written or verbal information about the health effects of SHS exposure. Resource booklets or tailored educational brochures were also given to participants. Interactive CDs were used in intervention by Yilmaz et al. [37] The health messages were reinforced by verses from holy scriptures in Bangladesh [41]. Some studies also incorporated counselling as part of the intervention, which included individual or group sessions, telephone calls, or home visits aimed at motivating participants to change their smoking behavior or adopt smoke-free home policies [7, 13, 14, 17, 19, 22, 27, 31, 34, 37, 39, 40 , 42]. Behavioural coaching [9, 14, 19 , 40] and motivational interviews [25, 27]were other intervention components.

In studies such as Harutyunyan et al. [39] reductions in home air pollution were also used to motivate participants. In the study by Greenberg et al. [23] nurses conducted home-visits to households in the intervention group. The intervention in the study by Renwick et al. [9] included nicotine replacement therapy and personalized feedback on home air quality. In Yucel et al's. [38] study, an intensive intervention consisting of smoking control measures were implemented within homes as part of the intervention. Some studies incorporated real-time particle-level feedback mechanisms using lights and sounds [18, 27], or computer-generated feedback letter [42] as part of the home-based intervention.

Table 1. Characteristics of Included Studies

Study	Country	Study design	Sample size	Intervention group sample size	Control group sample size	Home-based interventions	Outcomes measured
Kazemi et al,2012 [36]	Iran	RCT	130	65	65	Education	Mean number of cigarettes family member smoked per week at home
Harutyunyan et al, 2013 [40]	Armenia	RCT	250	125	125	Counselling sessions, demonstration of home air pollution	Hair nicotine concentration, survey of knowledge about health hazards of SHS, and household smoking-related practices
Yilmaz et al, 2013 [38]	Turkey	RCT	382	176	176	Mailing print materials and interactive CDs and coaching call	Urine cotinine level
Yu et al, 2017 [34]	China	RCT	300	204	97	Mobile-phone-based smoking cessation intervention	Tobacco use and household SHS exposure
Greenberg et al,1994 [24]	USA	Solomon four- group design RCT	933	493	440	Home visits by nurse, Booklets	Urine cotinine level, Exposure to tobacco smoke - number of cigarettes smoked per day in the presence of child, incidence and prevalence of respiratory illness in infants
Walker et al, 2015 [41]	Australia, New Zealand	RCT	321	161	160	Behavioral coaching	Number of Acute Respiratory Illness-related visits to a health provider in the first year of life, Hospitalization rates, mothers' report of infants' SHS exposure smoking restrictions (validated by urinary cotinine/creatinine ratios), and smoking cessation
Tong et al, 2018 [13]	USA	RCT	205	95	110	Educational sessions, booklet	Urine level of levels of 4-(methylnitrosamino)-1- (3-pyridyl)-1-butanol (NNAL), Non-smoker's past month exposure to tobacco
Intarut et al, 2016 [30]	Thailand	Cluster RCT	482	227	255	Education, booklet	Knowledge and Attitude to harms of smoking and Second-Hand Smoking, Self-confidence score in creating smoke free home, survey of smoking at home in the past seven days
Kegler et al, 2015 [7]	USA	RCT	498	246	252	Education, coaching	Presence of a full home smoking ban, self- reported second-hand smoking exposure in the home, and among smokers, cessation attempts, number of cigarettes smoked per day, and self-efficacy for quitting, air nicotine monitor
Hovell et al, 2011 [17]	USA	RCT	201	100	101	Coaching	Urine cotinine level, Complete ban of indoor smoking, child's second hand smoke exposure
Mdege et al, 2021 [42]	Bangladesh	RCT	1801	1200	601	Health messages supported by at least one Quran verse (ayah), or an Islamic faith- based decree, booklets	PM 2·5 concentration, smoking restrictions at home
Rosen et al, 2021 [12]	Israel	RCT	159	69	90	Counselling	Real-time feedback on home air quality (PM2.5), hair nicotine level, home smoking changes
Borelli et al, 2010 [21]	USA	RCT	133	68	65	Education	Passive nicotine monitors in home, survey regarding asthma morbidity
Kegler et al, 2016 [27]	USA	RCT	375	230	145	Education, coaching call	Complete ban of indoor smoking
Renwick et al, 2018 [10]	England	RCT	204	102	102	Behavioral support, nicotine replacement therapy, personalized feedback on home air quality	Aerosol monitor, Incremental cost-effectiveness of change in air quality in the home
Hovell et al, 1994 [18]	USA	RCT	91			Counselling	Nicotine air monitor
Emmons et al, 2001 [26]	USA	RCT	291	150	141	Motivational interviewing	Air nicotine levels
Conway et al, 2004 [20]	USA	RCT	143	71	72	Positive reinforcement, problem solving, and social support to assist families	Hair nicotine level, parent reports of the child's past month exposure from all sources in the household over the last 30 days as measured by number of cigarettes.

Table 1. Continued

Study	Country	Study design	Sample size	Intervention group sample size	Control group sample size	Home-based interventions	Outcomes measured
Suteerangkul et al, 2021 [32]	Thailand	RCT	54	27	27	Education, campaigns in the community, visiting and encouraging, and reflecting and evaluation	Smoking ban inside home and Emotional support for non-smoking inside home
Yücel et al, 2014 [39]	Turkey	RCT	80	40	40	Education, smoking controls at home	Urine cotinine level, home smoking bans
Hovell et al, 2009 [15]	USA	RCT	150	76	74	Counselling, behavioral contracting, self-monitoring, and problem solving	urine cotinine levels and home air nicotine levels
Boman-Davis 2014 [28]	USA	hybrid RCT	14	7	7	Counselling, motivational interviewing	air monitoring of daily fine particle counts, urine cotinine level, report of second hand smoke exposure, surface and air nicotine levels
Blaakman et al, 2015 [14]	USA	RCT	165	83	82	Counselling	Salivary cotinine level, infant exposure to second hand smoking, smoking ban, infant respiratory symptoms, and infant health care utilization
Hughes et al, 2018 [19]	USA	RCT	298	149	149	Education, real-time lights and sounds providing feedback about particle levels	Home air particle monitors of mean particle counts
Hovell et al, 2000 [16]	USA	RCT	108	53	55	Counselling	Urine cotinine level, Environmental exposure
Eakin et al, 2014 [22]	USA	RCT	330	165	165	Education	Household air nicotine, salivary cotinine, smoking ban
Abdullah et al, 2015 [35]	China	RCT	318	164	154	Education, Counselling	Urine cotinine level, Improvement of smoking hygiene practices within the household, reduction of total SHS exposure to child from all smokers inside and outside the home, reduction of respiratory illness incidence among children as reported by key household members, reduction of household members smoking cigarettes around the child, and improvement of smoking behavior of household members
Mcintosh et al,1994 [25]	USA	RCT	92			Education	Urine cotinine level, attempts to quit smoking inside the home
Semple et al, 2018 [33]	UK	RCT	117	58	59	Education	Air quality monitor, Changes in household concentrations of fine Particulate Matter (PM2.5)
Streja et al, 2014 [23]	USA	RCT	242	118	124	Education using video, workbook, counselling	Urine cotinine and parental reports of child's hours of SHS exposure and number of household cigarettes smoked
Intarut et al, 2020[31]	Thailand	RCT	305	144	161	Education	SHS exposure in the home within 7 days, number of days of SHS exposure in the home
Baheiraei et al, 2011 [37]	Iran	RCT	130	65	65	Education	Parental cigarette consumption in the presence of the child, home- and car-smoking ban
Ulbricht et al, 2014 [43]	Germany	RCT	917	477	440	Counselling, computer- generated feedback letter	Urine cotinine
Mullen et al, 2016 [29]	USA	RCT	508	258	250	Coaching	Home smoking ban

In the reviewed studies, control groups either received standard care or no intervention at all. Standard care typically involved minimal interventions, such as self-help materials, brief advice, or referrals to other services. In a few studies, the control arm received active interventions, such as education on the prevention of infectious diseases [35], brief educational modules [12], or counselling on child development [34]. In some cases, the control group underwent minimal interventions compared to the experimental group [22, 39]. The study by Kegler et al. [26] featured a passive control arm, characterized by the absence of a smoking ban at home. Standard care was provided to control group participants in several studies [9, 17 , 24 , 32].

Table 2. Studies According to Indoor Smoking Ban

Variable	Study	Sample size	No.of participants in intervention group	No.of participants in control group	Complete ban of indoor smoking (intervention grp)	Complete ban of indoor smoking (Control grp)
Smoking ban	Hovell et al, 2011	201	100	101	40%	25.40%
	Kegler et al, 2016	375	230	145	36.50%	22.10%
	Yücel et al, 2014	80	40	40	34.20%	15%
	Boman-Davis 2014	14	7	7	100%	16.70%
	Blaakman et al, 2015	165	83	82	96%	84%
	Eakin et al, 2014	330	165	165	39.3%	40.7%
	Abdullah et al, 2015	318	164	154	62%	45%
	Mullen et al, 2016	508	258	250	62.90%	38.40%

Synthesis of results

The final 34 studies reported diverse and broad outcomes, with limited overlap in units and varied reporting measures. Therefore, this review did not progress to a meta-analysis. Majority of included studies had biochemical markers like salivary cotinine [13], urine cotinine [14-16, 22-24, 36-38, 42], urine NNAL [12], hair nicotine [19, 39, 43], and hair cotinine [19] as their outcomes.

Blaakman et al demonstrated a statistically significant reduction in salivary cotinine levels among infants with asthma in the intervention group compared to those in control group (-1.32 ng/mL vs -1.08 ng/mL, p = 0.04) [13]. Salivary cotinine levels are generally lower than urine cotinine levels among both smokers and non smokers. Across studies comparing cotinine levels in biological samples, most have shown a significant reduction following intervention. Although randomised studies using Salivary cotinine are limited, those available have reported a significant decline in levels compared to control. These studies predominantly focus on infants, children or adolescents, with intervention durations ranging from three months to one year.

Urinary cotinine levels have also shown significant reductions in several studies. For instance, Yilmaz et al. [37], found a marked decrease among adolescents in the intervention group compared to control (2.09±0.44 vs 5.76±1.38, p <0.001) while Hovel et al. [16] reported similar findings (3.13[95% CI: 2.48, 3.90] vs 3.68[95% CI: 2.85, 4.69], p= 0.039). Baheiraei et al. [36] also observed a significant reduction (28.68 ng/mg vs 36.32 ng/mg, p= 0.029).

However, not all studies found a significant effect. A large trial from Germany with a one year intervention period reported no significant difference between the intervention and control groups [42]. Similarly, oneof the earliest studies [23] conducted in 1994 found no significant change. Across studies, interventions were commonly delivered by trained community health workers or counsellors [22, 34, 42], sometimes supervised by masters level student [36] and less frequently by Physicians [37, 38].

Yet another study, assessed the urine levels of 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL) to measure exposure to tobacco. In the intervention group, this tobacco-specific biomarker decreased during follow-up, from a baseline level of 8.8±36.0 urine NNAL/Cr to 7.0±40.8 urine NNAL/Cr though not statistically significant [12].

Some studies estimated hair nicotine level as the tobacco-exposure related outcome in participants. Studies among children have demonstrated contrasting results with Harutyunyan et al. [39] finding a significant difference in hair nicotine level in intervention group from baseline to follow-up (p=0.024) whereas, Rosen et al. [43] reported that there was no statistically significant difference in hair nicotine level between the intervention and control groups.

Besides biomarkers, tobacco levels in air and home-based smoking bans were also outcomes of interest. Four studies considered air particulate matter PM 2.5 concentration as their outcome [9, 17, 32, 41]. Renwick et al. [9] reported a statistically significant reduction in PM2.5 in the intervention group (p = 0.0096). The difference between the groups was reported to be 21.6 (95% CI: 5.4 to 37.9). Similarly, the environmental tobacco smoke was found to reduce more in intervention group (79% reduction) than control group (34% reduction). This difference in reduction was found to be statistically significant (p< 0.05) [17]. Air nicotine level was another air monitoring outcome considered [21, 22, 25]. Eakin et al reported that homes of experimental group participants had lower air nicotine level than control group(0.29 vs. 0.40 mg) [21].

Indoor smoking ban was another outcome measured [13, 16, 21, 26-28, 31, 34, 36, 38]. Intervention groups achieved higher percentage of smoking ban home policies than control groups in Suteerangkul et al ((92.6% vs 18.5%, p<0.05) [31], Baheiraei et al. [36] (33.3% vs 19.70%, p < 0.001),Kegler et al. [26] (36.50% vs 22.10%, p<0.0001), Blaakman et al. [13] (96% vs 84%, p= 0.03), Abdullah et al. [34] (62% vs 45%, p = 0.022), and Mullen et al. [28] (62.9% vs 38.4%, p<0.0001).

Most of the studies were among infants, children, adolescents and pregnant women. Most of the studies that had measured environmental exposure as an outcome measure using a feedback mechanism demonstrated a decrease in air nicotine or 2.5 pm. Smoking ban policies at home were found to be more effectively implemented in the intervention groups than control group (Table 2).

Methodological quality assessment of included studies

The revised JBI critical appraisal tool [44] for

Table 3. Critical Appraisal of Included Studies

Study ID	Selection and allocation			Administration of intervention/ exposure			Assessment, detection, and measurement of the outcome			Participant retention	STATISTICAL CONCLUSION VALIDITY			Risk of bias level
	Was true randomization used for the assignmen t of participant s to treatment groups?	Was allocat ion to groups conce aled?	Were particip ants blind to treatme nt assignm ent?	Were partici pants blind to treatm ent assign ment?	Were those delive ring the treatm ent blind to treatm ent assign ment?	"Were treatme nt groups treated identica lly other than the interven tion of interest ?"	Were outcom e assessor s blind to treatme nt assignm ent?	Were outcom es measure d in the same way for treatme nt groups?	Wer e outc omes meas ured in a relia ble way?	Was follow- up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Were particip ants analyze d in the groups to which they were randomi zed?	"Was appr opria te statis tical anal ysis used ?"	Was the trial design appropriate and any deviations from the standard RCT design (individual randomizati on, parallel groups) accounted for in the conduct and analysis of the trial?	
Kazemi et al,2012[36]	Y	N	Y	N	N	N	N	Y	N	N	Y	N	N	High
Harutyunyan et al, 2013[40]	Y	Uncle ar	Y	Y	Uncle ar	Y	Unclear	Y	Y	Y	Y	Y	Y	Unclear
Yilmaz et al, 2013[38]	Y	N	Y	Uncle ar	N	Y	Y	Y	Y	Y	Y	Y	Y	High
Yu et al, 2017[34]	Y	N	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	High
Greenberg et al,1994[24]	Y	Uncle ar	Y	Uncle ar	Uncle ar	Y	Y	Y	Uncl ear	Y	Y	Uncl ear	Y	High
Walker et al, 2015[41]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Tong et al, 2018[13]	Y	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	High
Intarut et al, 2016[30]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Kegler et al, 2015[7]	Y	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	High
Hovell et al, 2011[17]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Mdege et al, 2021[42]	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y	High
Rosen et al, 2021[44]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Borelli et al, 2010[21]	Y	Uncle ar	Y	Uncle ar	Uncle ar	Unclear	Y	Y	Y	Y	Y	Y	Y	Unclear
Kegler et al, 2016[27]	N	N	Y	N	N	Y	Unclear	Y	Y	N	Y	Y	Y	High
Renwick et al, 2018[10]	N	N	Y	N	N	Y	Y	Y	Y	N	N	Y	N	High
Hovell et al, 1994[18]	Y	N	Y	N	N	Y	Unclear	Y	Y	N	Y	Y	Y	High
Emmons et al, 2001[26]	Y	N	Y	N	N	Y	Unclear	Y	Y	Y	Y	Y	Y	High
Conway et al, 2004[20]	Y	Uncle ar	Y	N	Uncle ar	Y	Unclear	Y	Y	Y	Y	Y	Y	High
Suteerangkul et al, 2021[32]	Y	N	Y	N	N	N	N	Y	Y	N	N	N	Y	High
Yücel et al, 2014[39]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Hovell et al, 2009[15]	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	Y	High
Boman- Davis 2014[28]	Y	Uncle ar	Y	N	Uncle ar	Y	N	Y	Y	N	Y	Y	Y	High
Blaakman et al, 2015[14]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Hughes et al, 2018[19]	Y	N	Y	N	N	Y	Unclear	Y	Y	Y	Y	Y	Y	High
Hovell et al, 2000[16]	Y	Uncle ar	Y	N	N	Unclear	Y	Y	Y	N	Y	Y	Y	High
Eakin et al, 2014[22]	Y	Y	N	N	N	Y	N	Y	Y	N	Y	Y	Y	High
Abdullah et al, 2015[35]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Low

Table 3. Continued

Study ID	Selection and allocation			Administration of intervention/ exposure			Assessment, detection, and measurement of the outcome			Participant retention	STATISTICAL CONCLUSION VALIDITY			Risk of bias level
	Was true randomization used for the assignmen t of participant s to treatment groups?	Was allocat ion to groups conce aled?	Were particip ants blind to treatme nt assignm ent?	Were partici pants blind to treatm ent assign ment?	Were those delive ring the treatm ent blind to treatm ent assign ment?	"Were treatme nt groups treated identica lly other than the interven tion of interest ?"	Were outcom e assessor s blind to treatme nt assignm ent?	Were outcom es measure d in the same way for treatme nt groups?	Wer e outc omes meas ured in a relia ble way?	Was follow- up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Were particip ants analyze d in the groups to which they were randomi zed?	"Was appr opria te statis tical anal ysis used ?"	Was the trial design appropriate and any deviations from the standard RCT design (individual randomizati on, parallel groups) accounted for in the conduct and analysis of the trial?	
Mcintosh et al,1994[25]	Y	Uncle ar	N	Uncle ar	Uncle ar	Y	Y	Y	Y	Y	Y	Y	Y	High
Semple et al, 2018[33]	Y	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	High
Streja et al, 2014[23]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Low
Intarut et al, 2020[31]	Y	Y	Y	Uncle ar	Uncle ar	Y	Unclear	Y	Uncl ear	Y	Y	Y	Y	Unclear
Baheiraei et al, 2011[37]	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	High
Ulbricht et al, 2014[43]	Y	Y	Y	Uncle ar	N	Y	N	Y	Y	Unclear	Y	Y	Y	High
Mullen et al, 2016[29]	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Unclear

randomized control trials was used in this review for checking methodological quality of included studies. Two reviewers (MN and CJ) did the critical appraisal independently. Disputes in this stage was resolved by discussion with a third reviewer (PB, AS). We classified studies with more than 2 “NO” as having high risk of bias. Based on that, 22 studies were identified as having high risk of bias as they did not meet most of the criteria (Table 3). We identified four studies with unclear risk of bias. Eight studies had less than two “NO’s” and were identified as studies with low risk of bias.

Discussion

The present systematic review aimed to assess the effectiveness of home-based interventions in reducing SHS exposure among non-smoking household members. A total of 34 randomized controlled trials were included in the analysis. While the studies demonstrated variability in terms of intervention strategies, outcome measures, and study populations, several key findings emerged.

Educational interventions across varying time periods from 3-6months have been shown to significantly reduce second-hand smoke (SHS) exposure. Many studies highlight reductions in biochemical markers, such as urine cotinine, following these interventions. For example, one study [28] found that participants who received tailored educational brochures experienced a significant reduction in urinary cotinine levels compared to the control group. However, most of these studies, were among children, pregnant woman and adolescents with small sample size. Pragmatic randomised controlled trials or cluster randomised trials utilising natural population units may throw interesting light on the impact of behavioural intervention.

Counselling and behavioural interventions, especially those involving motivational interviewing, also contributed to reduced SHS exposure. Greenberg et al.[23] reported that home visits by nurses, who provided counselling and support for smoke-free home policies, resulted in a marked decrease in SHS exposure. Interventions incorporating feedback mechanisms, such as real-time air quality feedback or personalized reports on home air pollution, were similarly effective in reducing SHS exposure. A study by Renwick et al. [9] noted significant reductions in PM2.5 levels in homes where participants received personalized air quality feedback alongside behavioural coaching.

Nicotine Replacement Therapy (NRT), though used in fewer studies, demonstrated some effectiveness in reducing SHS exposure when combined with other interventions like counselling. This combination was particularly effective when it also targeted smoking cessation among household smokers.

The presence of clinical and methodological heterogeneity (interventions, outcome measures, and tools) compounded the challenge of conducting a meta-analysis, limiting the ability to draw definitive conclusions about the overall effectiveness of home-based interventions. Additionally, variations in control interventions made it difficult to compare the outcomes of different studies. The use of different time points for outcome assessments further complicated synthesis efforts. A key issue was the reliance on biochemical markers as primary outcomes, which do not fully capture the broader health impacts of SHS exposure. To comprehensively evaluate the effectiveness of home-based interventions, future studies should assess long-term health outcomes of participants. Another limitation was the varying quality of included studies, many of which demonstrated a high risk of bias, highlighting the need for future research with more rigorous methodological designs.

The intervention components also varied widely, making it difficult to determine which specific elements were most effective. The use of diverse outcome measures, such as biochemical markers and air quality metrics, further complicated cross-study comparisons. Additionally, short follow-up periods in many studies limited the evaluation of long-term intervention sustainability. Effectiveness also varied across different cultural and socio-economic contexts, suggesting that interventions should be tailored to specific populations. Most studies focused on infants, children, and adolescents, leaving a gap in understanding the impact on other demographic groups, such as the elderly. Comprehensive home-based interventions, when integrated into broader tobacco control strategies, show promise. Tailoring interventions to specific populations and incorporating culturally relevant components could further enhance their effectiveness. Ongoing support and follow-up may be necessary to sustain reductions in SHS exposure over time.

Future research should aim to develop and evaluate standardized outcome assessment tools, consistent time intervals for assessments, and reliable outcome measures, as well as explore the cost-effectiveness of various approaches. Studies investigating the long-term impact of home-based interventions on the health and well-being of non-smoking household members are also needed.

In conclusion, Home-based educational and behavioural interventions show considerable promise in reducing second-hand smoke exposure, as evidenced by significant improvements in both biological markers such as urinary cotinine and environmental indicators such as 2.5pm. These interventions offer a practical, scalable approach to addressing SHS exposure, particularly in vulnerable populations such as children. Future research should focus on evaluating long- term outcomes and exploring the influence of environmental and contextual factors to enhance effectiveness and sustainability of these interventions.

Author Contribution Statement

MN: validation, software, data extraction, formal analysis, writing-original draft, visualisation. PB: validation, software, resources, data extraction, formal analysis, writing-original draft, manuscript revision, visualisation. KRT: writing-review and editing, supervision, guarantor. AS: Conceptualization, writing-review and editing, resources, supervision. CJ: Conceptualization, methodology, validation, data extraction, formal analysis, software, resources, writing-review and editing, supervision, project administration.

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Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Approval

It was approved by ethical committee ECASM-AIMS-2023-112 dated 24 February, 2023.

Availability of data

All applicable data provided in supplementary files

The review was prospectively registered in PROSPERO CRD42023398093

Conflicts of interest

The authors do not have any competing interests.

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