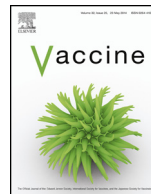




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Review

Parental reminder, recall and educational interventions to improve early childhood immunisation uptake: A systematic review and meta-analysis

Hannah Harvey^{a,*}, Nadja Reissland^a, James Mason^b

^a Department of Psychology, Durham University, Durham DH1 3LE, UK

^b Durham University School of Medicine, Pharmacy and Health, Wolfson Research Institute, Stockton-On-Tees TS17 6BH, UK

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ABSTRACT

Vaccination is one of the most effective ways of reducing childhood mortality. Despite global uptake of childhood vaccinations increasing, rates remain sub-optimal, meaning that vaccine-preventable diseases still pose a public health risk. A range of interventions to promote vaccine uptake have been developed, although this range has not specifically been reviewed in early childhood. We conducted a systematic review and meta-analysis of parental interventions to improve early childhood (0–5 years) vaccine uptake. Twenty-eight controlled studies contributed to six separate meta-analyses evaluating aspects of parental reminders and education. All interventions were to some extent effective, although findings were generally heterogeneous and random effects models were estimated.

Receiving both postal and telephone reminders was the most effective reminder-based intervention (RD = 0.1132; 95% CI = 0.033–0.193). Sub-group analyses suggested that educational interventions were more effective in low- and middle-income countries (RD = 0.13; 95% CI = 0.05–0.22) and when conducted through discussion (RD = 0.12; 95% CI = 0.02–0.21). Current evidence most supports the use of postal reminders as part of the standard management of childhood immunisations. Parents at high risk of non-compliance may benefit from recall strategies and/or discussion-based forums, however further research is needed to assess the appropriateness of these strategies.

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1. Introduction

The reduction in global mortality associated with vaccinations is second only to the introduction of safe drinking water [1]. According to the World Health Organisation, childhood vaccinations prevent an estimated 2–3 million deaths per year. Yet despite global increases in childhood vaccine uptake, rates remain sub-optimal (<95%), with vaccine-preventable diseases still posing a public health risk [2]. Neither is this risk limited to low- and middle-income countries (LMICs). Factors such as poor access to healthcare, indigenous or ethnic status, a large family size and low educational achievement are associated with pockets of low coverage in high-income countries (HICs) [3].

Maintaining reductions in mortality from vaccine-preventable disease relies upon continued immunisation uptake that, during childhood, is reliant on parental decision-making and subsequent

attendance at vaccine clinics [4]. However, several factors may act as barriers to childhood immunisation. Factors include parental concerns about vaccine safety, a lack of knowledge about the recommended schedule, pain caused by the injections, distrust of the medical community and difficulty accessing clinics [5]. Therefore, it is important to understand the effectiveness of interventions implemented by primary care settings that are designed to improve childhood immunisation. Interventions to increase childhood immunisation have been targeted at a variety of groups, including healthcare providers, healthcare practices and parents [6]. This review will focus on the effectiveness of interventions targeted at parents. Many strategies have been trialled, including financial incentives [7] and home vaccination [8]. However, as the majority of trials have addressed (a) the lack of schedule awareness using parental reminder systems and/or (b) knowledge about the safety and efficacy of vaccines through educational leaflets or discussion-groups, these interventions will be the primary focus of this review. Systems designed to remind parents that their child was due (reminder) or overdue (recall) their immunisations have been linked to a 1.5 times increase in uptake [9]. The effects of parental education are less clear,

* Corresponding author. Tel.: +44 0191 334 3251.

E-mail addresses: hannah.harvey@durham.ac.uk (H. Harvey), n.n.reissland@durham.ac.uk (N. Reissland), j.m.mason@durham.ac.uk (J. Mason).

with evidence presented both for [10,11] and against [3] their utility.

Previous reviews have focussed on the efficacy of intervention strategies in isolation and not all have made specific recommendations regarding childhood immunisations. Today, primary health care services are under increasing pressure to meet immunisation expectations at both an organisational and patient level [12]. In order to facilitate physician judgements about interventions to increase childhood immunisation, and to increase the efficacy of intervention implementation and policy updates, a review comparing the effectiveness of multiple interventions to be compared is timely. Therefore, a systematic review and meta-analysis was conducted to evaluate available evidence on parental interventions to improve childhood (birth to 5 years) vaccine uptake.

2. Material and methods

2.1. Literature search

A systematic literature search of five databases (MEDLINE, EMBASE, EMBAR, CINAHL and PsychINFO) was conducted in February 2014 using the OVID and EBSCOhost search platforms (with adaptation of terms for EBSCOhost). Search terms were pre-defined to allow a comprehensive search strategy that included text fields within records and Medical Subject Headings (MeSH terms). Terms related to immunisation, immunisation uptake, infants and young children and intervention study design. The OVID search strategy is reported in Table 1. This search was conducted as part of a wider review of barriers and facilitators of childhood immunisation and so included both qualitative and quantitative data. The present review refers only to quantitative intervention studies.

2.2. Study selection

Database search results were combined and duplicates were removed. Studies were screened for eligibility by the primary

Table 1
OVID search strategy.

Search no.	Search terms (number of records found)
1	Vaccination/or vaccin*.mp. (504,709)
2	Vaccines, Combined (Roberts et al.) (15,179)
3	Immunisation, Secondary/or Immunisation Schedule/or immuniz*.mp. or immunis*.mp. (259,183)
4	Child, Preschool/(1,015,179)
5	infant*.mp. or exp Infant/(1,419,667)
6	Intervention Studies/or intervention*.mp. (1,272,614)
7	Observational Study/or observational.mp. (186,994)
8	randomised controlled trials as topic/or epidemiologic research design/or cross-over studies/(302,583)
9	comparative study/or evaluation studies/or meta-analysis/(2,466,746)
10	Qualitative Research/or qualitative.mp. (253,593)
11	Attitude to Health/or attitude*.mp. (586,720)
12	Decision Making/or decision*.mp. (611,254)
13	uptake.mp. (506,659)
14	1 or 2 or 3 (629,636)
15	4 or 5 (1,921,801)
16	6 or 7 or 8 or 9 or 10 (4,175,191)
17	11 or 12 or 13 (1,636,383)
18	14 and 15 and 16 and 17 (1432)

Note. Databases searched <dates>: EBM Reviews – Cochrane Database of Systematic Reviews <2005 to December 2013>, EBM Reviews – ACP Journal Club <1991 to January 2014>, EBM Reviews – Database of Abstracts of Reviews of Effects <1st Quarter 2014>, EBM Reviews – Cochrane Central Register of Controlled Trials <January 2014>, EBM Reviews – Cochrane Methodology Register <3rd Quarter 2012>, EBM Reviews – Health Technology Assessment <1st Quarter 2014>, EBM Reviews – NHS Economic Evaluation Database <1st Quarter 2014>, Embase <1996 to 2014 Week 06>, Ovid MEDLINE(R) <1946 to January Week 5 2014>.

author, with uncertain citations discussed with J.M. Full-text reports were gained for all eligible studies. The reference lists of included studies were additionally searched for any relevant articles. A sample of studies was independently assessed for eligibility by J.M. to corroborate study selection. Any disagreements were resolved by discussion. Studies were eligible for inclusion in the systematic review if they reported interventions aimed at parents of children (≤ 5 years-old) due or overdue one or more routine immunisations, recommended to be administered by WHO, with outcomes that measured child immunisation uptake. Because of variations in the reporting of immunisation uptake [3] outcomes that addressed the uptake of individual or a combination of recommended vaccines were included. Studies without a control group and studies that did not provide outcome data in terms of the number of children completely immunised or up-to-date for their age were excluded from the meta-analysis. Interventions that met these criteria but for which only one study was found were also excluded from pooled analyses.

2.3. Data extraction and assessment of methodological quality

Study characteristics were recorded using a pre-defined data extraction sheet. Information was extracted on (a) study design, (b) country of study, (c) intervention (including type, population, setting, details and sample sizes), (d) outcomes (including the number of children completely immunised for their age, received at least one dose of the studies vaccine(s), or were vaccinated on-time), (e) study findings and (f) eligibility for inclusion within meta-analyses.

2.4. Risk of bias in individual studies

Risk of bias was performed by the primary author using the Cochrane Collaboration Risk of Bias Tool [13]. Studies were assessed as being at a high, low or unclear risk of six attributes: sequence allocation, allocation concealment, blinding, incomplete outcome data, selective reporting, and other sources of bias. Studies were assessed as 'unclear' when an attribute (e.g., blinding) was not or insufficient evidence to support a judgement was provided. Evidence of quality across studies was determined by the proportion of studies given each judgement for each methodological attribute assessed in the tool. Although assessment of study quality is reported here it was not used to weigh review findings.

2.5. Data analysis

Studies that were eligible for inclusion in the meta-analysis were grouped according to intervention type. Separate meta-analyses were conducted for each intervention type. Studies examining multiple interventions could contribute to several analyses. Where trials had a cluster randomised design, reported intra-cluster correlation coefficient (ICC) were sought. If ICCs were not reported, unadjusted values were included in the meta-analyses, accepting that this might overestimate the weight of these studies in the analysis. Risk difference values and 95% confidence intervals were used to calculate both individual and pooled effect sizes for the effect of each intervention on complete childhood immunisation uptake. Potential differences between studies were explored by sub-group analyses including where possible, the effect of the country of study income, time, frequency and method of intervention delivery and focus of intervention content.

Heterogeneity was assessed using Cochrane's Q statistic, with $p < .10$ denoting heterogeneity. Inconsistency across studies was measured using the I^2 statistic, with a value greater than 40% presenting evidence of moderate heterogeneity and signalling the need to use a random effects model [13]. Where heterogeneity was not reduced by sub-group analyses, variability in study method

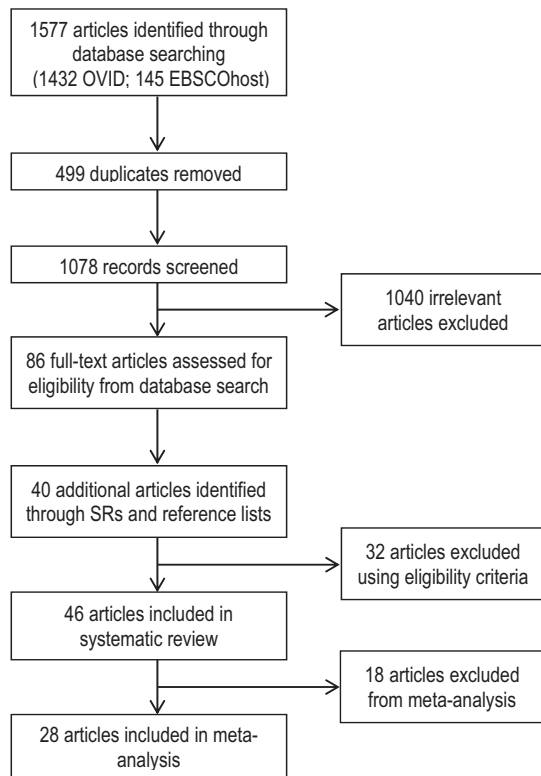


Fig. 1. Flow diagram of study selection.

was discussed. Evidence of publication bias was investigated by examining the symmetry of the funnel plot and quantified using the Egger statistic, with $p < .05$ denoting evidence of publication bias. All analyses were performed using StatsDirect [14].

3. Results

3.1. Selection of studies

The literature search generated 1577 articles. Following the removal of duplicates, 1040 of the remaining 1078 articles did not meet the inclusion criteria based on an appraisal of the abstract. This resulted in 86 full-text articles, which were examined in depth. Forty additional articles were identified from the reference lists of eligible papers and eight systematic reviews identified in the database search [3,6,9–11,15–17]. One hundred and twenty-six full text reports were examined, and 48 qualitative studies removed for later qualitative analysis. Based on the criteria cited above, 32 intervention studies were ineligible, leaving 46 articles suitable for inclusion in the systematic review. Of these, a further 13 articles were excluded because of inadequate study designs and outcomes measures, and 5 [8,18–21] because of a lack of comparable trials, leaving 28 articles suitable for meta-analysis (Fig. 1).

3.2. Characteristics of studies included in the meta-analysis

Table 2 summarises the characteristics of studies included in the systematic review and meta-analysis. Of the studies included in the meta-analysis ($n = 28$), 16 studies were conducted in the United States, 5 in the UK or Republic of Ireland, 2 in Pakistan and 1 each in Australia, Ghana, India and Japan. Twenty-four randomised controlled trials (RCTs), three cluster RCTs and one sequentially allocation control trial were included. One cluster RCT [22] reported an ICC of zero. Consequently, no adjustment was made for clustering and clustering had no impact upon any findings reported.

The studies included a total of 14,936 parent–child dyads whose immunisation uptake was assessed. Eight studies had data on the complete uptake of both DTP and Measles vaccines; 12 on DTP; 5 on MMR; and 1 each on DTP and OPV; Hib, HBV and PCV7; and DTP and HepB.

Each of the studies evaluated some form of parental reminder and/or education. These were grouped into six intervention types: (a) postal reminders [23–33]; (b) telephone reminders [25,26,29,32,34]; (c) combined recall and reminder [25,26,32,35]; (d) education [22,30,31,36–42]; (e) education and reminder [30,31,43–45]; and (f) lay health workers (LHWs) [46–49]. Studies that could not be included in the meta-analysis because of a lack of comparable trials investigated a variety of intervention methods. Interventions included home vaccination [8], financial incentives [19], individual case management [21], LHW-lead group discussions [18] and being tracked and escorted to the clinic by an LHW [20].

3.3. Risk of bias for individual studies

Using the risk of bias tool, 12 studies (43%) were judged to have an overall high risk of bias, 4 (14%) as low risk, and 12 studies (43%) as unclear risk. Risk of bias judgements for studies included in the meta-analysis are shown in Fig. 2. Nine studies were judged to be at a high risk of selection bias, describing a non-random component in the sequence generation process [38,41], inappropriate allocation concealment [37,42], or both [26,30,31,44]. The blinding of parents and/or health professionals was not possible where interventions were provided face-to-face. Only six studies included a blind outcome assessor. In the majority of studies, blinding was unclear or judged to be of high risk because those administering the intervention also assessed outcomes [22,30,31,36–38,40,44,48]. In the majority of studies, insufficient information was reported to provide a judgement regarding blinding. Approximately 10% of studies [36,38,46] were judged to be at high risk of attrition bias owing to high rates of exclusion and loss to follow-up. Only three studies [22,40,42] referred to protocols, so for the majority of studies it was unclear whether selected reporting had been an issue. No evidence of publication bias was found for included studies: for each pooled analysis, funnel plots were symmetrical, with studies published in each quarter of the plot. The associated Egger statistics were non-significant in each case.

3.4. Effectiveness of reminder-based interventions

Thirteen studies evaluated the impact of one or more methods of parental reminder. Pooled risk differences were calculated for the effect of postal and telephone reminders, as well as studies that utilised both methods in one study arm.

3.4.1. Postal

Eleven studies (1 sequentially allocated control trial, 10 RCTs) examined the effectiveness of postal reminders [23–33]. In all studies, parents were sent a letter or postcard reminding them that their child’s immunisations were due or overdue. Intervention groups within one study [24] examining personal and non-personal reminders were pooled to summarise the overall effect of intervention. The pooled fixed effect showed that postal reminders significantly improved immunisation uptake by 10.6% (RD = 0.106; 95% CI = 0.080–0.131; $p < .001$; Fig. 3a). However, individual studies reported a range of findings (from a 1.8% decrease to a 27.2% increase) and substantial heterogeneity ($I^2 = 76.3\%$), indicating that the fixed effect model is unreliable. Using the random effects model, the positive effect of postal reminders remained significant (RD = 0.099; 95% CI = 0.045–0.152, $p < .001$).

Table 2
Study characteristics.

Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)	
Reminder-based interventions							
Abramson et al. [35], USA	RCT	Postal and telephone reminder	Infants born at Forsyth Memorial Hospital receiving primary care from 1 of 2 health centres	A: Postcard reminder + telephone follow-up ($n = 302$) Control: Routine care. No reminder ($n = 299$) Intervention: Postal reminder sent 1 week before appointment and again if appointment missed. Families then telephoned every week until the child had been vaccinated, the family moved health care provider or the infant was >1 month behind the schedule	Complete age-appropriate immunisation by 2, 4 and 6 months	Postal reminder significantly increased uptake compared to routine care	Yes
Alemi et al. [50], USA	Non-randomised control trial	Telephone reminder	Mothers with infants <6 months attending Paediatric practice who were seen by 1 of 3 participating paediatricians and practice nurses	A: Computer-reminder ($n = 124$) Control: Routine care. No reminder ($n = 89$) Intervention: Computer telephone reminder attempted before scheduled appointment. If appointments were missed, parents reminded to reschedule	On-time immunisation	Computerised reminders significantly improved on-time immunisation compared to routine care	No; outcome measure (on-time immunisation)
Alto et al. [51], USA	Prospective cohort study	Postal and telephone reminder	Children between 2 months and 7 years who were behind schedule and enrolled at the family practice residency clinic	A: Postcard followed by telephone reminder after 6 weeks ($n = 231$) Control: Routine care. No reminder ($n = 233$) Intervention: Parents sent postcard detailing immunisation schedule and urging them to make an appointment at the clinic. Telephone calls were made up to 3 times over an 8-week period if children remained unimmunised 6 weeks from initial contact	Complete age-appropriate immunisation 8 months after intervention	Postal followed by telephone reminder significantly increases immunisation uptake compared to routine care	No; study design
Atchison et al. [52], UK	Before and after study	Postal reminder	All children between 0 and 5 years attending 44 GP practices	A: Standardised call/recall system ($n = 32$ practices) Control: No system implemented ($n = 12$ practices) Intervention: Postal reminders sent to all children who were due or overdue any immunisations. Overdue appointments were sent up to 3 invitations to attend. 3rd time defaulters were referred to the HV for follow-up	Complete immunisations at: 1. 12 months for 3× DTaP/IPV/Hib 2. 24 months for MMR1, Hib/MenC booster, PCV booster 3. 5 years for DTaP/IPV/Hib pre-school booster and MMR2	Post-implementation, uptake was significantly improved following postal reminders	No; study design
Bjornson et al. [23], Canada	Prospective RCT	Postal reminder cards	314 parents of children due 12 month MMR or 18 month DTP/IPV/Hib booster	A: Reminder card (MMR $n = 153$; DTP/IPV/Hib $n = 152$) Control: No reminder (MMR $n = 155$; DTP/IPV/Hib $n = 154$) Intervention: Bright-coloured reminder card posted 4 weeks before appointment reminding parents which immunisations were due and to make an appointment	Infant immunisation status after 2-month follow-up period	Postal reminders did not significantly improve infant immunisation status by 2 years old	Yes

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Campbell et al. [24], USA	RCT	Postal reminder	Parents of new-borns enrolled in Paediatric clinic who did not receive care from the primary author	A: Letter reminder ($n = 87$) B: Post-card reminder ($n = 96$) Control: Routine care. No reminder ($n = 105$) Intervention: Reminders sent 1 week before appointment and specified its date and time. Letters included information on the benefits of immunisation in accordance with the HBM	Complete uptake of 3 × DTP by 7 months of age	Postcard and letter reminders did not significantly improve immunisation uptake in comparison to the control group	Yes
Dini et al. [25], USA	RCT	Telephone and postal reminder	1227 children 60–90 days-old who had received the first dose of DTP and Polio registered at 1 of 4 public health practices	A: Telephone reminder followed by letter B: Telephone reminder only C: Letter reminder only $n = 96$) Control: Routine care. No reminder Intervention: Telephone messages sent 1 week before appointment and repeated every of schedule and the importance of immunisations. After the 5th telephone attempt, letters posted 2 days after the 1st missed appointment in group C and every week in group A	Complete uptake by 24 months	Children in all intervention groups had significantly improved immunisation rates compared to children in the control group. There were no difference in immunisation rates between the three intervention groups	Yes
Goldstein et al. [53], USA	Cohort study	Door-to-door recall and reminder	510 families with 1075 children <6 years living in inner city public housing	Paediatric Immunisation Programme (PIP) outreach workers carried out door-to-door to ascertain child immunisation status from records. Record form provided to caregiver detailing current uptake and vaccines due in the future	Final child immunisation status based on records categorised as receiving all, none or some of: DTP, PCV, Hib, MMR	Visits by an out-reach workers significantly improved immunisation rates from baseline measures	No; study design
Hicks et al. [54], USA	Before and after cohort study	Postal reminder	All children <35 months not up-to-date registered at a non-profit community health centre	Intervention: Up to 3 language-appropriate postal reminder cards sent to families. Postcards listed the type and number of vaccines the child needed and invited parents to attend the clinic. Postcards served as a physician order to the nurse to administer the vaccine ($n = 240$ at baseline; 263 after intervention)	Number (%) of children completely immunised and up-to-date for their age pre- and post-intervention	Reminder cards significantly increased immunisation uptake	No; study design

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Irigoyen et al. [26], USA	Non-randomised control trial	Postal and telephone reminder	Parents of children between 4 and 18 months attending hospital – Paediatric clinic in a low-income population	A: Postcard reminder ($n = 314$) B: Telephone reminder ($n = 307$) C: Postcard + telephone reminder ($n = 306$) Control: Routine care. No reminder ($n = 346$) Intervention: Postcards were sent 1 week before appointments. A bilingual clerk telephoned parents up to 3 times on the weekday evening before the appointment	Complete uptake of 4× DTP, 3× Polio, 1× MMR	No significant difference in uptake was found between intervention and control groups. Reminders significantly increased uptake for a subgroup of children who were not up-to-date at baseline	Yes
Irigoyen et al. [27], USA	RCT	Postal reminder	Children aged 6–15 weeks attending 1 of 5 community-based paediatric practices in an inner city community	A: Continuous postal reminder ($n = 549$) B: Limited postal (max. 3 letters) reminder ($n = 552$) Control: Routine care. No reminder ($n = 561$) Intervention: Bilingual (English/Spanish) reminder cards posted to parents who needed a repeat reminder for a previously missed dose or a reminder for a new dose.	Complete uptake of 4x DTP, 3x Polio and 1x MMR.	Postal reminders did not significantly increase uptake compared to routine care.	Yes
LeBaron et al. [34], USA	RCT	Reminder recall by audiodialer and LHW outreach	3050 parent–child pairs born between July 1995 and August 1996	A: Audiodialer only ($n = 764$) B: Outreach only ($n = 760$) C: Audiodialer + Outreach ($n = 763$) Control: Routine care ($n = 763$) Intervention: Audiodialer message left 1 week before appointment and followed up with postcard if no contact made. If child remained unvaccinated 6 days after due date the message repeated every 6 days before another postcard was sent	Complete uptake of 4× DTP, 3× Polio, 1× MMR, 3× Hib by 24 months	Children in the audiodialer only group were significantly more likely to have completed the recommended course of immunisations by 24 months	Yes
Lieu et al. [28], USA	RCT	Postal reminder	Parents of 20-month-old children who had not received MMR	A: Postal reminder ($n = 153$) Control: Routine care. No reminder ($n = 136$) Intervention: Personalised computer-generated letter reminding parents their child was overdue for immunisation and requesting them to schedule and appointment	MMR uptake by 24 months	Significantly more children received MMR by 24 months in the intervention than control group. Postal reminders significantly improved immunisation uptake by 19%	Yes
Lieu et al. [55], USA	Randomised trial	Postal and telephone reminder	752 unimmunised 20-month-olds registered with a HMO	A: Automated telephone message ($n = 188$) B: Letter ($n = 188$) C: Automated telephone message + letter after 1 week ($n = 188$) D: Letter + automated telephone message after 1 week ($n = 188$) Intervention. Letters were personalised, language-appropriate and stated the child was overdue recommended vaccines and detailing the location of the nearest HMO. Telephone messages were read in a language chosen by the listener	The receipt of any needed childhood immunisation(s) by 24 months	Receipt of a combined reminder strategy resulted in significantly greater uptake of needed immunisations than receipt of a letter or telephone message alone	No; study design

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Morgan and Evans [29], UK	RCT	Postal reminder or telephone inquiry to HV	Children born between 1994 and 1995 who were behind schedule at 9 months or who had not received MMR by 21 months	A: Telephone call to HV (n = 153) B: Postal reminder + questionnaire (n = 159) Control: Routine care. No intervention (n = 139) Intervention: (A) Telephone calls were made to HVs to confirm the child details and immunisation status. (B) Parents were sent a reminder letter and questionnaire asking about the child's immunisation status and reasons for non-compliance	Complete uptake of the primary immunisation schedule by 12 months or receipt of MMR by 24 months	Neither telephone calls to HVs or reminder letters had an effect on primary immunisation or MMR uptake compared to routine care	Yes
Stehr-Green et al. [56], USA	RCT	Telephone reminder	Parents of 2-year-old children attending 1 of 2 public health centres due DTP, OPV or MMR during the 6-week study period	A: Telephone reminder (n = 112) Control: Routine care. No reminder (n = 110) Intervention: Computer-generated telephone reminder message notifying parents of necessary immunisations and to make an appointment. Messages were made for 5 days starting the day before a child became due for immunisation. Calls were attempted a maximum of 9 times	Frequency of on-time immunisation for DTP, OPV 1, 2 or 3 and/or MMR within 1 month of becoming due for immunisation	Telephone reminders significantly increased immunisation uptake by 2.8% compared to routine care	No; outcome measure (on-time immunisation)
Vivier et al. [32], USA	RCT	Telephone and/or postal reminder	264 under immunised children <6 years enrolled in Medicaid or uninsured with a family income <250% of federal poverty line	A: Telephone reminder (n = 60) B: Mail reminder (n = 63) C: Sequential mail + telephone reminder (n = 70) Control: Routine care (n = 71) Intervention: Up to 3 telephone calls (group A) or a letter (group B) reminding parents their child's vaccines were overdue and to schedule appointment. Parents in group C sent letter and telephoned after 1 week if an appointment remained unscheduled	Immunisations received during 10-month follow-up Immunisation status at the end of the follow-up	Reminder programmes significantly improved uptake of any immunisations and being up-to-date. There was no difference in uptake rates between the three reminder groups	Yes
Vora et al. [57], USA	Non-randomised control trial	Postnatal health education and reminder	400 infants enrolled in Medicaid	A: Hep B + immunisation education at birth + reminder until uptake complete or infant 35 months (n = 400) Control: Citywide school entrants who completed kindergarten in 2001 and 2002 from the same zip code as intervention population (n = 67, 376)	Up-to date immunisations at 7, 13, 19 and 24 months of age Completeness defined for 7 and 13 months as: ≥ 2 HBV, ≥ 3 DTaP, ≥ 3 Hib, ≥ 2 IPV; and ≥ 3 HBV, ≥ 4 DTaP, ≥ 3 Hib, ≥ 3 IPV for 19 and 24 months	Education from outreach-workers significantly improved immunisation uptake in high-risk children compared to controls	No; study design
Yokley and Glenwick [58], USA	RCT	Postal reminder and/or increased access and/or incentive	1133 under immunised children <5 years	A: Prompt giving general vaccine information (n = 195) B: Specific prompt naming child and vaccines (n = 190) C: Increased access (2x out-of-hours clinics) + specific prompt (n = 185) D: Monetary incentive (lottery entry upon visit) + specific prompt (n = 183) E: Contact control: telephone call detailing uptake (n = 189) F: No contact control: Routine care (n = 191)	Number of children receiving 1 or more immunisations at the clinic Total number of immunisations received by target children	All interventions except the general prompt significantly increased uptake. The monetary incentive had the largest effect followed by increased access, specific prompts.	No; outcome measure (1 or more immunisations)

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Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Young et al. [33], USA	RCT	Postal reminder	Children at risk of being overdue based on ≤ 1 parent not educated past high school, or 1 parent with a college education and ≥ 4 children	A: Postal reminder ($n = 253$) Control: Routine care. No reminder ($n = 254$) Intervention: Letter posted to parents of high-risk children who were 6 months of age during the intervention period. The letter was intended to reduce immunisation dropouts and was intended to act as a 'motivation' to return to the health centre	Children who received at least one vaccine Children bought up-to-date with the recommended schedule (3 \times DTP, 2 \times OPV)	Significantly more children received a vaccination following a motivational letter. More children were bought up-to-date in the postal reminder group but this did not reach significance	Yes
Education-based interventions							
Bolam et al. [36], Nepal	RCT	Postnatal health education	Mothers living in 2 communities served by government funded hospital	A: Education at birth in hospital + 3 months at home ($n = 135$) B: Education at birth in hospital ($n = 135$) C: Education at 3 months at home ($n = 135$) Control: No education ($n = 135$) Intervention: 20 min one-one health education discussion facilitated by questions posed to mother	Complete age appropriate immunisation (1 \times BCG, at least 2 \times DTP, 2 \times OPV) after 3- and 6-month follow-ups	Maternal education at birth did not significantly increase immunisation uptake of Nepalese children	Yes
Owais et al. [37], India	RCT	Postnatal health education	366 mother-infant pairs <6 weeks living in 1 of 5 low-income sites	A: Pictorial information cards ($n = 183$) Control: Verbal message about general health promotion ($n = 183$) Intervention: 5 min session with CHW using pictorial cards. Cards depicted information regarding the benefits of vaccines, logistics surrounding clinics and the need to retain immunisation records for school admission	Immunisation status of DTP-3/HBV at 4 months after enrolment	Receipt of pictorial information cards significantly improved uptake compared to routine care	Yes
Porter-Jones et al. [38], UK	RCT	Informative teddy bear	974 children due their 1st dose of MMR being seen by the HV for routine 8-month check	A: Teddy bear + routine care ($n = 542$) Control: Routine care ($n = 432$) Intervention: Children given teddy bear wearing a T-shirt that showed a website address that directed parents to an NHS portal for MMR information and the number of a telephone helpline	Uptake of the 1st dose of MMR	Receiving a teddy bear with MMR information sources did not increase uptake of the 1st dose compared to routine care	Yes
Quinlivan et al. [39], Australia	RCT	Educational home visits	136 mothers attending antenatal appointment at teenage pregnancy clinic	A: Home visits + routine post-natal support ($n = 65$) Control: Routine post-natal support ($n = 71$) Intervention: 6 structured home visits provided by a midwife conducted at 1 week, 2 weeks, and then bimonthly. Visits lasted 1–4 h and covered issues surrounding breastfeeding, contraception and immunisation	Complete uptake of all recommended immunisations at 6 months	Home visits did not increase immunisation uptake compared to routine care	Yes

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Saitoh et al. [40], Japan	RCT	Perinatal health education	Mothers attending 1 of 3 Obstetrics hospitals	A: Prenatal education at 34–36 weeks gestation (<i>n</i> = 34) B: Postnatal education 3–6 days post-delivery (<i>n</i> = 36) Control: Routine check up (36) Intervention: One-to-one interactive educational information on immunisation, including: vaccine types, effectiveness, side effects and scheduling	Complete uptake by 3 months	Immunisation uptake was significantly higher in the educational intervention groups compared to the control group. There were no significant differences in uptake between the pre and postnatal education groups	Yes
Shourie et al. [22], UK	Cluster RCT	Decision aid for MMR	Parents with children between 3 and 12 months registered at 1 of 50 GP practices	A: MMR decision aid + routine care (<i>n</i> = 50) B: 'MMR your questions answered' leaflet + routine care (<i>n</i> = 93) Control: Routine care (<i>n</i> = 77) Intervention: MMR decision aid contained detailed information about the risks and benefits of having and not having MMR and encouraged parents to evaluate the information in accordance with their values	First dose MMR uptake by 15 months ICC estimated as zero, no adjustment for clustering	Both interventions were successful in reducing decisional conflict but neither significantly improved uptake compared to routine care	Yes
Stille et al. [41], USA	RCT	Education	323 infants born at participating hospital who presented to 1 of 3 participating primary care sites <28 days old	A: Parental education + routine care (<i>n</i> = 156) Control: Routine care (<i>n</i> = 159) Intervention: Parents provided with a graphic card written in accordance with the HBM depicting the primary immunisation schedules, and leaving space to document child uptake along with general information. Providers also explained the card and answered any questions	Complete age-appropriate immunisation by 7 months	Parental education did not increase uptake by 7 months compared to routine care	Yes
Williams et al. [42], USA	Cluster randomised trial (2 sites)	Education	Vaccine hesitant parents attending 2 paediatric practices for 2-week well-child visits	A: Parental education (<i>n</i> = 55) B: Routine care (<i>n</i> = 67) Intervention: Parental education constructed using the HBM containing an 8 min video describing common concerns amongst vaccine hesitant parents, and two leaflets about vaccine concerns and how to find accurate medical information on the Internet	On-time receipt of all recommended vaccinations by 2 months ICC not reported, no adjustment for clustering	Receiving a brief educational session significantly improved uptake compared to routine care	Yes

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)	
	Wroe et al. [59], New Zealand	Non-randomised control trial	Antenatal decision aid	100 women attending hospital antenatal classes	A: Decision aid ($n = 50$) Control: Standard immunisation leaflet ($n = 50$) Intervention: 20 page booklet containing detailed information regarding the benefits/risks of vaccines, the role of emotions (e.g., omission bias) and the golden rule to encourage decision-making from child's perspective	Number (%) of children immunised on-time, late or unimmunised by 3 months	A significantly higher proportion of infants who received the decision aid were immunised on time compared to control group infants	No; outcome measure (on-time immunisation)
Education- and reminder-based interventions								
	Hawe et al. [43], Australia	RCT	Educational postal reminder	Parents of children born 1987–1988	A: HBM reminder card ($n = 124$) Control: Usual vaccination reminder card ($n = 135$) Intervention: Reminder cards worded in accordance to the HBM. Cards worded to prompt immunisation by stating (1) the severity of measles, (2) the susceptibility of children <2 years and (3) the risks of the disease outweigh those of the procedure	Percentage of children vaccinated against measles/mumps in the 5 weeks following postal reminder	A significantly greater proportion of children were immunised following receipt of the HBM card compared to the usual reminder card	Yes
	Mason and Donnelly [45], UK	RCT	Postal reminder and information	Children living in a health authority born between November 1996 and April 1997 who had not received MMR by 21 months	A: Postal reminder + informational leaflet ($n = 255$) Control: Routine care. No reminder ($n = 256$) Intervention: Personal reminder letter sent to parents, GP and HV of child due for immunisation. Parents also sent the leaflet <i>MMR: the facts</i>	MMR uptake between 21 and 24 months-old	Personal reminder letters including an informational leaflet did not increase MMR uptake compared to routine care	Yes
	Oeffinger et al. [44], USA	RCT	Education and reminder	238 mother–infant pairs delivered by family practice residents	A: Educational discussion + postal reminder ($n = 116$) Control: Routine care ($n = 122$) Intervention: 10–15 min discussion on the 1st day postpartum with a nurse or physician about the risks and benefits of immunisation. Mothers also given 1-page hand-out summarising points made in the discussion and were sent a reminder letter 2 months post delivery	Complete uptake of first 3 doses of DTP/OPV by 1 year	Postnatal education and reminder did not significantly improve uptake compared with routine care	Yes
	Usman et al. [30], Pakistan	RCT	Immunisation card and centre-based education	1500 mother–child dyads attending 5 urban EPI centres	A: Redesigned card ($n = 375$) B: Centre-based education ($n = 375$) C: Redesigned card + centre-based education ($n = 375$) Control: Routine care ($n = 375$) Intervention: Parents were given a redesigned reminder card detailing date and location of their appointment and instructed to place the card in a visible location and/or received a 2–3 min education session emphasising the importance of immunisation at the EPI centre	Complete uptake of 2nd and 3rd doses of DTP at the end of 90 day follow-up	Immunisation uptake was significantly improved in all intervention groups. Reminder cards and centre-based parental education significantly increased uptake	Yes

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Usman et al. [31], Pakistan	RCT	Immunisation card and centre-based education	1506 mother–child dyads attending 6 rural EPI centres	A: Redesigned card (<i>n</i> = 378) B: Centre-based education (<i>n</i> = 374) C: Redesigned card + centre-based education (<i>n</i> = 376) Control: Routine care (<i>n</i> = 378) Intervention: Parents were given a redesigned reminder card detailing date and location of their appointment and instructed to place the card in a visible location and/or received a 2–3 min education session emphasising the importance of immunisation at the EPI centre	Complete uptake of 2nd and 3rd doses of DTP at the end of 90 day follow-up	Immunisation uptake was significantly improved in all intervention groups. Reminder cards and centre-based parental education significantly increased uptake	Yes
Lay Health Workers							
Barnes et al. [46], USA	Before and after RCT	Education by LHWs	434 parent–child pairs at 1 of 2 paediatric centres who were <2 years-old and behind schedule	A: LHW home visits (<i>n</i> = 218) Control: Reminder at enrolment visit (<i>n</i> = 216) Intervention: LHW home visits provided immunisation education and clinic referral, followed by 6-month reminder period	Complete age-appropriate immunisation after 6-month follow-up period	LHW home visits significantly improved immunisation uptake in the intervention group compared to routine care	Yes
Brugha and Kevany [47], Ghana	Cluster RCT	Home visits by LHW	60 clusters containing 36–39 residences containing children 12–18 months-old	A: Survey + clinic referral and home follow-up (<i>n</i> = 200) Control: Survey only (<i>n</i> = 219) Intervention: Child immunisation status established by interview and clinic referral made. Advice targeted to parents of incompletely immunised children. Nurse followed up non-attendance up to 3 times in 6 months	Immunisation coverage at completion of home visit intervention based on health record and mother's history. No ICC reported to adjust for clustering	Mean immunisation significantly higher in the 30 intervention clusters (clinic referral and home follow-up) than the control group clusters	Yes
Johnson et al. [48], Ireland	RCT	Education by LHWs	262 first time mothers living in a deprived area	A: Home visits from 'Community mother' + Routine care (<i>n</i> = 141) Control: Routine care (<i>n</i> = 121) Intervention: Monthly visits from the community mother providing information and guidance on child health and development, including immunisations	Complete uptake of primary immunisation schedule by 12 months	Infants whose mothers received home visits were significantly more likely to have completed their primary course of immunisations by 1 year	Yes
Norr et al. [49], USA	RCT	Home visits by LHW	588 mother–infant pairs attending 1 of 2 prenatal clinics living in a low-income area	A: Home visits + routine care (<i>n</i> = 258; A-A = 182; M-A = 26) Control: Routine care (<i>n</i> = 219; A-A = 141; M-A = 78) Intervention: Monthly home visits by the nurse and/or LHW 2 weeks after hospital discharge to discuss child health and development. Home visits were replaced by telephone calls after 2 months if mother–infant pairs were doing well	Complete uptake by 12 months documented by maternal report and medical records	Immunisation uptake not significantly improved by home visits compared to routine care. Immunisation rates were significantly higher in M-A compared to A-A children	Yes

Table 2 (Continued)

Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)	
Studies not included in the meta-analysis							
Andersson et al. [18], Pakistan	Cluster RCT	LHW lead group discussion	In each of the 32 enumeration areas, 100 children <60 months	A: Community discussion + health education programme (18 clusters) Control: Health education programme (14 clusters) Intervention: Three-phase community based discussion based on (1) the prevalence of childhood diseases, (2) costs and benefits to immunisation and (3) Community specific barriers and challenges to uptake	Uptake of measles and 3 × DTP between 12 and 23 months	Immunisation uptake was significantly higher for children in the community discussion clusters than clusters that received health education alone	No; not comparable with other studies
Banerjee et al. [19], UK	Cluster RCT	Incentive	30 households containing children aged 0–5 years randomly selected from 134 villages	A: Immunisation camp (30 villages, 379 children) B: Immunisation camp + incentive (30 villages, 382 children) Control: No camp or incentive (74 villages, 860 children) Intervention: Monthly 'immunisation camp' offering regular immunisation services. Additional incentive offered to group B consisting of 1 kg raw lentils per immunisation administered and a set of metal plates upon completion of full schedule	Complete or partial uptake of 1 × BCG, 3 × DTP, 3 × OPV, 1 × measles	Small incentives to immunise had a greater positive impact (RR = 6.7) on uptake compared to improving services alone (RR = 2.2)	No; not comparable with other studies
Bond et al. [8], Australia	RCT	Home vaccination	Children 90 days late for 3rd dose DTP/OPV/Hib or 120 days late for MMR living in 1 of 10 council areas	A: Home vaccination service (n = 81) Control: Routine care (n = 88) Intervention: Home vaccination at a time convenient to parents	Complete uptake of DTP/OPV/Hib or MMR	Home vaccination significantly increased immunisation uptake compared to routine care	No; not comparable with other studies
Bond et al. [60], Australia	Cross-sectional before and after	Incentive	Children <3 years attending a registered child care centre	Governmental parent incentive scheme. To receive childcare benefits and Maternity Allowance parents must demonstrate complete immunisation of child	Proportion of children between 1997 and 2000 who were: 1. Fully immunised; 3 milestones complete (1. 3 × DTP, 3 × Hib, 3 × OPV; 2. MMR; 3. DTP/Hib). 2. Age appropriately immunised	Significantly more children were fully immunised in 2000 following the introduction of the governmental incentive compared to 1997 before it was introduced	No; study design
Crittenden and Rao [61], UK	Before and after study	General encouragement	Parents of non-attending children	Intervention: Reasons for non-compliance discussed with GP and HV before postal contact made. If necessary a home visit was made to discuss vaccination or administration scheduled for a hospital visit (n = 93)	Complete uptake of primary vaccines or preschool booster		No; study design

Table 2 (Continued)

	Study design	Intervention type	Population/setting	Intervention	Outcomes measured	Summary of findings	Included in meta-analysis? (Yes/No; reason for exclusion)
Ferson et al. [62], Australia	Randomised trial (no control)	School-nurse	239 incompletely immunised 5 year olds attending 1 of 28 primary schools	A: Written material in appropriate language ($n = 119$) B: Written materials + phone call 1–2 months after information ($n = 120$) Intervention: Written material to encourage immunisation uptake. Telephone call established uptake or encouraged uptake in cases where child remained unimmunised	Uptake of measles and/or booster immunisations classified as complete, some or none	Significantly more children were immunised following a telephone call compared to the provision of written materials alone	No; study design
Rodewald et al. [20], USA	RCT	Tracking with outreach LHW and provider prompting	3015 infants attending 1 of 9 primary care practices born between 01/03/1993 and 28/02/1994	A: Tracking/outreach + prompting ($n = 732$) B: Tracking/outreach only ($n = 715$) C: Prompting only ($n = 801$) Control: Routine care ($n = 767$) Intervention: Tracking/outreach was provided by LHWs who worked with parents of under immunised infants to bring them to the primary care office using postcards, telephone calls and home visits. Prompting was provided by the primary care office that used reduced missed opportunities by immunising necessary children regardless of visit type	Immunisation status on the last day of the intervention classed as complete uptake for age-appropriate schedule	Tracking/outreach and prompting significantly increased immunisation uptake by 20% and reduced the delay in immunisation by 63 days	No; not comparable with other studies
Wood et al. [21], USA	RCT	Case management	419 mother–infant dyads living in 1 of 10 enrolment zip codes	A: Case management + Health Passport ($n = 209$) Control: Health Passport only ($n = 210$) Intervention: In-depth assessment at home when infant <6 weeks and subsequent visits 2 weeks before scheduled appointment by case manager. Managers provided information about immunisation and sought to overcome barriers such as lack of insurance and transport	Complete immunisation by 12 months defined as the receipt of 3 × DTP, 2 × OPV, 3 × Hib	Immunisation uptake was significantly improved by 13.2% in the case management group compared to routine care	No; not comparable with other studies

Note. DTP = Diphtheria, Tetanus, Pertussis; DTaP = Diphtheria, Tetanus, acellular Pertussis; IPV = inactivated Polio vaccine; OPV = oral Polio vaccine; Hib = *Haemophilus influenzae* type b; Hib/MenC = *Haemophilus influenzae* type b and meningitis C; MMR = Measles, Mumps and Rubella; HBV = Hepatitis B vaccine; PCV = Pneumococcal vaccine; BCG = Tuberculosis vaccine; M-A = Mexican-American; A-A = African-American; HBM = Health Belief Model.

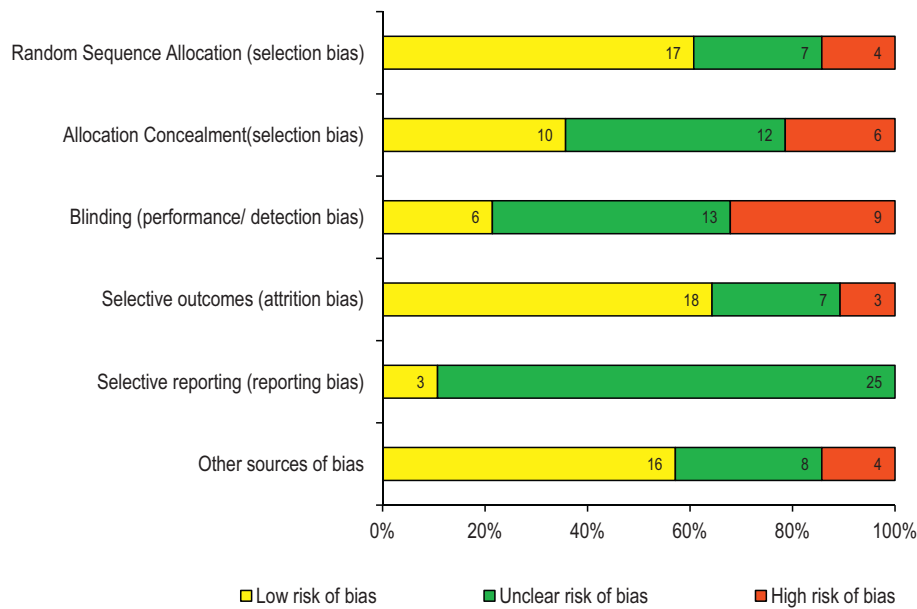


Fig. 2. Risk of bias chart for studies included in the meta-analysis ($n=28$). Numbers at the end of each bar show the number of studies within each judgement for each attribute in the tool.

Sub-group analyses were performed according to the personalisation and focus of postal reminders to explore the heterogeneity between studies. Sub-group findings also displayed heterogeneity and hence, random effects models are reported. Results suggest that the specificity of postal reminders did not influence efficacy, as all results were similarly positive. Both personal [23,24,26–28,30,31] (including the child’s name, immunisations due and/or appointment detail; $n=7$; $RD=0.112$; $95\% \text{ CI}=0.037–0.187$, $p=.004$) and non-personal reminders [24,25,29,32,33] ($RD=0.075$; $95\% \text{ CI}=0.024–0.125$, $p=.004$) were associated with a significant increase in uptake. Likewise, letters that were targeted (recall) to children overdue their scheduled vaccines or those at a high-risk of non-compliance [27–29,32,33] ($RD=0.091$; $95\% \text{ CI}=0.030–0.153$, $p<.001$), and those that were not [23–26,30,31] (reminder; $RD=0.10$; $95\% \text{ CI}=0.020–0.190$ $p<.001$) had a positive effect on uptake.

3.4.2. Telephone

Five studies (1 sequentially allocated control trial, 4 RCTs) examined the efficacy of telephone reminders [25,26,29,32,34]. Telephone calls were made and/or messages were left with parents to remind them that their child’s immunisations were due or overdue. As heterogeneity was minimal, a fixed effects model was used. Receiving a telephone reminder (Fig. 3b) was associated with a significant 4% increase in immunisation uptake ($RD=0.040$; $95\% \text{ CI}=0.006–0.073$, $p=.019$). One large study [34] dominated the analysis. Heterogeneity of findings was low and thus a random effects model produced similar findings.

3.4.3. Combined postal and telephone (recall and reminder)

Four studies (1 sequentially allocated control trial, 3 RCTs) assessed the impact of receiving a postal reminder letter and telephone prompt on childhood immunisation uptake [25,26,32,35]. The fixed effect model found that the receipt of both postal and telephone reminders (Fig. 3c) was associated with a significant 10.6% improvement in immunisation uptake compared with controls ($RD=0.106$; $95\% \text{ CI}=0.070–0.143$, $p<.001$). Substantial heterogeneity was found between the studies, with individual study findings ranging from a 3.2% to 18.9% increase in uptake, meaning the size of the effect cannot be accurately determined. Nevertheless,

use of combined reminders remained significant using a random effects model ($RD=0.113$; $95\% \text{ CI}=0.033–0.193$, $p<.006$).

One study [26] was methodologically different from others in the group because it used a combination of postal and telephone reminders to inform parents of their child’s appointment before they were due, whereas the remaining studies used one method to inform parents of their child’s appointment details (recall), and only used another method if children remained unimmunised after 1 week (reminder). Excluding this trial reduced heterogeneity ($I^2=31.6\%$), while the overall effect remained similar ($RD=0.147$; $95\% \text{ CI}=0.10–0.195$, $p<.001$).

3.5. Effectiveness of education-based interventions

Seventeen studies evaluated the impact of parental education. Pooled risk differences were calculated for the effect of educational interventions, education and reminder and the support of a Lay Health Worker (LHW).

3.5.1. Immunisation education

Ten studies (2 cluster RCTs; 8 RCTs) examined the effect of providing parents with immunisation-based education [22,30,31,36–42]. Parents were advised about immunisation or general child health before their child’s immunisation appointment. Education was facilitated by a discussion with a trained professional, or by written information in picture card or leaflet format. One study provided parents with the details of how to access several written educational sources. Two studies included intervention groups who received education at different time points; intervention groups are pooled for these trials [36,39]. The overall fixed effect suggests that parental education significantly improved immunisation uptake by 8.3% (Fig. 4a; $RD=0.083$; $95\% \text{ CI}=0.056–0.110$, $p<.001$). However, findings from individual studies ranged from a 1.6% decrease to 26% increase in immunisation uptake and substantial heterogeneity was found in the data. A random effects model reported a similar average effect of intervention ($RD=0.078$; $95\% \text{ CI}=0.013–0.142$, $p=.018$).

Heterogeneity was explored by sub-group analyses performed according to study country income, intervention timing, frequency and method. Similar levels of heterogeneity were found, thus

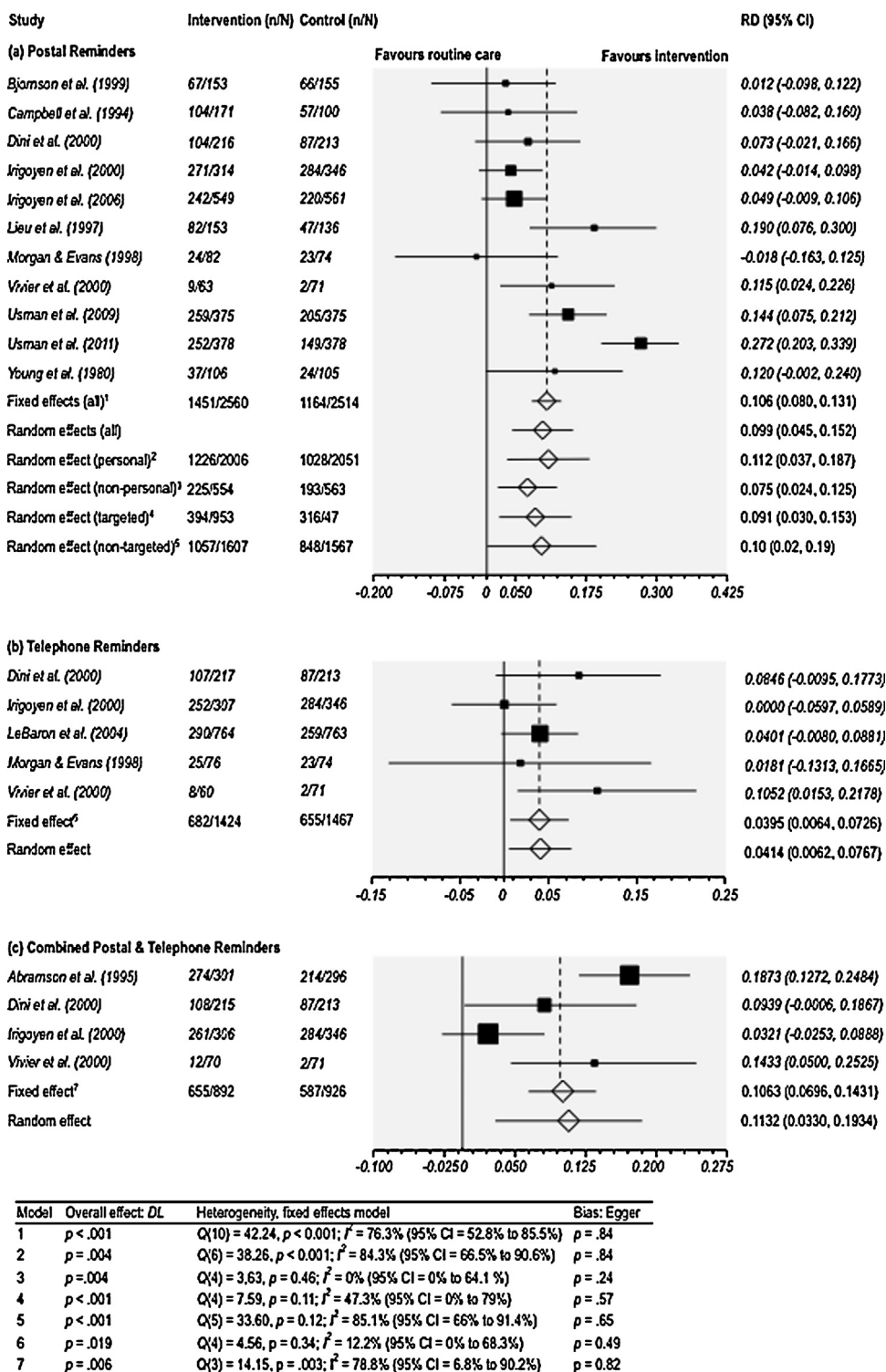
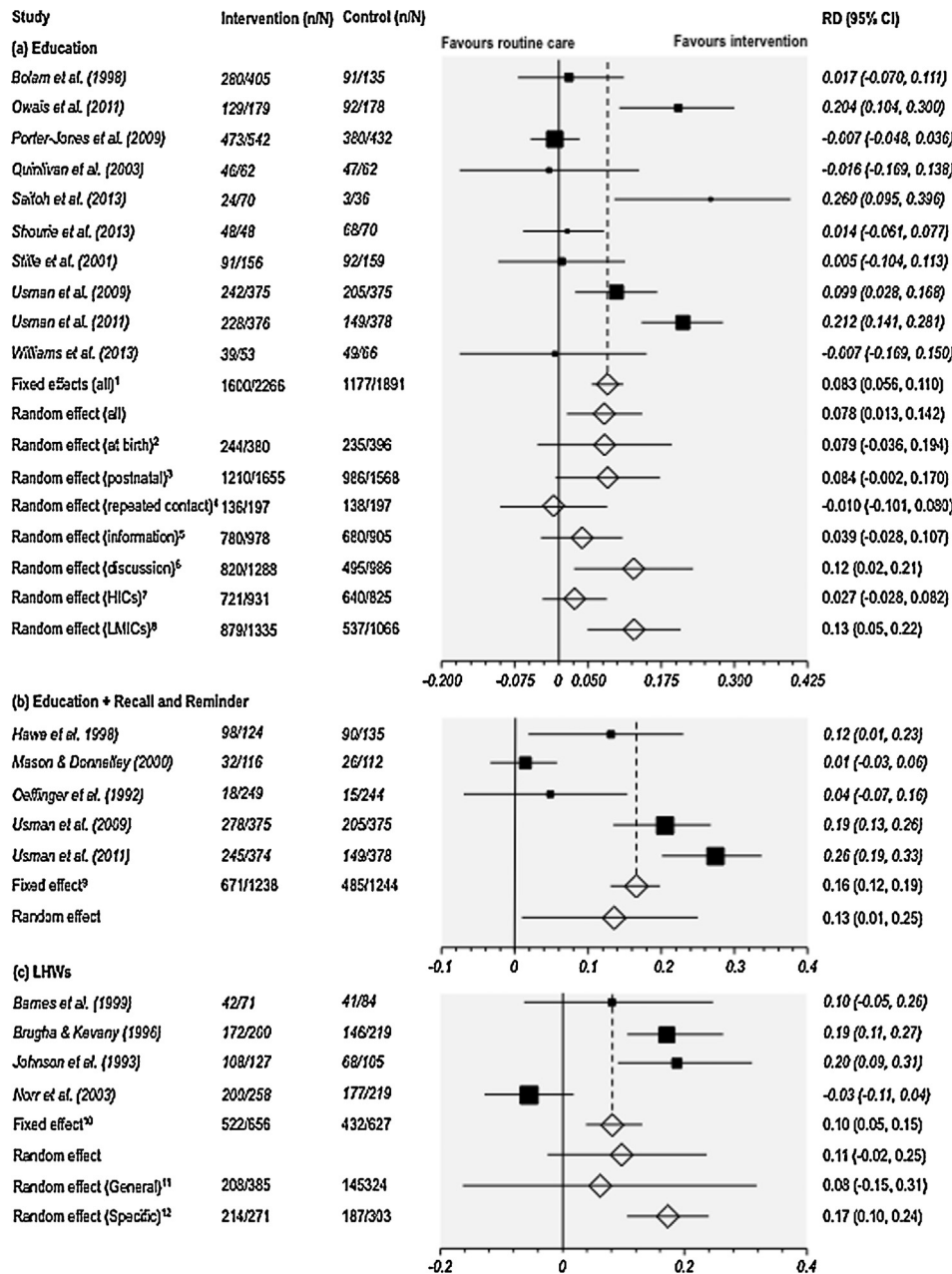


Fig. 3. Reminder-based interventions.

random effects models are reported. The overall effects of studies offering parental education at birth [36,40–42] (infant < 1 month) and post-natally [22,30,31,36–38] (infant > 1 month) were similar. Results suggested that the efficacy of educational interventions varied between low- and high-income countries, and the method of education used. LMIC studies [30,31,36,37] found education to be significantly more effective than routine care, improving uptake by 13% (RD=0.13; 95% CI=0.05–0.22, $p=.002$), while

those in HICs [22,38–42,63] were not found to be consistently effective. Discussion-based interventions [30,31,36,39,40] significantly improved uptake by 12% compared to routine care (RD=0.12; 95% CI=0.02–0.21, $p=.014$). Interventions providing parents with written educational information [22,37,38,41,42] were not found to be effective. Study numbers were too small to explore interactions between country income and intervention methods.



Model	Overall effect: DL	Heterogeneity	Bias: Egger
1	$p = .018$	$Q(9) = 59.36, p < .001; I^2 = 84.8\%$ (95% CI = 72.9% to 90.1%)	$p = .38$
2	$p = .176$	$Q(3) = 8.68, p = .034; I^2 = 65.4\%$ (95% CI = 0% to 88.1%)	$p = .38$
3	$p = .055$	$Q(5) = 50.09, p < .001; I^2 = 0\%$ (95% CI = 82.7% to 94.1%)	$p = .31$
4	$p = .82$	$Q(1) = 0.008, p = .928; I^2 = \text{test not performed}$	$p = \text{test not performed}$
5	$p = .253$	$Q(4) = 16.90, p = .002; I^2 = 76.3\%$ (95% CI = 15.6% to 88.4%)	$p = .47$
6	$p = .014$	$Q(4) = 18.62, p < .001; I^2 = 78.5\%$ (95% CI = 28.7% to 89.2%)	$p = .76$
7	$p = .330$	$Q(5) = 12.49, p = .029; I^2 = 60\%$ (95% CI = 0% to 81.7%)	$p = .34$
8	$p = .003$	$Q(3) = 14.05, p = .003; I^2 = 76.8\%$ (95% CI = 5.5% to 90.1%)	$p = .81$
9	$p = .04$	$Q(4) = 56.42, p < 0.01; I^2 = 92.9\%$ (95% CI = 86.9% to 95.5%)	$p = .56$
10	$p = .085$	$Q(3) = 21.51, p < 0.001; I^2 = 86.1\%$ (95% CI = 57% to 92.8%)	$p = .65$
11	$p = .491$	$Q(1) = 12.22, p < 0.001; I^2 = \text{test not performed}$	$\text{test not performed}$
12	$p < .001$	$Q(1) = 1.04, p = 0.31; I^2 = \text{test not performed}$	$\text{test not performed}$

Fig. 4. Education-based interventions.

3.5.2. Immunisation education and postal reminders

Five RCTs examined the efficacy of interventions that provided parents with some form of immunisation education in addition to a postal reminder [30,31,43–45]. The fixed effect model found parental education and postal reminders (Fig. 4b) led to

a 16% increase in uptake (RD = 0.16; 95% CI = 0.12–0.19, $p < .001$), although with substantial heterogeneity. Individual study findings ranged from 1% to 26% improvements, with the two largest studies reporting the greatest effect, being conducted in Pakistan [30,31]. A positive effect of education and postal reminders remained,

using a random effects model (RD=0.13; 95% CI=0.01–0.25, $p=.04$).

3.5.3. Support from Lay Health Workers (LHWs)

Four studies (1 cluster RCT, 3 RCTs) examined the impact of parental education about immunisation and advice from a LHW [46–49]. For the purposes of this review, LHWs were defined as a health worker providing education about immunisation, but who had not received any formal healthcare training. LHWs comprised of volunteer mothers, O-level graduates and community workers. A significant effect of LHWs (Fig. 4c) was found using the fixed effects model (RD=0.10; 95% CI=0.05–0.15, $p<.001$). However, individual study findings were mixed (ranging from a decrease of 3% to an increase of 20%) and substantial heterogeneity was found. A random effects model did not reach statistical significance (RD=0.11; 95% CI=−0.02 to 0.25, $p=.09$). Sub-group analyses accounting for the specificity of LHW advice found that specific immunisation advice [46,47] was associated with a significant 17% increase in immunisation uptake (RD=0.17; 95% CI=0.10–0.24, $p<.001$).

4. Discussion

There is evidence to support the efficacy of postal and/or telephone reminders, parental education, and parental education with postal reminders for improving child immunisation uptake.

Reminder-based interventions were significantly more effective than routine care independent of their method of delivery. This finding is comparable to that of a previous Cochrane review that found that reminder systems were efficacious for immunisation uptake across the lifespan [9]. The present review however, conducted separate meta-analyses for individual reminder strategies specific to childhood immunisations and found that postal reminders were more effective than telephone reminders. Hence postal reminders are recommended for use in primary care to improve childhood vaccine uptake. Moreover, postal and telephone reminders had an additive impact on uptake; their combined use was associated with a greater increase in immunisation uptake than the use of each strategy alone. However, this effect could be an artefact of the more intensive recall-reminder strategies used in these trials and suggests that recall strategies may be particularly effective in parents whose children may be at risk of non-attendance. There is a need for future research to explore the efficacy of this intervention in trials comparing children at high and low risk of non-compliance.

The overall group analysis suggested that educational interventions significantly increased childhood immunisation uptake. However, sub-group analyses suggested that this effect was driven by two factors: (a) the study occurring in an LMIC and (b) parents having a discussion with a professional expert, rather than receiving information in written form. Analysis did not suggest that the timing or intensity of education impacted upon its effectiveness. The baseline education levels of the participants enrolled in included studies may explain the increased efficacy of interventions conducted in LMICs. Approximately 50% of mothers enrolled in studies within this comparison were illiterate or had no education. Secondary levels of maternal education have been associated with a two-fold increase in childhood immunisation compared to mothers with no education [63]. Interventions that raise the basic level of parental knowledge are therefore more effective in areas where understanding is low compared to countries where it is comparatively higher and educational barriers to immunisation may be more subtle and linked to vaccine belief [2,4]. Contrary to a previous meta-analysis [11,64], the overall effectiveness of LHWs could not be recommended following the application of a random effects model [20,34,46–49]. Sub-group analyses did suggest that parents

who received specific vaccine support from an LHW might be more effective than general support that did not extend beyond topics covered by health visitors in routine care, suggesting an avenue for future research.

Keys to the efficacy of discussion-based educational interventions may come from qualitative findings that suggest that discussion with a trusted medical practitioner may facilitate immunisation compliance owing to the depth and clarity of understanding gained compared to the reported overwhelming nature of written information leaflets [65–67]. These findings suggest that providing parents with the opportunity to discuss immunisations in detail with a healthcare professional may further facilitate immunisation rates. However, due to the additional human resources needed to incorporate practitioner-lead discussion within primary care settings, policy planners may be mindful to reserve these strategies for vaccine-hesitant parents.

The overall utility of educational strategies within standard practice may be further questioned when examined alongside the results of trials that provided parents with both immunisation education and appointment reminders. Using the same methods in both rural and urban settings, the two Usman et al. trials [30,31] examined education and reminder strategies in separate and combined study arms. In both communities, improvements of uptake in groups who received the combined intervention were minimal in comparison to postal reminders alone. This finding has implications for policy as it suggests that reminder systems may be sufficient facilitators of childhood immunisation in the majority of cases, and that discussion-based strategies may be most effective in families with children at high-risk of non-compliance. Such strategies may increase compliance because they acknowledge parental concerns about vaccination. Addressing these concerns in a discussion with a medical professional regarding the risks and benefits of vaccination may change the parental attitudes, knowledge and beliefs about vaccination. Changes in attitude may facilitate behaviour change; facilitating a pro-vaccination decision further facilitates subsequent vaccine uptake. However, the effectiveness of such strategies must be tested in future trials.

4.1. Strengths and limitations

Whilst the findings of this review help to summarise the large body of literature on parental interventions for childhood immunisation uptake, several limitations were apparent. First, substantial heterogeneity was evident in all of the comparisons except telephone reminders. Although random effects models were utilised to investigate the mean distribution of underlying intervention effects, such models do not identify reasons for variation. Unexplained heterogeneity suggests there may be some differences in study method and/or services provided that explain why interventions were effective in some cases but not in others. Although there were too few studies within the published research sampled to explore this formally, the effect of differences in study context can be illustrated by the two Usman et al. studies [30,31]. These studies utilised the same method of allocation, intervention strategy and outcome measure but were conducted in urban and rural areas of Pakistan respectively. However, they found a 12.8% difference in immunisation uptake of parents who received postal reminders in favour of rural communities, suggesting factors not reported such as access to, and interaction with, healthcare services may contribute to the success of interventions. Owing to the limits of journal space, the authors were unable to provide additional detail regarding risk of bias judgements for individual studies and excluded studies however; such details are available on request.

Variation between studies may also explain the discrepancy between the results of the present study and two previous reviews on LHWs [11,65]. The present review examined the effects of

education provided by LHWs and therefore did not include two [20,34] out of four studies [20,34,46,48] previously analysed. Instead, two additional studies [47,49] were included. This difference and the high levels of heterogeneity found between studies in each review may explain this disagreement and further exaggerates the limited conclusions that can be made by presently available studies in the field.

Second, many of the strategies used in reminder-based interventions may not be relevant to the parents of today. Mobile phones are owned by large majorities of people living in major countries around the world, 75% of whom use their mobile phones for texting [68]. For example, 96% of mobile phone owners in Indonesia, a country where less than 50% of children do not receive the three doses of DTP [2], use their mobile phones to text. The increasing commonality of access to technology including mobile phones and text messaging may offer increased effectiveness in terms of outcome and cost. Several small-scale studies have linked text message reminders to improvements in both adolescent [69,70], and childhood [71] immunisations. However, larger RCTs are necessary to make firmer conclusions about the efficacy of such interventions.

4.2. Conclusions

The findings of this review suggest that several interventions, particularly postal reminders, combined recall and reminder strategies and discussion-based education, can increase childhood immunisation uptake. The precise effectiveness of these interventions is likely to be influenced by numerous factors such as country of intervention and levels parental vaccine hesitancy that need to be explored by future trials. This review highlights the potential benefits to childhood vaccine uptake of incorporating parental interventions, particularly postal reminders into the standard management of childhood immunisations, and the use of recall strategies and/or discussion-based forums with parents whose children are at high risk of non-compliance.

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Conflict of interest

None declared.

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