

Reducing second-hand smoke exposure among non-smoking pregnant women: a systematic review

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Keywords: Environmental Tobacco Smoke, Passive smoking, Child Health, Interventions, Pre-natal, Pregnancy, Spouses

Word count: 4097; 1 supplementary file and 1 figure. References: 54

Abstract word count: 246

ABSTRACT

Introduction: Exposure to second-hand smoke (SHS) in pregnancy leads to an increased risk of stillbirths, congenital malformations and low birth weight. There is a lack of evidence about how best to achieve reductions in SHS exposure among non-smoking pregnant women. This work systematically reviews individual or household interventions to reduce pregnant women's exposure to SHS.

Methods: MEDLINE, EMBASE and CINAHL databases were searched from their dates of inception to 17th April 2019. Studies were included if: participants were non-smoking pregnant women; involved an intervention to reduce SHS exposure or encourage partner quitting; and measured SHS exposure of pregnant women and/or recorded quit rates among partners. The UK National Institute for Health & Care Excellence (NICE) Quality Appraisal checklist was used to determine internal and external validity.

Results: Nine studies met the inclusion criteria. Educational interventions were primarily targeted at the pregnant woman to change her or others' behaviour, with only two studies involving the partner who smoked. Intervention delivery was mixed, spanning brief discussions through to more involving sessions with role play. The effective interventions involved multiple follow-ups. There was no standardised method of assessing exposure to SHS. Many of the included studies had moderate to high risk of bias.

Conclusion: There is mixed evidence for interventions aimed at reducing pregnant women's exposure to SHS, though multi-component interventions seem to be more effective. The effectiveness of family-centred approaches involving creating smoke-free homes alongside partner smoking cessation, perhaps involving pharmacological support and/or financial incentives, should be explored.

IMPLICATIONS

- Measures to protect non-smoking pregnant women from second-hand smoke tend to place the responsibility for ‘avoidance’ on the woman.
- There is little work that seeks to involve the smoking partner or other smokers in protecting pregnant women from SHS.
- Interventions to create smoke-free homes and/or smoking partner cessation need to be developed: pharmacological and financial support should be explored.

INTRODUCTION

The deleterious effects of active smoking to the pregnant woman and her unborn child have been demonstrated in various studies. These include: increased risks of premature delivery [1]; low birth weight babies [2]; certain congenital anomalies [3]; foetal death [4]; and pregnancy complications such as placenta praevia, placenta abruption and premature rupture of membranes [5-6].

Studies have also shown that exposure of non-smoking pregnant women to second-hand smoke (SHS) may also be linked to negative health effects including pre-term birth [7], a 30-40 gram reduction in birth weight [8-9] and increased risk of still births and congenital malformations [9-11]. Analysis of the impact of introducing smoke-free public spaces in England in 2007 suggests that there may be an association between population reductions in SHS exposure and a 7.8% reduction in stillbirth, a 3.9% reduction in low birth weight, and a 7.6% reduction in neonatal mortality [12] with similar data showing reductions in pregnancy complications after smoke-free legislation in Scotland [13].

The mechanisms of harm by SHS to the foetus are similar to those by active maternal smoking and include exposure of the foetus to toxins from tobacco smoke such as nicotine and carbon monoxide through the placenta and amniotic fluid [14]. Nicotine causes narrowing of blood vessels reducing blood flow to the foetus [15]. In addition, foetal haemoglobin easily binds to carbon monoxide further disrupting oxygen supply to foetal tissues [14]. Exposure during pregnancy to fine particulate ($PM_{2.5}$) – a major component of SHS – has also been associated with infant mortality [16] and development of wheeze and asthma in children [17]. $PM_{2.5}$ is also strongly linked to hypertensive disorders in pregnancy

with the associated risks to the health of the foetus [18]. A review by Amegah and colleagues in 2014 [19] showed a strong association between combustion of solid fuels at home and an increased risk of both low birth weight and stillbirth providing further evidence that exposure to PM_{2.5} is likely to be detrimental to the foetus.

Pregnant women who relapse to smoking after quitting during pregnancy and those who persistently smoke during pregnancy are more likely to be those who live with a smoking partner or family member [20-21]. Reducing exposure of pregnant women to SHS will not only reduce health risks to them and their unborn babies, but can also influence and sustain their quit decisions [22]. Providing a smoke-free home for the mother and child can be an important stepping stone to successful quitting for anyone who smokes in the home [23].

While the prevalence of pregnant women who smoke in the UK is under 11%, the proportion of pregnant women exposed to SHS is much higher [24]. A 2016 study of 10,768 UK mothers reported that 22.5% lived with a smoking partner during pregnancy [20].

More generally it is estimated that 31% of women (15 years and above) in high income countries are exposed to SHS [25]. A recent analysis of health data from over 37,000 women across 30 low- and middle-income countries (LMICs) indicated that prevalence of daily SHS exposure during pregnancy ranged from 6% in Nigeria to over 70% in Armenia, and was greater than active tobacco use in pregnancy in all LMICs studied [26]. In these countries exposure to SHS accounted for a greater population attributable fraction of stillbirths than active smoking.

The WHO recommendations [27] for the prevention and management of tobacco use and SHS exposure in pregnancy include screening and identification of pregnant women exposed to SHS, psychosocial intervention, and establishing smoke-free public places especially hospitals. This report also identified gaps in available evidence and suggested areas of focus for future research which included ‘how best to approach and engage the partners of pregnant women, and other household members to decrease tobacco use among family members and subsequently reduce SHS exposure in homes for pregnant women [27]. This was further raised in a recent research workshop that brought together scientists and practitioners working on smoke-free homes in the UK, Malaysia and Bangladesh. Participants highlighted that interventions should be delivered at a household level rather than specifically targeting women, particularly in Asian countries where male smoking prevalence is many times higher than female smoking rates [28].

A systematic review [29] of pharmacological and psychosocial interventions for reducing SHS exposure among pregnant women, was unable to make firm conclusions on the effectiveness of interventions on reducing SHS exposure due to design weaknesses in the included studies. This review will update the latter, whose search for evidence was in January 2013, although the inclusion criteria are narrower. The aim of this review is to identify and examine individual and household level interventions aimed at reducing the exposure of non-smoking pregnant women to SHS with a view to providing an evidence base for the development of best policy and practice globally. This review was informed by the PRISMA Statement [30] (see online supplement).

METHODS

The literature was systematically reviewed with inclusion criteria stipulated in advance. Studies were included if participants were non-smoking pregnant women who were the focus of any intervention (either targeted at them or their partner) to reduce their SHS exposure and/or encourage partner quitting. Interventions were broadly defined as engagement involving one or more of: counselling, motivational interviewing, awareness raising, educational feedback, and Nicotine Replacement Therapy (NRT). Included studies had to use randomised control, quasi-experimental or pre-/post-test designs, and contain reports of some indicator of the exposure of the pregnant women to SHS (through self-report, markers of SHS air concentrations, or biological markers such as salivary, urinary or serum cotinine) or recorded smoking quit rates among partners. No publication date or language restrictions were imposed. However, a *post hoc* decision was made at the full-text screening stage to exclude two non-English language papers that the team were unable to translate themselves. Both papers had been reviewed in another English-language systematic review [31].

MEDLINE, CINAHL, and EMBASE databases were searched from their dates of inception to October 11, 2017 with combinations of the following search terms: passive, indirect, secondhand, second hand, second-hand, environmental tobacco, smok*, SHS, ETS, partner, spouse, husband, father, dad, paternal, pregnant, woman, mother, pregnancy, maternal, antenatal, initiative, intervention, action, project, demonstration project, trial, pilot, reduc*, exposure, harm, risk. Details of the search strategy are provided in the online supplement. Searches were re-run on April 17, 2019 in MEDLINE, CINAHL, and Web of Science SCI-EXPANDED and SSCI databases from January 1, 2017 to date. Reference lists of systematic reviews were also checked for relevant articles [22, 29, 31-33]. Unpublished studies were

searched via theses.com and ethos.ac.uk, and experts in the field of smoking in pregnancy were contacted for unpublished work.

Initially, titles and abstracts were single-screened for relevance to the research objective, then full texts were downloaded to reference management software for assessment, with three authors checking the final list. A customised data extraction form was used to extract relevant information on study characteristics, sample, intervention, outcome measures, and results by one author. The extracted data were checked by a second author for errors or omissions.

Individual studies were assessed using the UK National Institute for Health & Care Excellence (NICE) recommended Quality Appraisal checklist [34] which rates components of internal and external validity for risk of bias. Assessments were made by one author and results checked by a second author for errors. Any disagreements were discussed until a consensus was reached. Risk of bias threshold was not an inclusion criteria; all studies were included in the narrative synthesis of results.

RESULTS

Figure 1 provides a PRISMA diagram depicting the flow of information through the different phases of the systematic review. Out of 1827 search hits and records identified through other sources, 267 abstracts were screened for relevance to the research objective after removal of irrelevant titles and duplicates. A total of 38 were then selected for full text screening.

Twenty-nine studies were then excluded: 15 as they were not carried out on a population that met the inclusion criteria; six due to study design or publication type; three had no relevant outcome measure; two did not satisfy the intervention type; two were excluded as the full texts were not available in English language; and one was a duplicate publication. Full details of excluded full-text papers and unmet criteria are provided in the online supplement. Nine individual studies were identified that met the inclusion criteria.

Table 1 (see online supplement) presents the main characteristics and summary results of the included studies [35-43]. There were two studies each from China [40,43], Taiwan [36-37], Iran [39,42], and the USA [38,41], with one study covering centres in both Argentina and Uruguay [35]. In terms of design, two studies [35,43] employed a cluster randomised controlled design while the remaining seven [36-42] were Randomised Controlled Trials (RCTs).

Seven of the studies [35-40,43] targeted the intervention solely at the pregnant women primarily through education materials, counselling or guidance around the health effects of SHS, and how to best avoid SHS exposure in the home or workplace. Two studies [41-42] involved both the pregnant woman and her smoking partner receiving intervention material.

The interventions delivered solely to the pregnant women typically involved advice on strategies on how to persuade other family members and/or partners on the benefits of a smoke-free home. This 'avoidance' advice seeks to help women to change their behaviour and move away from smokers, and avoid areas or rooms where smoking is taking place. Additional elements of such strategies involve empowering women to motivate their partners or other adults to create a smoke-free home or not to smoke around the woman. The interventions that involved the partner of the pregnant woman focussed on the benefits of smoking cessation [41] or changing the smoking behaviour of the man to reduce the SHS exposure of his pregnant partner [42].

All nine studies employed educational interventions using direct teaching or counselling, brochures, posters, role-play, and/or videos. One study [41] additionally offered Nicotine Replacement Therapy (NRT) to the pregnant woman's smoking partner. That intervention also offered participants a financial incentive for the smoking partner through biochemically validated abstinence. Six studies provided detail on the duration of the intervention and this ranged from the initial advice taking 2-3 minutes followed by reminders lasting about 90 seconds [40], through to much more intensive sessions lasting 15-20 minutes [39], 30-45 minutes [42], 36 +/- 15 minutes [38] or 50 minutes [36-37].

Methods of assessing intervention effectiveness were mixed, with outcome measures ranging from self-reported SHS exposure by the pregnant woman [35-38,42-43], the number of cigarettes smoked by their partner [39-40,42-43], and reports of their smoking cessation [40-41], through to biochemical markers of the pregnant woman's exposure to SHS through salivary cotinine [38] or hair nicotine [43]. Several studies used more than one outcome measure. Seven of the nine included studies recruited, or took baseline measures from,

women in the first trimester [36-37,39,42-43] and first or second trimester [40-41] of their pregnancy. For these studies, the longest follow-up measures that were taken after the intervention varied from 1 or 2 months later [36-37,42], to between 3 and 5 months later [39,40], to 6 months later [43] and birth [41]. The eighth study compared results taken in the second trimester, before the intervention, with results taken 2 months later during the third trimester of their pregnancy [38]. The study with the longest follow-up period in the nine included studies, compared women's recall of exposure to SHS during pregnancy collected after birth, with data collected 12-18 months after the baseline SHS exposure measures [35].

Interventions were primarily carried out in health care settings usually centred around the pregnant woman's visit to ante-natal care [35-40,43]. All of the interventions were face-to-face and delivered either in a one-to-one exchange [35-42] or in a group setting [37,43]. Three of the interventions involved follow-up telephone calls [36,41,43], one provided text messages [42], and five studies carried out in-person repeat or reminder sessions [38-41,43].

Where intervention theory models were provided these were: diffusion of innovation theory [35], expanded health belief model [36-37,39,42], the trans-theoretical model [38] or the social cognitive theory following the teachable moment model [41].

In terms of study quality only two papers [38,43] were considered to be at low risk of bias (internal validity), and only two [35, 43] were deemed to be generalizable to the source population (external validity). The assessment of study validity (both internal and external) is provided in Table 1 (see online supplement). Most of the studies did not report blinding or concealment of allocation and did not give much information about how and why the study

population was selected. Study-specific reasons for risk of bias are provided in the online supplement.

Seven of the included studies – six where the SHS intervention targeted pregnant women [36-40,43] and one that targeted partners who smoked [42] – reported effective interventions when compared to the control groups. (Two of these seven studies were rated as having high internal validity [38,43], three were rated as having potential sources of bias [36-37,40] and two as having poor internal validity [39,42], based on the descriptions of the study in the papers.) Only two of the included studies [35,41] reported no statistically significant difference between intervention and control group in the primary outcome measure. Of the ineffective SHS interventions, one was targeted at non-smoking pregnant women [35] (with the study's design rated as having poor internal validity) and the other at couples where the partner smoked [41] (with the study's design rated as having some potential sources of bias). It should be noted that the latter two studies had some of the longest time periods between intervention and follow-up, as described earlier.

DISCUSSION

This review shows that there is limited research evidence on how to protect non-smoking pregnant women from the known harmful effects of SHS exposure. Nine intervention studies were identified and while the studies spanned the globe from the USA, Argentina/Uruguay, Iran, Taiwan, and China there was a notable lack of published research from Europe, Australia, and sub-Saharan Africa.

The majority of SHS interventions identified in this review have targeted non-smoking pregnant women [35-40, 43], with very little work carried out to directly change the behaviours of smoking partners or other adults who smoke in the home or workplace of pregnant women [41-42]. From an exposure science perspective the concept of controlling harmful emissions at source is always preferable to introducing measures to reduce concentrations or personal exposures once the hazard is generated: applying this to pregnant women and SHS would see partners encouraged to quit smoking or, at a minimum, implement rules around having a smoke-free home.

The review demonstrates a lack of international agreement on how best to assess non-smoking pregnant women's exposure to SHS in RCTs. Outcome measures in the studies identified were highly variable and there is no standard research tool to assess pre- and post-intervention exposure. Self-report of exposure or of the number of cigarettes smoked by a partner are likely to be subject to considerable bias [44]. Objective measures such as salivary cotinine are expensive and involve time consuming laboratory analysis [45]. Intervention studies of smoke-free homes have utilised methods that combine the measure of airborne markers of SHS in the home with an educational intervention about the effect of smoking on household air quality [46-48], and this approach may be useful for future work on protecting non-smoking pregnant women from SHS.

The results of the review and the mixed evidence of effectiveness in terms of various intervention approaches demonstrate that there is no clear factor that evidently helps reduce pregnant women's exposure to SHS. Most interventions have used educational approaches delivered by health professionals in health care settings with a variety of messages and materials. Seven of the nine identified studies lay the responsibility for SHS

avoidance/reduction solely on the non-smoking pregnant woman at a time of life when she has many other concerns and responsibilities, and may not feel she is in a position to dictate behaviour change to her partner or other smoking adults around her. There is a need for educational approaches that are household or family centred involving all adults living with the non-smoking pregnant woman. Only one intervention has investigated [41] the provision of pharmacological support to smoking partners in the form of NRT, and only one (the same) intervention [41] considered the advantages of financial incentives for smoking partners to quit smoking. Future work is required to examine the potential effectiveness of NRT support (both for creating a smoke-free home and for cessation purposes) and/or financial incentives in helping to reduce the exposure of non-smoking pregnant women to SHS.

Evidence from this review suggests that educational approaches may be more effective when delivered in groups than individually. Counselling should be carried out by trained health professionals and early enough in pregnancy to achieve the desired effect of reduced risks of harm to foetus and pregnancy complications. The content of the educational message for pregnant women and their partners should be the creation of smoke-free homes and avoidance of SHS, emphasising that “there is no safe level of SHS exposure” [27]. It is also important for the woman to know that practices like opening windows do not solve the problem of SHS exposure [10] and that SHS can remain in the air for many hours after a cigarette is smoked [49]. Follow-up by phone, email or text message may also be useful to remind and encourage women to keep their homes smoke-free. Dherani et al. [32] comprehensively reviewed interventions targeted at men attempting to change their smoking behaviours where their pregnant partner was the agent of change, including some of the studies reviewed here, and found none met all the generalisability, feasibility, and scalability

criteria. These criteria are important to identify and understand what works and how, within intervention components.

Brown and colleagues' review [50] of interventions to create smoke-free homes in families with young children identified the need for approaches that are both tailored and targeted to specific populations and highlighted the need to target the social and psychodynamics of the family. A Cochrane review of family programmes for reducing children's exposure to SHS [51] recently reported that the scientific evidence around effective interventions was of low or very low quality and that the features of interventions that were effective were generally poorly understood. Recent work [52] has also identified that there is little understanding of the barriers and facilitators that fathers experience in creating a smoke-free home, and that there is a need for research to improve insight into fathers' roles in creating and maintaining a smoke-free home to protect their children and partners from SHS. A father or partner-inclusive rather than a purely mother-led intervention around SHS exposure is likely to benefit the entire household, improve gender equity, and change social norms.

Partners should be counselled to quit smoking or at least make the home smoke-free and supported in their attempts to provide a smoke-free living environment. The potential for accessible and affordable NRT to help with such changes in smoking behaviour should be studied. Multiple telephone follow-ups may be necessary to keep their motivation and address any barriers or hindrances. Interventions should be delivered directly to partners through the health professionals and not through pregnant women. Since it is common in some countries for partners to be present at the woman's first ultrasound or pregnancy booking appointment this opportunity may be useful to advise partners about cessation and offer pharmacological support.

The current review has focussed on interventions aimed at the individual or household level. Policy or population level approaches are also likely to play an important role in protecting non-smoking pregnant women from the harms of SHS. These include measures such as smoke-free public spaces which have been shown to be highly effective in reducing both the proportion of non-smoking adults exposed to SHS and the intensity of that exposure. Recent work [53] examining population salivary cotinine data in Scotland has shown that the proportion of adult non-smokers with measurable cotinine on any given day has reduced from nearly 88% in 1998 to less than 19% in 2016; and the concentration of cotinine in the saliva of the non-smoking population has reduced by over 97%. Policy measures to reduce general smoking prevalence through tools such as taxation, pricing, and plain packaging; smoke-free legislation to reduce the number of enclosed public spaces where non-smokers are exposed to SHS; and mass media campaigns to reduce the acceptability of smoking at home, have all played a role in these reductions. There is a need to test the potential effectiveness of population level mass media interventions centred round the societal responsibility to protect pregnant women from SHS. Further focus on such population level policies can help to drive down the exposure of pregnant women to SHS.

Strengths and limitations of the review

Strengths of the review are that it was designed to encompass global evidence, updating the previous reviews (although Chinese exclusions are acknowledged), to provide a simple, narrative summary of experimental studies of household and individual level interventions to reduce pregnant non-smokers' exposure to SHS. The review adds five further studies to an earlier review [29]. To ensure accuracy in the data, the review processes of data extraction and quality appraisals of included studies used peer-reviewed assessment tools and were

checked by a second reviewer. The review does have limitations, however. It was limited in its design by single-screening studies for relevance at the titles and abstracts screening stage making it possible that studies of relevant SHS interventions were missed from the synthesis. Risk of bias was not explicitly addressed in the synthesis. In addition, through the lack of universal translation resources, this review introduced a language bias towards Latin script languages, by excluding two studies available in Chinese full text only. This geographical and language bias is diminished by the recent English-language review by Zhang et al. [31] of interventions for reducing SHS exposure among pregnant women in China which included the two studies. Both studies observed non-smoking pregnant women: Gao et al. 2004 (as cited by [31]) was an RCT evaluation of an SHS educational intervention in the 1990s (education from doctors and brochures) with significant results in a positive direction reported using subjective measures of avoidance behaviour and reporting partners' smoking behaviours. Hu et al. 2011 (as cited by [31]) was a pre-test – post-test evaluation of an SHS educational intervention (using mass media, video, and role play) in 2011 with significant results in a positive direction reported using subjective measures of SHS exposure (self-efficacy of stopping others smoking). However as a secondary data source, it was impossible to assess from Zhang et al. [31] whether the studies would have passed the current review's full text screening criteria or not, or to assess the internal and external validity of the studies. It is unlikely, given the design of the latter study, as reported by [31], that it would have provided robust evidence, and the former has similar characteristics to other studies in the current review and is unlikely to have substantially altered the current review's findings.

There are limitations in the identified evidence. Owing to the substantial heterogeneity in SHS intervention types and exposure measures across the included studies, it was not possible to conduct a statistical synthesis. This made it difficult to draw instructive

conclusions on the effectiveness of individual and household level interventions aimed at reducing the exposure of non-smoking pregnant women to SHS. The review shared some inclusion criteria and overlapping objectives with three recent systematic reviews of second-hand smoke exposure and interventions among pregnant women, although they also included studies of pregnant women who were current smokers [29, 31-32], studies with no control groups [31,32] and studies that examined attitudes and intentions [30,31], or were restricted to studies from one country [32]. All concluded that the state of the current evidence base is found wanting.

CONCLUSIONS

Although smoking rates in pregnancy are declining in many countries [54], SHS exposure in pregnancy continues to be a problem, primarily due to exposure at home by smoking partners and other household members. This review shows that there is limited evidence of effective methods to reduce non-smoking pregnant women's exposure to SHS globally. There is a need for work to quantify the extent of the problem; consider where and when pregnant women are typically exposed to SHS; determine the source of the exposure; and identify novel approaches to ensure that all children are born without the disadvantages that can occur from being exposed to SHS *in utero*. Involving partners and wider society in the process of protecting pregnant women from the harms of SHS is likely to be key.

Funding

This work was conducted by C Nwosu as part of an internship at ASH London while studying for a Masters in Public Health at the University of Nottingham. K Angus was supported by funding she received from ASH London for conducting this work at the University of Stirling.

Declaration of Interests

None of the authors have any competing interests.

Acknowledgements

We would like to thank Dr Tessa Langley for overseeing the Masters in Public Health internship and Prof Linda Bauld for advice on key elements of the literature to examine in the review.

Contribution statement

CN and HC designed the systematic review; CN and KA ran searches and screened results; CN and KA extracted data and appraised quality; KA and SS second-checked review tasks; CN and SS synthesised data and drafted initial manuscript; KA created tables, figures and compiled supplementary data; all authors commented on and revised the manuscript.

REFERENCES

1. Shah NR, Bracken MB. A systematic review and meta-analysis of prospective studies on the association between maternal cigarette smoking and preterm delivery. *Am J Obstet Gynecol*. 2000;182(2):465–472.
2. DiFranza JR, Lew RA. Effect of maternal cigarette smoking on pregnancy complications and sudden infant death syndrome. *J Fam Pract*. 1995;40(4):385–394.
3. Hackshaw A, Rodeck C, Boniface S. Maternal smoking in pregnancy and birth defects: A systematic review based on 173 687 malformed cases and 11.7 million controls. *Hum Reprod Update*. 2011;17(5):589–604.
4. Marufu TC, Ahankari A, Coleman T, Lewis S. Maternal smoking and the risk of still birth: systematic review and meta-analysis. *BMC Public Health*. 2015;15(1):239. doi:10.1186/s12889-015-1552-5.
5. Shobeiri F, Jenabi E. Smoking and placenta previa: a meta-analysis. *J Matern Neonatal Med*. 2016;0(0):1–6.
6. U.S. Department of Health and Human Services. The Health Consequences of Smoking: A Report of the Surgeon General. *Natl Libr Med*. 2004;2012:51576.
7. Hoyt AT, Canfield MA, Romitti PA, et al. Does maternal exposure to secondhand tobacco smoke during pregnancy increase the risk for preterm or small-for-gestational age birth? *Matern Child Health J*. 2018;22(10):1418–1429.
8. Leonardi-Bee J, Smyth A, Britton J, Coleman T. Environmental tobacco smoke and fetal health: systematic review and meta-analysis. *Arch Dis Child Fetal Neonatal Ed*. 2008;93(5):F351–61.
9. Salmasi G, Grady R, Jones J, McDonald SD. Environmental tobacco smoke exposure and perinatal outcomes: a systematic review and meta-analyses. *Acta Obstet Gynecol Scand*. 2010;89(4):423–441.
10. Ashford KB, Hahn E, Hall L, Rayens MK, Noland M, Ferguson JE. The effects of prenatal secondhand smoke exposure on preterm birth and neonatal outcomes. *J Obstet Gynecol Neonatal Nurs*. 2010;39(5):525–535.
11. Leonardi-Bee J, Britton J, Venn A. Secondhand Smoke and Adverse Fetal Outcomes in Nonsmoking Pregnant Women: A Meta-analysis. *Pediatrics*. 2011;127(4):734–741.
12. Been JV, Mackay DF, Millett C, Pell JP, van Schayck OC, Sheikh A. Impact of smoke-free legislation on perinatal and infant mortality: a national quasi-experimental study. *Sci Rep*. 2015;5: 13020. doi:10.1038/srep13020.
13. Mackay DF, Nelson SM, Haw SJ, Pell JP. Impact of Scotland's smoke-free legislation on pregnancy complications: retrospective cohort study. *PLoS Med*. 2012;9(3):e1001175. doi: 10.1371/journal.pmed.1001175.
14. Lambers DS, Clark KE. The maternal and fetal physiologic effects of nicotine. *Semin Perinatol*. 1996;20(2):115–126.
15. Wickstrom R. Effects of Nicotine During Pregnancy: Human and Experimental

Evidence. *Curr Neuropsychopharmacol*. 2007;5(3):213–222.

16. Son JY, Lee HJ, Koutrakis P, Bell ML. Pregnancy and lifetime exposure to fine particulate matter and infant mortality in Massachusetts, 2001–2007. *Am J Epidemiol*. 2017;186(11):1268–1276.
17. Hehua Z, Qing C, Shanyan G, Qijun W, Yuhong Z. The impact of prenatal exposure to air pollution on childhood wheezing and asthma: A systematic review. *Environ Res*. 2017;159:519–530.
18. Pedersen M, Stayner L, Slama R, et al. Ambient air pollution and pregnancy-induced hypertensive disorders: a systematic review and meta-analysis. *Hypertension*. 2014;64(3):494–500.
19. Amegah AK, Quansah R, Jaakkola JJ. Household air pollution from solid fuel use and risk of adverse pregnancy outcomes: a systematic review and meta-analysis of the empirical evidence. *PLoS One*. 2014;9(12):e113920. doi:10.1371/journal.pone.0113920.
20. Fitzpatrick KE, Gray R, Quigley MA. Women’s longitudinal patterns of smoking during the pre-conception, pregnancy and postnatal period: Evidence from the UK infant feeding survey. *PLoS One*. 2016;11(4): e0153447. doi:10.1371/journal.pone.0153447.
21. Harmer C, Memon A. Factors associated with smoking relapse in the postpartum period: An analysis of the child health surveillance system data in Southeast England. *Nicotine Tob Res*. 2013;15(5):904–909.
22. Hemsing N, O’Leary R, Chan K, Okoli C, Greaves L. *Interventions to Improve Partner Support and Partner Cessation during Pregnancy*. NICE Rapid Review, 2009. <https://www.nice.org.uk/guidance/ph26/evidence/interventions-to-improve-partner-support-and-partner-cessation-during-pregnancy-pdf-376423165>. Accessed August 28, 2018.
23. Jones LL, Atkinson O, Longman J, Coleman T, McNeill A, Lewis SA. The motivators and barriers to a smoke-free home among disadvantaged caregivers: identifying the positive levers for change. *Nicotine Tob Res*. 2011;13(6):479–486.
24. Government Statistical Service. *Statistics on Smoking England: 2017*. NHS Digital; 2017.
25. Global Health Observatory data repository. Second-hand Smoke Exposure - Data by region 2004. WHO website. <https://apps.who.int/gho/data/node.main.159?lang=en>. Accessed October 30, 2017.
26. Reece S, Morgan C, Parascandola M, Siddiqi K. Secondhand smoke exposure during pregnancy: a cross-sectional analysis of data from Demographic and Health Survey from 30 low-income and middle-income countries. *Tob Control*. 2019;28(4):420–426.
27. World Health Organization. *WHO recommendations for the prevention and management of tobacco use and second-hand smoke exposure in pregnancy*. Geneva: WHO; 2013.
28. Semple S, Abidin E, Amos A, et al. The Kuala Lumpur Charter on Smoke-Free Homes. *Blog Tobacco Control*. 2018. Available at: <https://blogs.bmj.com/tc/2018/06/25/the-kuala-lumpur-charter-on-smoke-free-homes>.

Accessed April 10, 2019.

29. Tong VT, Dietz PM, Rolle IV, et al. Clinical interventions to reduce secondhand smoke exposure among pregnant women: a systematic review. *Tob Control*. 2015;24(3):217–223.
30. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med* 6(7): e1000097. doi:10.1371/journal.pmed1000097.
31. Zhang LL, Bi Z, Liu H, Li X, Stanton B. Exposure to secondhand tobacco smoke and interventions among pregnant women in China: a systematic review. *Prev Chronic Dis*. 2015;12:140377. doi:10.5888/pcd12.140377.
32. Dherani M, Zehra SN, Jackson C, et al. Behaviour change interventions to reduce second-hand smoke exposure at home in pregnant women - a systematic review and intervention appraisal. *BMC Pregnancy Childbirth*. 2017;17:378. doi:10.1186/s12884-017-1562-7.
33. Duckworth AL, Azulay Chertok IR. Review of perinatal partner-focused smoking cessation interventions. *MCN Am J Matern Nurs*. 2012;37(3):174–181.
34. National Institute for Health and Care Excellence. *Methods for the development of NICE public health guidance*. 3rd ed. NICE; 2012.
35. Alemán A, Morello P, Colomar M, et al. Brief counseling on secondhand smoke exposure in pregnant women in Argentina and Uruguay. *Int J Environ Res Public Health*. 2017;14(1):28. doi:10.3390/ijerph14010028.
36. Chi Y-C, Wu C-L, Chen C-Y, Lyu S-Y, Lo F-E, Morisky DE. Randomized trial of a secondhand smoke exposure reduction intervention among hospital-based pregnant women. *Addict Behav*. 2015;41:117–123.
37. Chi Y-C, Sha F, Yip PSF, Chen J-L, Chen Y-Y. Randomized comparison of group versus individual educational interventions for pregnant women to reduce their secondhand smoke exposure. *Medicine (Baltimore)*. 2016;95(40):e5072. doi:10.1097/MD.0000000000005072.
38. El-Mohandes AA, Kiely M, Blake SM, Gantz MG, El-Khorazaty MN. An intervention to reduce environmental tobacco smoke exposure improves pregnancy outcomes. *Pediatrics*. 2010;125(4):721–728.
39. Kazemi A, Ehsanpour S, Nekoei-Zahraei NS. A randomized trial to promote health belief and to reduce environmental tobacco smoke exposure in pregnant women. *Health Educ Res*. 2012;27(1):151–159.
40. Loke AY, Lam TH. A randomized controlled trial of the simple advice given by obstetricians in Guangzhou, China, to non-smoking pregnant women to help their husbands quit smoking. *Patient Educ Couns*. 2005;59(1):31–37.
41. Pollak KI, Lyna P, Bilheimer AK, et al. Efficacy of a couple-based randomized controlled trial to help Latino fathers quit smoking during pregnancy and postpartum: the Parejas trial. *Cancer Epidemiol Biomarkers Prev*. 2015;24(2):379–385.
42. Sahebi Z, Kazemi A, Loripour M, Shams N. An educational intervention to men for reducing environmental tobacco smoke exposure in their pregnant wives. *J Matern*

Fetal Neonatal Med. 2019;32(10):1595-1601.

43. Yang L, Tong EK, Mao Z, Hu T, Lee AH. A Clustered Randomized Controlled Trial to Reduce Secondhand Smoke Exposure Among Nonsmoking Pregnant Women in Sichuan Province, China. *Nicotine Tob Res.* 2015;18(5):1163–1170.
44. Liber AC, Warner KE. Has Underreporting of Cigarette Consumption Changed Over Time? Estimates Derived From US National Health Surveillance Systems Between 1965 and 2015. *Am J Epidemiol.* 2018;187:113–119.
45. Lidón-Moyano C, Fu M, Perez-Ortuño R, et al. Assessment of salivary cotinine concentration among general non-smokers population: Before and after Spanish smoking legislations. *Cancer Epidemiol.* 2017;51:87–91.
46. Wilson I, Semple S, Mills LM, et al. REFRESH--reducing families' exposure to secondhand smoke in the home: a feasibility study. *Tob Control.* 2013;22(5):e8. doi:10.1136/tobaccocontrol-2011-050212.
47. Hovell MF, Bellettiere J, Liles S, et al. Randomised controlled trial of real-time feedback and brief coaching to reduce indoor smoking. *Tob Control.* 2019 Feb 15. doi:10.1136/tobaccocontrol-2018-054717.
48. Semple S, Turner S, O'Donnell R, et al. Using air-quality feedback to encourage disadvantaged parents to create a smoke-free home: Results from a randomised controlled trial. *Environ Int.* 2018;120:104–110.
49. Semple S, Latif N. How long does secondhand smoke remain in household air: analysis of PM2.5 data from smokers' homes. *Nicotine Tob Res.* 2014;16(10):1365–1370.
50. Brown N, Luckett T, Davidson PM, Di Giacomo M. Interventions to reduce harm from smoking with families in infancy and early childhood: a systematic review. *Int J Environ Res Public Health.* 2015;12(3):3091–3119. doi:10.3390/ijerph120303091.
51. Behbod B, Sharma M, Baxi R, Roseby R, Webster P. Family and carer smoking control programmes for reducing children's exposure to environmental tobacco smoke. *Cochrane Database Syst Rev.* 2018;1:CD001746. doi:10.1002/14651858.CD001746.pub4.
52. O'Donnell R, Angus K, McCulloch P, Amos A, Greaves L, Semple S. Fathers' views and experiences of creating a smoke-free home: A scoping review. *Int J Environ Res Public Health.* 2019;16(24):E5164. doi:10.3390/ijerph16245164.
53. Semple S, Mueller W, Leyland AH, Gray L, Cherrie JW. Assessing progress in protecting non-smokers from secondhand smoke. *Tob Control.* 2019;28(6):692–695.
54. *WHO global report on trends in prevalence of tobacco use 2000-2025.* 3rd ed. Geneva: World Health Organization; 2019. <https://www.who.int/publications-detail/who-global-report-on-trends-in-prevalence-of-tobacco-use-2000-2025-third-edition>. Accessed December 18, 2019.

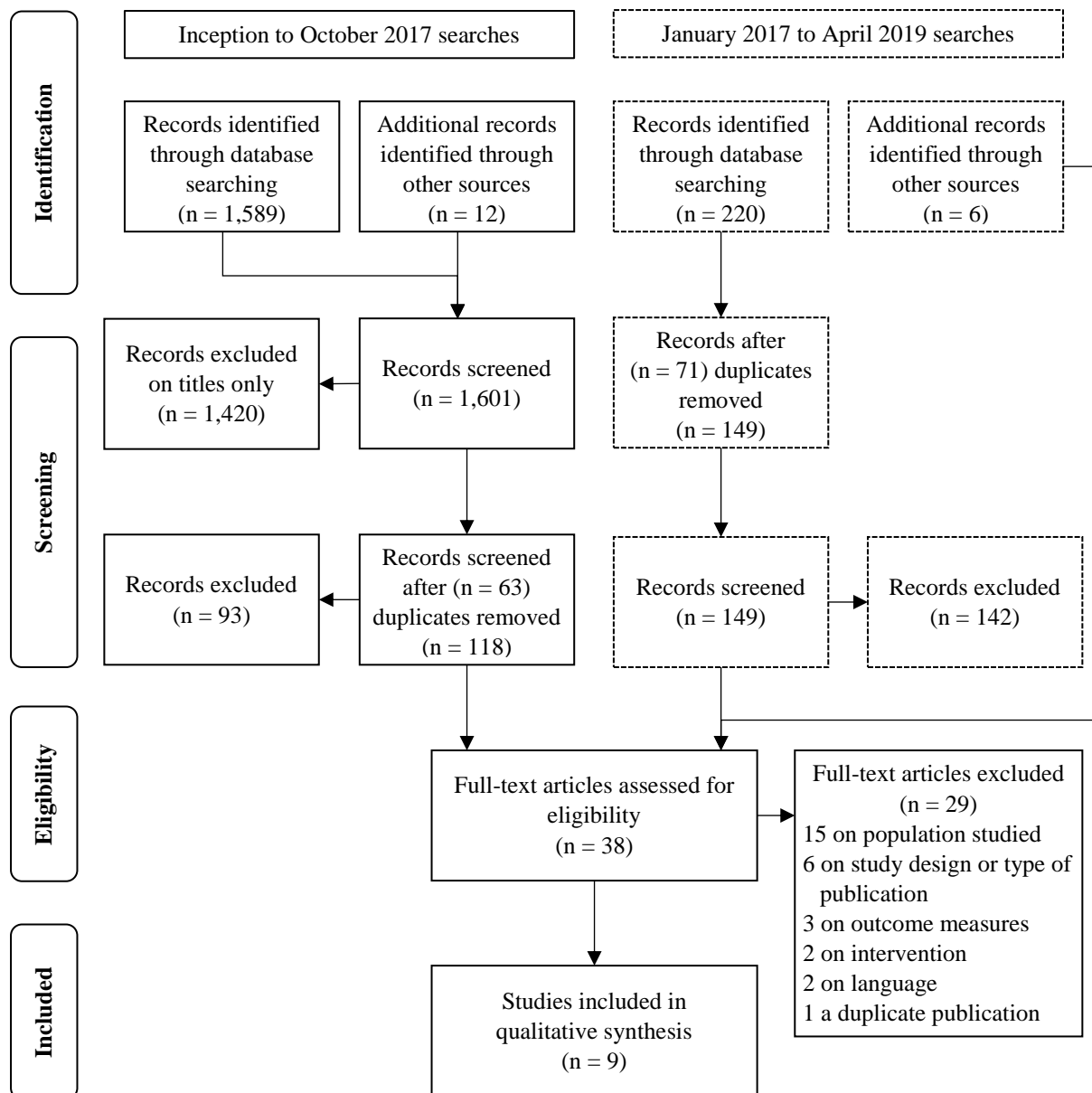


Figure 1: Flow of information through the phases of the systematic review