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REVIEW ARTICLE

Environmental change interventions to prevent unintentional home injuries among children in low- and middle-income countries: A systematic review and meta-analysis

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Abstract

Introduction: Unintentional home injury is an important cause of death and disability among children, especially those living in low- and middle-income countries (LMICs). This systematic review aimed to synthesize evidence about the effectiveness of environmental interventions to prevent unintentional child injury and/or reduce injury hazards in the home in LMICs.

Methods: Seven electronic databases were searched for randomized controlled trials (RCTs) and controlled before and after (CBA) studies published up to 1 April 2018. Potentially eligible citations were screened by title and abstract and full texts of studies obtained. Synthesis was reported narratively, and where possible, meta-analysis was conducted.

Results: Four studies met the inclusion criteria: One CBA study reported changes in injury incidence, and three RCTs reported changes in frequency of home hazards. In one study, child resistant containers were found effective in reducing the incidence of paraffin ingestion by 47% during and by 50% postintervention. A meta-analysis of two trials found that home inspection, safety education and safety devices reduced postintervention mean scores for poisoning hazards [mean difference (MD) −0.77; 95% CI [−1.36, −0.19]] and burn-related unsafe practices (MD −0.37; 95% CI [−0.66, −0.09]) but not for falls or electrical and paraffin burn hazards. A single trial found that home inspection and safety education reduced the postintervention mean scores for fall hazards (MD −0.5; 95% CI [−0.66, −0.33]) but not for ingestion hazards.

Conclusion: There is limited evidence that environmental change interventions reduce child injuries but evidence that they reduce some home hazards. More evidence is needed to determine if altering the physical home environment by removing potential hazards reduces injuries in LMICs.

KEYWORDS

child injury, environmental change, home hazards, LMICs, systematic review

1 | INTRODUCTION

Worldwide, unintentional injuries are responsible for more than 830,000 deaths among children under 18 years annually. More than 95% of these deaths occur in low- and middle-income countries (LMICs) (Peden et al., 2008; World Health Organisation, 2014). Most injuries among young children occur in the home environment (Fatmi et al., 2009; Halawa, Barakat, Rizk, & Moawad, 2015; Hyder et al., 2009; Hyder, Wali, Fishman, & Schenk, 2008) and are associated with the developmental characteristics of the child, socio-economic factors of the family and the physical home environment (Munro, Van Niekerk, & Seedat, 2006). Low-income communities are more likely to live in environments where there are greater numbers of injury hazards (Peden et al., 2008; Peden, McGee, & Sharma, 2002). These include poor housing infrastructure, lack of barriers to cooking or washing areas, open fires, paraffin stoves, lack of safe storage for harmful substances, unprotected balconies and open water reservoirs (Balan & Lingam, 2012; Hyder et al., 2008).

In high-income countries (HICs), the efficacy of home interventions to reduce injuries, injury hazards or to increase use of safety equipment or safety practices has been well explored (Hubbard et al., 2015; Kendrick et al., 2000; Kendrick et al., 2013; Sznajder et al., 2003; Watson et al., 2005). Education with the provision of safety equipment is effective in promoting safe storage of poisoning hazards (Achana et al., 2015; Kendrick et al., 2017) and using education, with or without the provision and/or fitting of safety equipment and home safety inspection, was effective in promoting the use of safety gates (Hubbard et al., 2015; Kendrick, Young, et al., 2013) and safe hot tap water (Kendrick et al., 2017). However, there is insufficient evidence to demonstrate that interventions to modify the physical home environment reduce the number of home injuries (Turner et al., 2011). Single component interventions, such as education to reduce baby walker use, may reduce injury risks (Hubbard et al., 2015; Watson & Errington, 2016), and interventions in HICs appear to increase the likelihood that safety devices are used or safety practices promoted (Kendrick et al., 2013; Kendrick et al., 2017; Kendrick, Young, et al., 2013), though multifaceted interventions are more likely to be successful in reducing injuries in the home (Achana et al., 2015; Morrongiello, Ondejko, & Littlejohn, 2004).

It is not known whether similar interventions reduce the incidence of childhood injuries in LMICs where housing conditions, family characteristics, living arrangements and cultural practices are very different to HICs. Therefore, this systematic review aimed to identify and critically appraise evidence of the effectiveness of environmental change interventions that prevent unintentional child injury and reduce injury hazards in the home in LMICs.

Key messages

- Unintentional injuries in and around the home are an important cause of healthcare use and potentially death and disability among children. The burden of such injuries is highest in LMICs.
- There is limited evidence from LMICs that environmental change interventions reduce child injuries, but a meta-analysis indicated some evidence that they reduce home hazards.
- This review provides the evidence to argue for the further development and evaluation of environmental change interventions for injury reduction in LMICs.
- More evidence is needed to determine if altering the physical home environment by removing potential hazards reduces child injuries in the home in LMICs.

2 | METHODS

The review was completed according to a predefined protocol, developed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher, Liberati, Tetzlaff, Altman & the PRISMA Group, 2009) and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2011).

2.1 | Study eligibility

Studies suitable for inclusion met all the following criteria:

Population: recipients of interventions living in LMICs.
Intervention: any environmental change intervention to reduce injury and/or injury hazard for children under 18 years of age, including home visits to undertake hazard risk assessments, safety education and provision/and installation of safety devices.
Comparison: participants or settings who did not receive the environmental change interventions.
Outcome: number of children with unintentional home injuries and/or number of child injury hazards present in the home environment.
Study design: experimental designs [randomized controlled trials (RCTs), quasi-experimental designs] including controlled before and after (CBA) studies.
Exclusion criteria: studies were excluded if they only reported intentional injury outcomes, were from countries not classified as LMICs by the World Bank (World Bank, 2016), did not include a home environment change/modification, were non-intervention studies or without a control group, were focused only on adult categories or did not measure child injuries or hazards.

2.2 | Search strategy and keywords

A search was performed for eligible studies in MEDLINE (Ovid), EMBASE (Ovid), Cumulative Index to Nursing and Allied Health

Literature (CINAHL Plus) via EBSCO, Psych INFO (EBSCO), Applied Social Sciences Index and Abstracts (ASSIA) via ProQuest and SafetyLit (www.safetylit.org). Free text and thesaurus words were combined for the concepts of 'home, 'injury' and 'child' together with a LMIC filter developed by Cochrane Effective Practice and Organisation of Care Group (http://epoc.cochrane.org/lmic-filters). Searches were not restricted by language, publication date or publication status. Searches were conducted in March 2014 and updated in April 2018. Reference lists of included studies and of relevant reviews were searched, and corresponding authors of all included studies were contacted. The full MEDLINE (Ovid) search strategy is presented in the appendix (Appendix A).

2.3 | Study selection and data extraction

Identified studies were imported into RefWorks (bibliographic management software) and duplicates removed. Potentially eligible studies were screened against inclusion/exclusion criteria by reading titles and abstracts by one reviewer (SB). Full texts of the remaining studies were retrieved, and further ineligible studies are excluded. Eligibility of included studies was agreed by all authors, and queries are resolved through discussion.

A data extraction form was prepared by SB, in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2011), and pilot–tested by TD and JM, following which amendments were made. All data were extracted by SB using the finalized form and checked by TD and JM, independently. Any disagreements in the extracted data were resolved through discussion.

2.4 | Assessment of risk of bias

Risk of bias in included studies was assessed using the appropriate tool based on study design. For CBA studies, the Effective Practice and Organization of Care (EPOC) tool for assessing risk of bias was used (Mowatt, Grimshaw, Davis, & Mazmanian, 2001). The Cochrane Collaboration risk of bias tool was used for RCTs (Higgins et al., 2011). The response for each criterion was reported as low risk, high risk or unclear risk of bias.

2.5 | Data synthesis and statistical analysis

Meta-analysis was undertaken using Cochrane Collaboration Review Manager 5.3.5 software (RevMan 5.3.5, 2014) where two or more studies were sufficiently homogenous in terms of study design, participants, interventions and outcomes. Calculations were based on postintervention mean scores for the number of injury hazards in the intervention and control groups. The mean difference (MD) in scores was used as the effect measure for estimated continuous summary data. Assuming a degree of heterogeneity with respect to study design and implementation, a random-effects model was applied (Hedges & Vevea, 1998); 95% confidence intervals (CIs) were calculated and the test for overall effect was performed. P- values of <0.05 were regarded as statistically significant. Heterogeneity of the trials was assessed through visual inspection of forest plots and calculation of the I^2 statistic. A 50% limit was used to indicate substantial heterogeneity (Higgins et al., 2011) and reasons for statistical variation, if results exceeded this limit, were explored. No sensitivity analyses were performed due to the small number of included studies. Outcomes unsuitable for combining through meta-analysis were synthesized narratively (Popay et al., 2006).

3 | RESULTS

3.1 | Identification of studies

A total of 9,630 records were identified through the electronic database searches with 6,970 records remaining after duplicates were removed (Figure 1). No additional studies were found from other sources. 6,855 records were excluded after reading the titles and a further 96 records after reading the abstracts. If abstracts met two or more inclusion criteria, they were retained for full text screening. Nineteen full text articles were assessed, 15 of which were excluded (Appendix 2012). Four records that met all the inclusion criteria remained.

3.2 | Participants and study characteristics

Of the four studies, one was a CBA study (Krug, Ellis, Hay, Mokgabudi, & Robertson, 1994), reported the primary outcome, injury incidence. One cluster RCT (Swart, van Niekerk, Seedat, & Jordaan, 2008) and two individually randomised RCTs (Odendaal, van Niekerk, Jordaan, & Seedat, 2009; Rehmani & LeBlanc, 2010) reported only the secondary outcome, the number of injury hazards. All included studies were conducted in LMICs: one study in Pakistan (Rehmani & LeBlanc, 2010) and the other three in South Africa. The CBA study did not report the number of participants (Krug et al., 1994). A total of 961 households were included across three RCTs (Odendaal et al., 2009; Rehmani & LeBlanc, 2010; Swart et al., 2008). The participants were families with children ≤10 (Odendaal et al., 2009; Swart et al., 2008), <5 (Krug et al., 1994) and ≤ 3 years old (Rehmani & LeBlanc, 2010). Duration of the CBA study was 28 months (14 months during the intervention and 14 months follow-up). The postintervention follow-up period in the single RCT (Rehmani & LeBlanc, 2010) was longer (6 months) than the other RCTs: 4 (Swart et al., 2008) and 3 months (Odendaal et al., 2009).

In the CBA study (Krug et al., 1994), the intervention included the distribution of child-resistant containers and health education about paraffin poisoning prevention, without a home inspection for hazards. All three RCTs combined home inspection for hazards

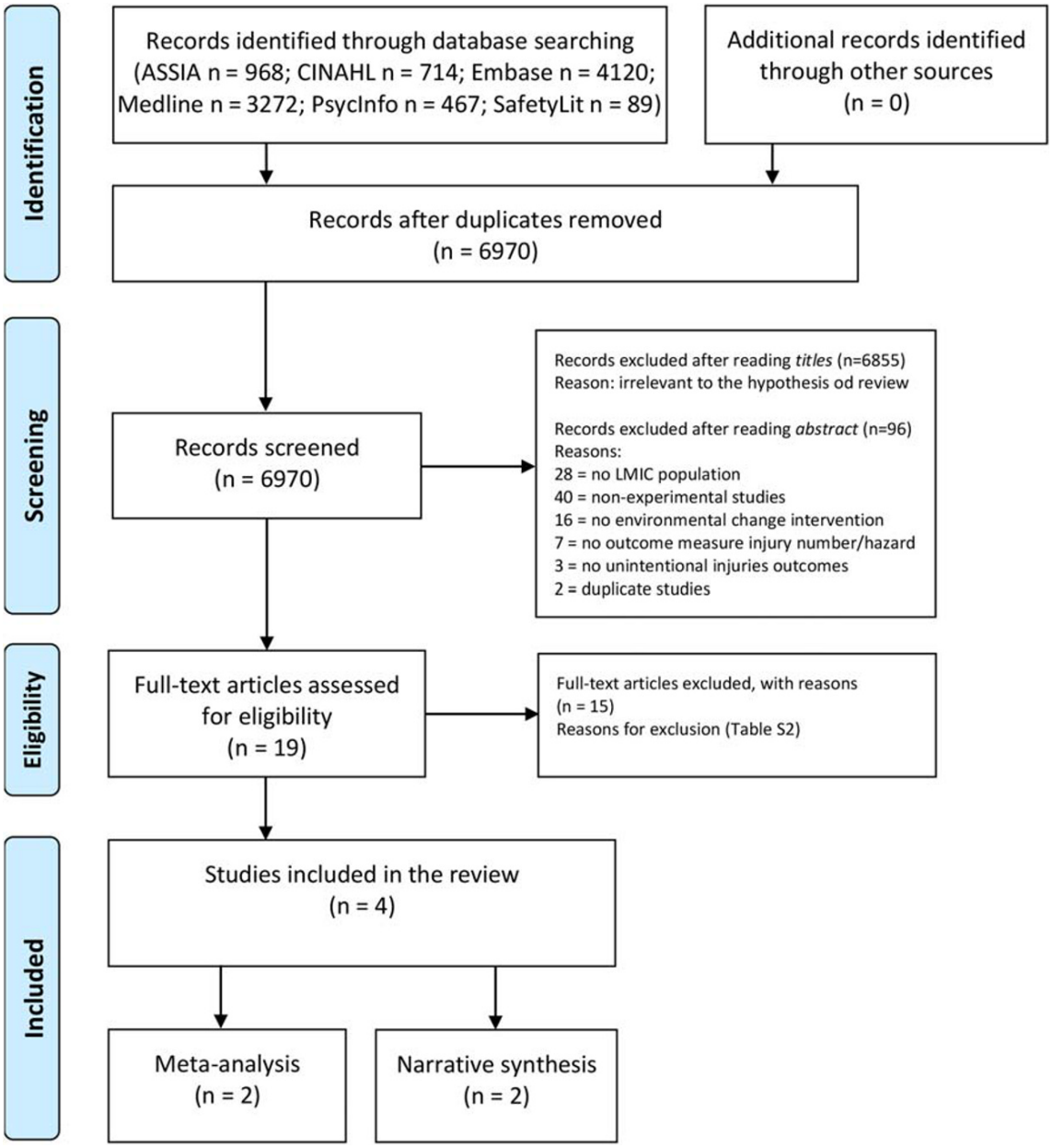

FIGURE 1 Flow diagram of study selection [Colour figure can be viewed at wileyonlinelibrary.com]

with safety education (Odendaal et al., 2009; Rehmani & LeBlanc, 2010; Swart et al., 2008). In each RCT, home inspection for hazards was conducted by trained community workers using a standardized instrument consisting of several items that related to each hazard. Two RCTs collected data on burns, poisoning and fall hazards (Odendaal et al., 2009; Swart et al., 2008), and one RCT collected data on ingestion hazards (poisoning and choking) and fall hazards (Rehmani & LeBlanc, 2010). Home visitors collected the data and then provided caregivers with information about safety practices and discussed possible changes to reduce risks for child injury. In two RCTs (Odendaal et al., 2009; Swart et al., 2008), caregivers were also given free or discounted safety devices, such as child-proof locks, paraffin containers with safety caps, a bag and hook for safe storage of poisonous substances (see detail in Table 1).

3.3 | Risk of bias in the included studies

The CBA study was considered to have a high risk of performance bias, detection bias and attrition bias due to the lack of reporting of blinding of participants, personnel and outcome assessors and incomplete outcome data (Krug et al., 1994) (Appendix C). The two RCTs included in the meta-analysis were of robust quality except that neither clearly reported blinding of participants or personnel (Odendaal et al., 2009; Swart et al., 2008). The outcome assessors

TABLE 1 Characteristics of studies that are included in the systematic review

Authors (year)	Methods	Participants	Intervention	No. per arm	Outcomes and follow-up period
(Krug et al., 1994)	CBA Settings = Western Transvaal in Bophuthatswana, South Africa	Population = Any household living in study area (Gelukspan district) and control areas (Lehurutshe district) Parent's age = Not specified Parent's sex = Not specified Exclusion = Not specified Sample size calculation = Not specified Required sample size = Not specified Approached HHs = Not specified Eligible HHs = Not specified	Safety education and safety devices I = Specifically designed child-resistant container (CRC) was introduced to evaluate whether its use would decrease the incidence of paraffin ingestion. CRCs were distributed to 20,000 households (both households with and without small children) C = No CRCs were distributed Health education about paraffin poisoning prevention was given to the HHs of both control and the study areas.	I = Not reported C = Not reported	Injury cases = Incidence rate of paraffin ingestion per 100,000 population Injury hazards = Not reported. Measured for 14 months for preintervention and for 14 months for postintervention.
(Swart et al., 2008)	RCT (cluster) Settings = Low-income communities in South Africa	Population = Households with children ≤10 years. Parent's age = Average of 34 years Parent's sex = Male and female Exclusion = Not specified Sample size calculation = Yes Required sample size = 120 HHs per arm (80% power and 5% significance level with 1.2 cluster design inflation factor) Approached HHS = 731 Eligible HHs = 515	Home inspection, safety education and safety devices I = Trained home visitors provided caregivers with information on safety practices, completed an injury hazard checklist with the caregiver (the presence/absence of household hazards generated scores for burns, poisoning and falls hazards). Possible changes to reduce risks associated with burns, poisoning and falls injuries were discussed. Caregivers were also given safety devices, such as child-proof locks and paraffin container safety caps, along with demonstrations on how they should be used. C = Not visited. Were given safety devices after the injury risk postassessment.	Randomized I = 202 HHs C = 208 HHs Completed I = 189 HHs C = 188 HHs 92% follow-up	Injury cases = Not reported Injury hazards = Number of household hazards for -burns (safety practices, paraffin and electrical), -poisoning -falls injury Measured at 4 months.
(Odendaal et al., 2009)	RCT (individual) Settings = Low-income neighbourhood in South Africa	Population = Households with children ≤10 years. Parent's age = Not specified Parent's sex = male and female Exclusion = Not specified Sample size calculation = Yes	Home inspection, safety education and safety devices. I = Intervention by trained paraprofessionals included educational inputs (sharing information and printed materials on household hazards to caregivers), enforcement	Randomized I = 112 HHs C = 99 HHs Completed I = 112 HHs C = 91 HHs 91% follow-up	Injury cases = Not reported Injury hazards = Number of household hazards for -burns (safety practices, paraffin and electrical) -poisoning -falls injury Measured at 3 months.

(Continues)

TABLE 1 (Continued)

Authors (year)	Methods	Participants	Intervention	No. per arm	Outcomes and follow-up period
		Required sample size = 120 HHs per arm (80% power and 5% significance level) Approached HHs = 265 Eligible HHs = 211	(completing the checklist on household hazards inducing self-initiated behavioural and home environment changes, the presence/absence of household hazards generated scores for burns, poisoning and falls hazards.) and engineering (distribution of free safety devices such as insulation tape, safety nails, plastic container with childproof cap and warning label, a bag and hook, along with demonstration of their use). C = Received a courtesy visit after the postintervention assessment and were given the same information as intervention group and at least one of the safety devices.		
(Rehmani & LeBlanc, 2010)	RCT (individual) Settings = Urban area within 45-min driving distance from the Aga Khan University Hospital (AKUH), Karachi, Pakistan	Population = Household with children ≤3 years old discharged home from the ED following a visit for any reason other than an injury Parent's age = Average of 30 years Parent's sex = Male and female Exclusion = Household with those children who presented with an injury were excluded. Sample size calculation = Yes Required sample size = 142 HHs per arm (80% power and 5% significance level) Approached HHs = 414 Eligible HHs = 370	Home inspection and safety education Research assistants administered the questionnaire after which s/he inspected the home for hazards in the presence of the family. The presence/absence of household hazards generated scores for ingestion and falls hazards. The family was then assigned to either the falls (Group 1) or poisoning/ingestion (Group 2) intervention branches of the study. I1 = Parents received falls safety and prevention counselling only; I2 = Parents received ingestion safety and prevention counselling. Each intervention group acted as a control for another intervention group.	Randomized I1 = 170 HHs I2 = 170 HHs Completed I1 = 153 HHs I2 = 151 HHs 90% follow-up	Injury cases = Not reported Injury hazards = Number of household hazards for -ingestion (poisoning and choking) -falls injury Measured at 6 months.

Note. CBA, control before and after; C, control group; I, intervention group; NA, not applicable; RCT, randomized controlled trial.

were not blinded in the third RCT (Rehmani & LeBlanc, 2010), and therefore, this RCT was judged to have had a high risk of detection bias (Appendix D).

3.4 | Effect of home environmental change interventions

The effect of the interventions on the reported outcomes is presented in Table 2.

3.4.1 | Injury cases

Poisoning incidence

The CBA study was the only one to report the primary outcome, the number of injuries (Krug et al., 1994). The multicomponent paraffin ingestion prevention intervention resulted in a reduction in the incidence of paraffin ingestion by 47% (p = 0.022) in the study area where child resistant containers were distributed. There was a statistically significant difference (p = 0.015) in the incidence rate of paraffin ingestion in the study area (mean incidence rate = 4.54,

TABLE 2 Results of included studies

Study ID	Intervention	Results
(Krug et al., 1994)	Safety education and safety devices	The mean monthly incidence rate of paraffin ingestion in the study area during the preintervention period (14 months) was 8.63 (SD 4.87), and during the intervention period (14 months) was 4.54 (SD 3.46). Incidence of paraffin ingestion dropped by 47% in the study area during the intervention period (p = 0.022). During the preintervention period, the incidence rate in the intervention area was not statistically significantly different from those in the control area: The mean incidence rate was 8.63 (SD 4.87) for intervention versus 7.94 (SD 4.26) for the control area. After the CRC distribution, the incidence rates in the study area were less than half those in the control area (mean 4.54 ± 3.46 vs. 9.80 ± 5.63), respectively (p = 0.015).
(Swart et al., 2008)	Home inspection, safety education and safety devices	Results for postintervention, mean scores for intervention and control households: For total household hazards, intervention households reported a lower total injury risk mean score of 13.9 (SE 0.53) than the control households 14.2 (SE 0.54), but the intervention effect (IE) of −0.31 was not statistically significant (95% CI [−1.18, 1.2], p = 0.68). Statistically significant changes were observed for burns related to unsafe practices (IE = −0.41, 95% CI [−0.76, −0.07], p = 0.02). No significant differences were noted for the injury risks related to electrical burns (IE = −0.19, 95% CI [−0.54, 0.16]), paraffin burns (IE = −0.03, 95% CI [−0.64, −0.57]) and poison ingestion (IE = − 0.45, 95% CI [−1.01, 0.11]). No decline was observed in mean scores for fall-related risks (IE = 0.09, 95% CI [−0.60, 0.78]).
(Odendaal et al., 2009)	Home inspection, safety education and safety devices	Results for postintervention mean scores for intervention and control households: For total household hazards, intervention households had a lower total injury risk mean score of 20.3 (SE) than the control households 23.9 (SE), and the IE of −3.64 was statistically significant (95% CI [−6.16, −1.12], p < 0.05). A significant difference was noted in the hazards associated with electrical burns (IE = 0.93, 95% CI [−1.70, −0.15], p = 0.02), paraffin appliances (IE = 0.71, 95% CI [−1.37, −0.04], p = 0.037), as well as in hazards related to poisoning (IE = 1.10, 95% CI [−1.77, −0.44], p < 0.05). Significant reduction was observed for total burns hazards (IE = 1.9, 95% CI [−3.41, −0.35], p = 0.01). No significant changes were observed for burn safety household practices (IE = 0.25, 95% CI [−0.80, 0.31]). Similarly, no significant changes in fall injury hazards (IE = 0.65, 95% CI [−1.47, 0.16]).
(Rehmani & LeBlanc, 2010)	Home inspection and safety education	The mean number of fall hazards was reduced from 3.1 (SD 0.7) at baseline to 2.4 (SD 0.8) in the fall intervention counselling group, and the mean number of ingestion hazards decreased from 2.3 (SD 1.2) to 1.9 (SD 1.3). There was a significant reduction in both hazards (p < 0.001). For fall related hazards, a significant difference was observed at postintervention between the intervention and control households (IE = −0.5, 95% CI [−0.66, −0.33], p < 0.001). However, there was no significant difference in ingestion hazards (IE = −0.1, 95% CI [−0.36, 0.16], p = 0.45). The percentage of homes deemed 'safe' (no injury hazards at follow-up) in which the families had received fall intervention counselling was 13.5% (19 homes became safe out of 141 unsafe) compared with 3.5% (5 out of 142) in the control group (RR 3.8, 95% CI [1.5, 10.0], p = 0.002). The percentage of homes deemed 'safe' in which the families had received the ingestions intervention counselling was 18.8% (24 homes became safe out of 128 unsafe) compared with 2.4% (3 out of 125) in the control group (RR 7.8, 95% CI [2.4, 25.3], p < 0.001).

Note. C, control group; IE, intervention effect; I, intervention group; n = number of households; SD, standard deviation; SE, standard error.

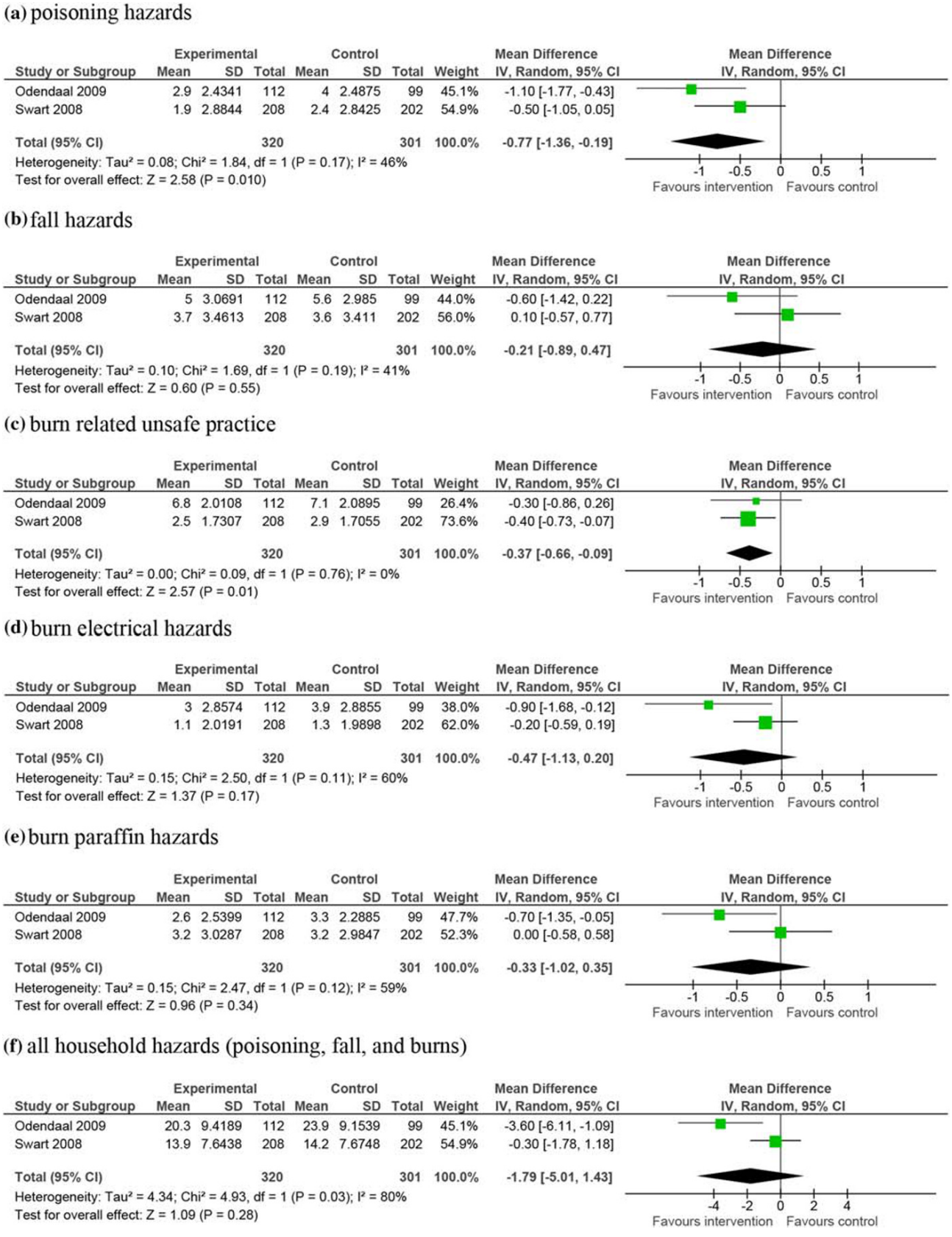

FIGURE 2 Forest plot of comparison: environmental change intervention versus control, outcomes: A, poisoning hazards; B, fall hazards; C, burn related unsafe practice; D, burn electrical hazards; E, burn paraffin hazards; F, all household hazards (poisoning, fall and burns) [Colour figure can be viewed at wileyonlinelibrary.com]

SD = 3.46) compared with the control area (mean incidence rate = 9.80, SD = 5.63).

3.4.2 | Injury hazards

Three RCTs reported data on household hazard reduction (Odendaal et al., 2009; Rehmani & LeBlanc, 2010; Swart et al., 2008). The results from two RCTs (Odendaal et al., 2009; Swart et al., 2008) pooled into a meta-analysis of 621 households and the results from a single RCT study (Rehmani & LeBlanc, 2010) of 340 households are presented below.

Poisoning hazards

Two RCTs reported poisoning hazards (Odendaal et al., 2009; Swart et al., 2008) and one RCT reported ingestion hazards (poisoning and choking) (Rehmani & LeBlanc, 2010). A pooled result from two RCTs found significant differences in postintervention mean scores for poisoning hazards between the intervention and control groups (MD −0.77, 95% CI [−1.36, −0.19]) (Odendaal et al., 2009; Swart et al., 2008). Statistical heterogeneity between the studies was moderate (I^2 = 46%, p = 0.010) (Figure 2). The third RCT reported no significant difference in the postintervention mean scores between the intervention and control groups for ingestion hazards (MD −0.1; 95% CI [−0.36, 0.16], p = 0.45) (Rehmani & LeBlanc, 2010).

Fall hazards

All three RCTs reported fall hazards (Odendaal et al., 2009; Rehmani & LeBlanc, 2010; Swart et al., 2008). A pooled result from two RCTs found no significant difference in the postintervention mean scores for fall hazards between the intervention and control groups (MD −0.21, 95% CI [−0.89, 0.47]) (Odendaal et al., 2009; Swart et al., 2008). Statistical heterogeneity between the studies was moderate (I^2 = 41%, p = 0.19) (Figure 2). One RCT found a significant difference in postintervention mean scores between the intervention and control groups for fall-related hazards (MD −0.5; 95% CI [−0.66, −0.33], p < 0.001) (Rehmani & LeBlanc, 2010).

Burn hazards

Two RCTs reported burn hazards (Odendaal et al., 2009; Swart et al., 2008). A pooled analysis of the homogenous data (I^2 = 0%; p = 0.01) indicated statistically significant differences in postintervention mean scores for burn-related unsafe practices between the intervention and control groups (MD −0.37, 95% CI [−0.66, −0.09]). The results showed no significant difference between the intervention and control groups for electrical burn hazards (MD −0.47, 95% CI [−1.13, 0.20]) and paraffin burn hazards (MD −0.33, 95% CI [−1.02, 0.35]) (Figure 2).

Total hazards (poisoning fall and burns)

The pooled analysis of two RCTs suggested no statistically significant differences in postintervention mean scores for total household hazards (burns, poisoning and falls) between the intervention and control groups (MD −1.79, 95% CI [−5.01, 1.43]) (Odendaal et al., 2009; Swart et al., 2008). Statistical heterogeneity between the studies was high (I^2 = 80%, p = 0.04) (Figure 2).

4 | DISCUSSION

This systematic review included four studies, only one of which reported the primary outcome of this review, incidence of child injury (Krug et al., 1994), and three reported the secondary outcome: number of injury hazards (Odendaal, 2009; Rehmani & LeBlanc, 2010; Swart, 2008). All the interventions in the included studies were delivered before 2010. Collecting injury outcomes often requires both large samples and long follow-up, making studies expensive to conduct; this could be one reason for finding only one study that measured injury outcome. The CBA study reported a significant reduction in paraffin ingestion incidence in the study area during and after the intervention (Krug et al., 1994). Thus, this study provided good evidence that distribution of child tamper-proof paraffin containers in South Africa can reduce the incidence of poisoning. However, this result should be interpreted with some caution since the CBA study design places it at risk of bias.

This finding supports evidence from HICs of the effectiveness of safety products used in the home to reduce child injuries. For example, a US study reported that child-resistant packaging reduced child mortality from the unintentional ingestion of medicines by 1.40 per 100,000 (95% CI [0.85, 1.95]) among children <5 years of age (Rodgers, 1996). A similar study in the USA found that use of child-resistant packaging was associated with a 34% reduction in aspirin-related mortality rate for children <5 years of age (Rodgers, 2002). Studies in HICs have found that education and engineering are effective in improving home poison prevention practices, but there is limited evidence to show whether this intervention reduces clinical harm from poisoning in children (Wynn et al., 2016).

Reasons for differences in results between the meta-analysis (Odendaal et al., 2009; Swart et al., 2008) and the single RCT (Rehmani & LeBlanc, 2010) might be due to methodological differences in the studies. The postintervention follow-up period in the single RCT (Rehmani & LeBlanc, 2010) was longer (6 months) than the other RCTs (3 and 4 months). Therefore, it can be hypothesized that structural changes in the home to reduce hazards may not have been practical within a short period. There were also differences in the socio-demographics of the participants between the two pooled studies in the meta-analysis (both in a South African low-income setting) and the RCT based in an urban neighbourhood in Karachi, Pakistan (Rehmani & LeBlanc, 2010). Families within households in an urban area may live in better socio-economic conditions and be more likely to have access to, and be able to afford, safety equipment than the households in rural, lower income settings.

In HICs, some safety interventions, including removal of injury hazards, have been shown to be effective in reducing injury incidence. A network meta-analysis and overview of reviews found that home safety interventions were effective in improving childhood fall-related

outcomes in the home (Hubbard et al., 2015; Young, Wynn, He, & Kendrick, 2013). Educational campaigns were found effective in increasing knowledge about prevention of burn or scald injuries and smoke alarm distribution was effective in reducing fire-related injuries (Towner, Dowswell, & Jarvis, 2001). There was little evidence to suggest that educational campaigns alone were effective in reducing injuries from hot water or burns or scalds in the home. Most of the papers used in these studies were from HICs; therefore, findings may not be generalizable to LMICs.

4.1 | Strengths and limitations of this review

Strengths of this review include the absence of language restrictions, that the risk of bias was assessed in the included studies and that a meta-analysis was carried out for a more precise estimation of the true intervention effects. The internal validity of the review was assured with two reviewers checking the consistency and accuracy of data extraction and the appraised quality of the included studies.

Only published studies were identified for inclusion in the review. Negative or neutral effect studies are less likely to be published, therefore only analysing the results from published data may lead to a false positive effect (Bartolucci & Hillegass, 2010). To counter this, efforts to find unpublished work, by contacting authors directly, were made, but only one out of four authors responded, and no further data or studies were identified for inclusion.

Heterogeneity is important to consider in any meta-analysis, and it is equally important to explore the reasons for it (Higgins & Thompson, 2002). Despite combining two sufficiently homogeneous studies, the I^2 statistic indicated substantial heterogeneity (I^2 > 50%) in some of their results (Figure 2). Statistical heterogeneity in these results might be due to the limited number of trials, differences in sample size or the potential bias in the trials included.

4.2 | Recommendations

All four included studies used multicomponent interventions, so it is difficult to know which, if any approach, had more influence than another. In LMICs, more research is needed to clarify the role of different interventions, such as home visits, education to parents/caregivers and distribution of safety devices. Where offered, interventions should include some element of education or discussion to support parents/carers to understand both the hazard, and how their actions could reduce injury risks associated with that hazard. In future, the use of standardized and consistent definitions and measurement tools would enable comparisons between studies, for example, using the same validated questionnaire or checklist for measuring injury cases or injury hazards.

The use of rigorous, experimental methodologies, such as RCTs, are needed to support or refute the effectiveness of an intervention to reduce hazards in the home environment in reducing injuries in LMICs. There is a need for standardized outcome measures that assesses behaviour change to reduce home hazards. In recognition that a 'one size fits all' approach to interventions does not work, (Hayes & Kendrick, 2016) future research should explore the relative contribution of each element of complex interventions to reduce child injuries in the home in LMICs settings.

5 | CONCLUSIONS

This systematic review found limited evidence from LMICs to determine whether environmental change interventions reduced child injury or home hazards compared with no intervention. The review provides the evidence to argue for the further development and evaluation of environmental change interventions for injury reduction; it also suggests that passive interventions, along with safety messages, have the potential to improve safety. More evidence is needed to determine if altering the physical home environment by removing potential hazards reduces injuries in LMICs.

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AUTHOR CONTRIBUTIONS

All of the authors contributed to the conception, design and drafting of this review. Santosh Bhatta, Toity Deave and Julie Mytton contributed to the idea and developed methodologies. Santosh Bhatta wrote the initial draft of the manuscript, Toity Deave and Julie Mytton reviewed and revised the manuscript. All of the authors read and approved the final manuscript.

CONFLICT OF INTERESTS

None declared.

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APPENDIX A: Detail search strategy in Medline (Ovid)

1	(house* or housing or home or homes or abode* or residence* or residential or accommodation* or apartment* or flat* or maisonette* or condo or condominium* or menage* or dwelling* or domicil* or domestic*).tw.	409912
2	exp housing/	24728
3	exp public housing/	975
4	exp household products/	34904
5	or/1–4	454607
And		
6	(fall* or scald* or burn* or drown* or near drown* or poison* or chok* or asphyx* or suffocate* or injur* or accident*).tw.	784617
7	((chemical* or thermal or electri*) adj5 injur*).tw	8151
8	((unintentional or accident*) adj injur*).tw.	2781
9	((injur* or accident*) adj prevent*).tw.	4810
10	poisons/	1731
11	exp drowning/	3227
12	exp near drowning/	516
13	exp fires/	7022
14	exp burns/	47742
15	exp accidental falls/	14975
16	exp accidents/	137440
17	accidents, home/	3969
18	exp accident prevention/	58446
19	exp 'wounds and injuries'/	691709
20	or/6–19	1288559
And		
21	developing countries.sh,kf.	71625
22	(africa or asia or caribbean or west indies or south america or latin america or central america).hw,kf,ti,ab,cp.	180097
23	(afghanistan or albania or algeria or angola or antigua or barbuda or argentina or armenia or armenian or aruba or azerbaijan or bahrain or bangladesh or barbados or benin or byelarus or byelorussian or belarus or belorussian or belorussia or belize or bhutan or bolivia or bosnia or herzegovina or hercegovina or botswana or brasil or brazil or bulgaria or burkina faso or burkina fasso or upper volta or burundi or urundi or cambodia or khmer republic or kampuchea or cameroon or cameroons or cameron or camerons or cape verde or central african republic or chad or chile or china or colombia or comoros or comoro islands or comores or mayotte or congo or zaire or costa rica or cote d'ivoire or ivory coast or croatia or cuba or cyprus or czechoslovakia or czech republic or slovakia or slovak republic or djibouti or french somaliland or dominica or dominican republic or east timor or east timur or timor leste or ecuador or egypt or united arab republic or el salvador or eritrea or estonia or ethiopia or fiji or gabon or gabonese republic or gambia or gaza or georgia republic or georgian republic or ghana or gold coast or greece or grenada or guatemala or guinea or guam or guiana or guyana or haiti or honduras or hungary or india or maldives or indonesia or iran or iraq or isle man or jamaica or jordan or kazakhstan or kazakh or kenya or kiribati or korea or kosovo or kyrgyzstan or kirghizia or kyrgyz republic or	2674174

APPENDIX A: (Continued)

	kirghiz or kirgizstan or lao pdr or laos or latvia or lebanon or lesotho or basutoland or liberia or libya or lithuania or macedonia or madagascar or malagasy republic or malaysia or malaya or malay or sabah or sarawak or malawi or nyasaland or mali or malta or marshall islands or mauritania or mauritius or agalega islands or mexico or micronesia or middle east or moldova or moldovia or moldovian or mongolia or montenegro or morocco or ifni or mozambique or myanmar or myanma or burma or namibia or nepal or netherlands antilles or new caledonia or nicaragua or niger or nigeria or northern mariana islands or oman or muscat or pakistan or palau or palestine or panama or paraguay or peru or philippines or philipines or phillipines or phillippines or poland or portugal or puerto rico or romania or rumania or roumania or russia or russian or rwanda or ruanda or saint kitts or st kitts or nevis or saint lucia or st lucia or saint vincent or st vincent or grenadines or samoa or samoan islands or navigator island or navigator islands or sao tome or saudi arabia or senegal or serbia or montenegro or seychelles or sierra leone or slovenia or sri lanka or ceylon or solomon islands or somalia or south africa or sudan or suriname or surinam or swaziland or syria or tajikistan or tadzhikistan or tadjikistan or tadzhik or tanzania or thailand or togo or togolese republic or tonga or trinidad or tobago or tunisia or turkey or turkmenistan or turkmen or uganda or ukraine or uruguay or ussr or soviet union or union soviet socialist republics or uzbekistan or uzbek or vanuatu or new hebrides or venezuela or vietnam or viet nam or west bank or yemen or yugoslavia or zambia or zimbabwe or rhodesia).hw,kf,ti,ab,cp.	
24	((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or underserved or deprived or poor*) adj (countr* or nation? or population? or world)).ti,ab.	50420
25	((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)).ti,ab.	226
26	(low* adj (gdp or gnp or gross domestic or gross national)).ti,ab.	136
27	(low adj3 middle adj3 countr*).ti,ab.	2580
28	(lmic or lmics or third world or lami countr*).ti,ab.	2982
29	transitional countr*.ti,ab.	93
30	or/21–29	2771398
And		
31	exp child/	1522112
32	exp infant/	923728
33	exp infant, newborn/	490308
34	exp adolescent/	1583881
35	exp minors/	2170
36	exp child, preschool/	740360
37	(child* or adolesc* or infan* or young* or minor* or toddl* or baby or babies or new born or youth* or preschool* or preschool* or teenager* or neonat* or paediatric* or pediatric* or boy* or girl*).tw.	1986900
38	or/31–37	3505443
39	5 and 20 and 30 and 38	3272

APPENDIX B: Characteristics of excluded studies (ordered by study ID)

Study ID	Study titles	Reasons for exclusion
(Mashreky et al., 2011)	Experience from community-based childhood burn prevention programme in Bangladesh: Implication for low resource setting.	Pilot study, No experimental or CBA. No intervention that met inclusion criteria. No outcome that met inclusion criteria
(Sinha, Patel, Kim, MacCorkle, & Watkins, 2011)	Comic books can educate children about burn safety in developing countries.	Before and after study without control group. No intervention that met inclusion criteria. No outcome that met inclusion criteria
(Callaghan et al., 2010)	Child supervision practices for drowning prevention in rural Bangladesh: A pilot study of supervision tools.	Community based pilot study/observational study. No comparison groups. No outcome that met inclusion criteria
(Wang & Zhu, 2009)	[peer education's effects on preventing accidental injuries in middle school students]	No intervention that met inclusion criteria
(Kumar, Singh, & Singh, 2013)	Prevention of chaff cutter injuries in rural India.	No intervention that met inclusion criteria. No control groups
(Konradsen et al., 2007)	Community uptake of safe storage boxes to reduce self-poisoning from pesticides in rural Sri Lanka.	Before and after without control group, single group study. Not unintentional injury study. No outcome that met inclusion criteria
(Weerasinghe et al., 2008)	Safe storage of pesticides in Sri Lanka–identifying important design features influencing community acceptance and use of safe storage devices.	Qualitative study
(Hawton, Ratnayeke, Simkin, Harriss, & Scott, 2009)	Evaluation of acceptability and use of lockable storage devices for pesticides in Sri Lanka that might assist in prevention of self-poisoning.	Qualitative study
(Jordaan, Atkins, Van Niekerk, & Seedat, 2005)	The development of an instrument measuring unintentional injuries in young children in low-income settings to serve as an evaluation tool for a childhood home injury prevention program.	Before and after study without control group. No intervention that met inclusion criteria. No outcome that met inclusion criteria
(Hyder et al., 2012)	Childhood unintentional injuries: Need for a community-based home injury risk assessment in Pakistan.	Community based pilot study/observational study. No comparison groups
(Jetten, Chamania, & Van Tulder, 2011)	Evaluation of a community-based prevention program for domestic burns of young children in India.	Pretest–post-test study design without control group.
(Altundağ & Oztürk, 2007)	[the effects of home safety education on taking precautions and reducing the frequency of home accidents].	Pretest–post-test study design without control group
(Turan, Altundağ, Yorgancı, & Yıldırım, 2010)	[the prevention of home accidents among children aged 0–6 years].	Pretest–post-test study design without control group. No outcome that met inclusion criteria
(Chandran et al., 2013)	Disseminating childhood home injury risk reduction information in Pakistan: Results from a community-based pilot study.	Pretest–post-test study design without control group
(Gimeniz-Paschoal, Pereira, & Nascimento, 2009)	Effect of an educative action on relatives' knowledge about childhood burns at home.	No outcome that met inclusion criteria

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APPENDIX C: The EPOC tool used for assessing risk of bias in CBA study with description

C.1 | Summary of risk of bias in CBA study

Generation of randomized sequence and concealment of sequence allocations prior to assignment are not a part of CBA study; therefore, this study had a high risk of selection bias in terms of generating a random sequence and allocation concealment. There was low risk of selection bias in terms of baseline outcome measurement because the incidence rate in study area were not significantly different from those in the control area during the preintervention period. Risk of confounding bias was unclear because the study had not reported enough data on population characteristics to see the similarity on baseline characteristics across the groups. Risk of performance bias in terms of contamination was not clear but high in terms of blinding as participants and personnel were not blinded. Lack of blinding of outcome assessors and incomplete outcome data made the study high risk in terms of detection bias and attrition bias, respectively. The risk of reporting bias was unclear as the study protocol was not available.

APPENDIX D: Summary of risk of bias in three RCTs

D.1 | Selection bias (random sequence generation and allocation concealment)

The risk of selection bias was assessed on whether the generation of a randomized sequence and concealment of sequence allocations prior to assignment were adequate or not. One study provided sufficient information to judge low risk of selection bias (Swart, 2008). This study had used computer generated lists for household selection and data collectors were masked to group assignment. The risk of selection bias in terms of random sequence generation was unclear for Odendaal et al. (2009) and low risk for Rehmani (2010). Allocation concealment was poorly reported by Rehmani (2010) and was judged low risk in the study by Odendaal et al. (2009).

D.2 | Performance bias (blinding of participants and personnel)

The risk of performance bias was assessed based on knowledge of the allocated interventions by participants and personnel during the study. Poor reporting of blinding of participants and personnel in two studies (Swart, 2008; Odendaal, 2009) prevented clear judgement of the risk of performance bias. Performance bias was judged high for the nonblinded study (Rehmani, 2010) due to the lack of blinding of participants and personnel during the study.

D.3 | Detection bias (blinding of outcome assessment)

The risk of detection bias was assessed based on knowledge of the allocated interventions by outcome assessors. In two studies (Swart, 2008; Odendaal, 2009), data collectors were not informed of the intervention or control status of households at the postintervention assessment. Hence, these two studies were judged to be at low risk of bias. Outcome assessors were not blinded in the other study (Rehmani, 2010) so was judged high risk.

D.4 | Attrition bias (incomplete outcome data)

The risk of attrition bias was assessed based on the amount, nature or handling of incomplete outcome data. All three studies had similar numbers of dropouts in the intervention and control groups and similar reasons for missing data were provided in one study (Odendaal, 2009). Reasons for loss to follow-up were not reported in two studies (Swart, 2008; Rehmani, 2010), but it is unlikely to affect true outcomes. In both studies, the number of households that was lost to follow-up for intervention and control group was similar. Therefore, all these studies were judged as having low risk of attrition bias.

D.5 | Reporting bias (selective reporting)

The risk of reporting bias was assessed based on selective outcome reporting. Although the study protocol was not available to confirm all outcomes reported, all possible outcomes stated in the methods section were reported in the results section of two studies (Swart, 2008; Odendaal, 2009); hence, these two studies were judged to be at low risk of bias. Risk of selective reporting bias was unclear for one study (Rehmani, 2010) due to the lack of study protocol.