VOLUME 22 NO 5 PP 526–538 MAY 2017

Systematic Review

Does targeting children with hygiene promotion messages work? The effect of handwashing promotion targeted at children, on diarrhoea, soil-transmitted helminth infections and behaviour change, in low- and middle-income countries

Julie A. Watson[1,a], Jeroen H. J. Ensink[1], Monica Ramos[2], Prisca Benelli[2], Elizabeth Holdsworth[3], Robert Dreibelbis[1] and Oliver Cumming[1]

1 *Department for Disease Control, London School of Hygiene and Tropical Medicine, London, UK*
2 *Save the Children, London, UK*
3 *Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine, London, UK*

Abstract

OBJECTIVES To synthesise evidence on the effect of handwashing promotion interventions targeting children, on diarrhoea, soil-transmitted helminth infection and handwashing behaviour, in low- and middle-income country settings.

METHODS A systematic review of the literature was performed by searching eight databases, and reference lists were hand-searched for additional articles. Studies were reviewed for inclusion according to pre-defined inclusion criteria and the quality of all studies was assessed.

RESULTS Eight studies were included in this review: seven cluster-randomised controlled trials and one cluster non-randomised controlled trial. All eight studies targeted children aged 5–12 attending primary school but were heterogeneous for both the type of intervention and the reported outcomes so results were synthesised qualitatively. None of the studies were of high quality and the large majority were at high risk of bias. The reported effect of child-targeted handwashing interventions on our outcomes of interest varied between studies. Of the different interventions reported, no one approach to promoting handwashing among children appeared most effective.

CONCLUSION Our review found very few studies that evaluated handwashing interventions targeting children and all had various methodological limitations. It is plausible that interventions which succeed in changing children's handwashing practices will lead to significant health impacts given that much of the attributable disease burden is concentrated in that age group. The current paucity of evidence in this area, however, does not permit any recommendations to be made as to the most effective route to increasing handwashing with soap practice among children in LMIC.

keywords hand washing, systematic review, children, behaviour change, diarrhoea, helminth

Introduction

The global burden of disease associated with poor water, sanitation and hygiene (WASH) is concentrated among children and thus promoting the practice of handwashing with soap (HWWS) among children presents an important public health measure [1].

Pneumonia and diarrhoea are two of the leading causes of child mortality globally and account for over 900 000, and 500 000 deaths per year in children under five years, respectively [2], many of which may be preventable with improved hygiene [3–5]. Systematic reviews have consistently shown that HWWS is effective at reducing diarrhoeal disease, and can reduce the risk of diarrhoea by up to 48%, [1, 6–8], with the current best estimate believed to be around a 23% risk reduction [9]. In fact,

[a]This article is dedicated to the late Dr. Jeroen Ensink. As a researcher, and as a teacher, Jeroen made a huge contribution to the field of environmental health. His wisdom, patience and good humour are much missed by his many collaborators and friends around the world.

it has been argued that HWWS is one of the single most cost-effective of all public health interventions [10]. HWWS acts as an important barrier in the transmission of diarrhoea-causing aetiological agents via the faecal–oral pathway by preventing faeces from entering, and being transmitted in the domestic environment [11].

In 2015, the sustainable development goals (SDGs) were launched and the target set for SDG 3.2 was to end, by 2030, the preventable deaths of newborns and children under five years [12]. With pneumonia and diarrhoea among the leading causes of deaths in these age groups, WASH interventions represent one of the most cost-effective methods to help achieve this goal [10]. HWWS is a key part of the integrated Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea (GAPPD) framework, which proposes a cohesive approach to ending preventable pneumonia and diarrhoea deaths [13].

Children also are the population most vulnerable to soil-transmitted helminth (STH) infection, with prevalence and intensity peaking between the ages of 5 and 14 [14]. STHs are parasitic intestinal nematodes passed to humans through contact with soil contaminated with infected faeces and are one of the most common human infections worldwide, with a disproportionate burden in the poorest and most deprived populations [15]. STH infection is recognised as one of the most important causes of stunting in children and can also lead to long-term effects on cognitive development and educational achievement, which may hinder future economic development [14].

Whilst, historically, there has been less research assessing the relationship between HWWS and STH than between HWWS and diarrhoea, a recent systematic review also found handwashing interventions to be an effective measure to prevent the transmission and reduce the infection intensity of *Ascariasis lumbricoides*, a common STH. Handwashing can reduce the risk of *A.lumbricoides* infection by up to 62% [16].

No previous systematic reviews seem to have assessed the effectiveness of targeting handwashing promotion at children in LMICs. A recent Cochrane review of handwashing promotion to prevent diarrhoea did assess the effect of handwashing promotion on preventing diarrhoea, however, results were stratified by setting before being stratified by age, and, within these settings, the author did not analyse the effect of targeting handwashing promotion at children but only the effect of *any* handwashing promotion on diarrhoeal episodes in children [1]. The purpose of this systematic review is to assess if handwashing promotion, targeted at children in LMICs, is effective at increasing handwashing behaviour and consequently reducing diarrhoea and STH infection among children and their families. Handwashing behaviour is a primary outcome of interest in this review as this is the proposed mechanism to achieve reductions in communicable disease. Diarrhoeal disease is also a primary outcome of interest as this outcome is commonly used to measure the effectiveness of hygiene interventions and the link between diarrhoea and WASH is well known [8, 9]. Including STH infection as a primary outcome offers a measure which potentially has a lower risk of bias because diarrhoea is often measured by self-report, whilst STH can be measured objectively through standard diagnostic tests, such as the commonly used Kato–Katz method and the more sensitive FLOTAC method [17]. Although there is only evidence that handwashing reduces *A. lumbricoides* infection, this helminth is commonly grouped together with the helminths *Trichuris trichuria* and hookworm, and referenced as 'STH'.

Methods

Search strategy

Searches were carried out in July 2016, using eight bibliographic databases: MEDLINE, EMBASE, Global Health, CINAHL Plus, Scopus, IBSS, Africa-Wide Information and Web of Science. The search strategy incorporated terms related to: (i) children; AND (ii) handwashing promotion; AND (iii) (diarrhoea OR soil-transmitted helminths, OR behaviour). The search strategy was originally developed for MEDLINE (MESH terms were identified), before being adapted for use in bibliographic databases using database-specific controlled vocabulary terms and search filters. Reference lists of included studies were hand-searched for additional relevant citations. A full description of the search strategy and search terms for the MEDLINE database can be found in Appendix S1.

Screening and inclusion criteria

Studies were eligible for inclusion if they were published in a peer-reviewed journal, on any date up until 7 July 2016, and available in English. Qualitative studies and studies that were published as conference abstracts or posters were excluded. Eligible study designs included: randomised controlled trials (RCTs), non-randomised controlled trials (NRCTs) and controlled before–after (CBA) studies (with a concurrently enrolled control group). These study designs were selected to limit the risk of bias.

After screening, articles needed to meet five criteria to be included: (i) the study evaluated a clearly described hygiene promotion intervention including, or exclusively focussed on, messages around handwashing; (ii) the evaluated intervention targeted children between the ages of five and eighteen; (iv) the study was conducted in a low- or middle-income country, as defined by the World Bank [18]; (v) the study reported an effect on one or more of the outcomes of interest (detailed below). We excluded studies in which water, sanitation or other health interventions (with the exception of soap provision) were implemented concurrently, unless the study was able to report the effect of the hygiene promotion component targeting children separately. Similarly, studies in which children were not the only main targets of the intervention were excluded unless the effects of a distinct intervention component targeting only children could be clearly stratified.

Intervention

We included interventions that promoted handwashing (with or without soap) at any specified key moment, for example: after toilet use (defecation or urination), before preparing or handling food, before eating, after sneezing and coughing, upon arriving at school, after playing with soil, and during bathing. Intervention activities could include, for example: hygiene education, posters, group discussions, theatre, peer-monitoring, teacher monitoring, handwashing pledges, videos, comic books, songs, poems, games, drawing, puppet shows, mascots, rewards, competitions and environmental cues.

Outcomes

The primary outcomes of interest were the following: [1] handwashing behaviours (cleansing hands with water, with soap and water, or with hand sanitiser, at any key moment as listed above); [2] diarrhoea morbidity [prevalence or incidence] or mortality [regardless of aetiology and case confirmation]; and [3] one or more soil-transmitted helminth[1] infection [including prevalence and/or intensity]. Any reported change in knowledge with regard to handwashing with soap was a secondary outcome of interest. For all outcomes of interest, we included measurements taken at an individual or cluster level, and for either the target children or their families, since evidence suggests children can be effective agents of change [20]. For the handwashing behaviour outcome, we included studies using either direct measures of handwashing behaviours or soap consumption as a proxy measure.

[1]The main species that infect humans are roundworm (Ascaris lumbricoides), whipworm (Trichuris trichuria), and hookworm (Necator americanus and Ancylostoma duodenale) [19].

Study selection, data extraction and analysis

All results retrieved from database searches were exported into Endnote X7.1 (Thomson Reuters, New York, USA) and duplicates removed. Results were screened by title and abstract, by a single reviewer (JW), and non-eligible studies excluded. The full text for eligible studies was then independently reviewed by two reviewers (JW and OC), and a final decision on the inclusion of studies was reached by consensus.

Data were extracted into a pre-specified data extraction table, recording the following information: (i) study authors and publication date, (ii) intervention content, (iii) intervention methods, (iv) control group, (v) setting, (vi) study design, (vii) intervention length/intensity (intervention intensity was graded as 'low' if intervention activities were implemented at one point in time and 'high' if intervention activities were implemented at multiple points in time over the length of the intervention), (viii) outcomes, (ix) participants, (x) soap provision, (xi) results. A quantitative meta-analysis was not conducted due to the limited number of studies, and the heterogeneity in study interventions and outcomes, and instead a narrative synthesis of results was undertaken. Studies were grouped by outcome measure (behaviour change, diarrhoea and STH infection) and by secondary outcome (knowledge) to allow for qualitative comparison.

The review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA guidelines) [21]. A PRISMA checklist can be found in Appendix S2.

Quality assessment

Two reviewers (JW and OC) independently assessed the risk of bias in studies selected for inclusion in the review using the Cochrane 'Risk of Bias' Assessment Tool [22]. This tool is designed to assess if adequate steps have been taken to reduce bias across five domains by assessing sources of bias in each domain. 'Risk of bias' judgements were categorised as 'high risk', 'low risk', or 'unclear risk'. Table 1 outlines the assessment undertaken for each domain.

To assess the quality of NRCTs and CBAs, two additional criteria were included, as used in a recent relevant Cochrane Review [23]:

Table 1 Tool for assessing risk of bias

Domain	Source of bias	Assessment
Selection bias	Random sequence generation	Studies were categorised as 'low risk' if method used to generate allocation was sufficient to produce comparable groups
	Allocation concealment	Studies were categorised as 'low risk' if concealment of allocation before assignment was sufficient to ensure intervention allocations could not have been foreseen before or during enrolment
Performance bias	Blinding of participants and personnel	Studies were categorised as 'low risk' if trial participants and researchers were blinded from knowledge of which intervention a participant received and if intended blinding was effective
Detection bias	Blinding of outcome assessment	Studies were categorised as 'low risk' if outcome assessment was blind from knowledge of which intervention a participant received and if intended blinding was effective
Attrition bias	Incomplete outcome data	Studies were categorised as 'low risk' if outcome data were complete for each main outcome, including attrition and exclusions from the analysis. The reviewers assessed if attrition and exclusions were reported, the numbers in each intervention group (compared with total randomised participants), if reasons for attrition or exclusions were reported, and any re-inclusions in analyses for the review
Reporting bias	Selective reporting	Studies were categorised as 'low risk' if publication of outcomes measured, or of analyses performed, was complete

(i) comparability of baseline characteristics – studies were categorised as 'low risk' if baseline characteristics were similar between the intervention and control groups.
(ii) contemporaneous data collection – studies were categorised as 'low risk' if data were collected at similar points in time in the intervention and control groups.

Results

Search results

A total of 2,827 studies were identified from MEDLINE (349), EMBASE (494), Global Health (390), CINAHL (183), Africa-Wide Information (125), Scopus (865), IBSS [19] and Web of Science (402). One further study was identified from reference-list scanning and was also included in the final analysis. After deduplication, 1300 studies were screened by title and abstract and 43 studies selected for full-text screening. Applying the pre-defined inclusion criteria, eight studies were selected for inclusion in the final analysis [24–31]. The flow diagram in Figure 1 outlines the results of the database searches and the screening process, according to PRIMSA guidelines [21]. Appendix S3 lists the reasons for excluding the 35 studies on full-text screening.

Characteristics of included studies

Full details of the characteristics of included studies can be found in Appendix S4.

Settings and participants

Studies were conducted across six different countries: Malaysia [1], Peru [1], India [1], Egypt [1], China [2] and Kenya [2]. All studies targeted children of primary-school age, between the ages of five and twelve. Seven of the studies selected for inclusion were implemented in primary schools [24–28, 30, 31] and the one remaining study (Nicholson, 2014) [29] was implemented in communities, but targeted five-year-old children attending the first grade of a primary school.

Study design and length

Of the eight included studies, seven were cluster-RCTs [25–31] and one was a cluster-NRCT [24]. No eligible CBAs were identified. Six of the cluster-RCTs used schools as the unit of randomisation [25–28, 30, 31] and the other used low-income communities [29]. The NRCT used schools as the unit of allocation [24]. The intervention length of the included studies ranged from eight to forty-one weeks and intervention intensity was graded as 'high' in the six of the studies [24–26, 28, 29, 31].

Intervention

Of the eight included studies, four employed interventions focussed exclusively on handwashing promotion [26, 27, 29–31] and three studies employed interventions that promoted general hygiene messages around STH

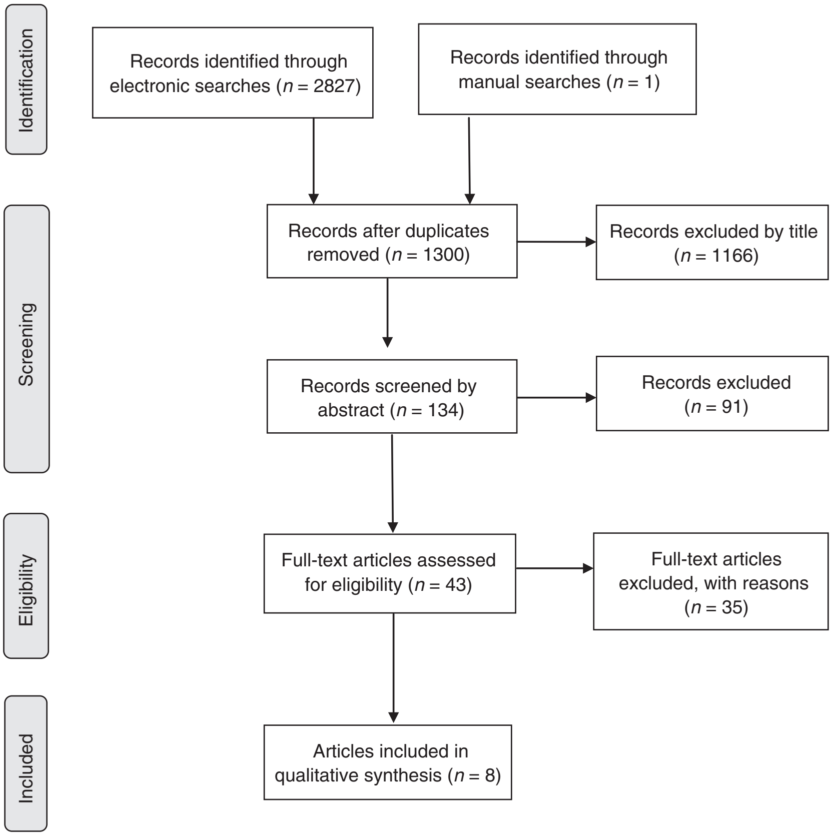

Figure 1 PRISMA flow diagram.

transmission and prevention, including handwashing [24, 25, 28]. One study (Pickering, 2013) [30], a three-arm cluster RCT, compared two independent interventions of combined soap provision and handwashing promotion versus a waterless hand sanitiser and hand cleaning promotion. For this study, we considered the results of both the soap and hand sanitiser interventions. The interventions in five of the studies included soap or hand sanitiser provision [24, 26, 29–31], whereas soap was not provided as part of the intervention in the other three studies [25, 27, 28]. Table 2 outlines the intervention activities, intervention intensity, and soap provision in each of the studies. More detailed characteristics of included studies can be found in Appendix S4.

Outcomes

Table 3 shows a summary of the outcomes measured in each study and if a positive effect was observed. To facilitate comparison, the studies were categorised according to their outcomes. Studies were marked as having a 'positive effect' if there was an increase in handwashing behaviour, a reduction in diarrhoea, a reduction in STH infection, and/or an increase in knowledge related to handwashing, in the intervention group compared to control group, and the effect was statistically significant at $P < 0.05$. Due to heterogeneity of the studies in terms of interventions and outcome measures, a meta-analysis was not considered appropriate and a narrative summary of the results is presented below. The magnitude of the positive effect is also presented in the narrative summary.

Handwashing behaviour change

Six studies measured the effect of handwashing promotion on handwashing behaviour change [24, 25, 27–30]. Across the studies, three methods were used to measure handwashing behaviour change. Al-delaimy (2014) [24] and Gyorkos (2013) [28] used self-reported measures. Bieri (2013) [25], Graves (2011) [27] and Pickering (2013) [30] used structured observations and Nicholson (2014) [29] indirectly assessed handwashing behaviour using soap consumption as a proxy measure (soap wrapper collection).

Al-delaimy (2014) [24] measured the handwashing behaviour of the parents of target children, at 12-week follow-up, and reported that the proportion of the parents

Table 2 Intervention activities

Study	Intervention activities	Intervention intensity	Soap provision
Al-delaimy (2014) [24]	Fun activities (comics books, drawing, puppet shows, nursery song videos, mascot)	High – activities repeated regularly throughout length of intervention (up to twice a week]	Soap provided
Bieri (2013) [25]	'Magic Glasses' cartoon, group discussions, drawing and essay competitions	High – activities throughout length of intervention	No soap provided
Bowen (2007) [26]	Standard intervention: 40-minute classroom session (animated videotape, hygiene competition, posters)	Standard: Low – 1 session only	Standard: one soap bar (hygiene pack)
	Expanded intervention: standard intervention plus peer handwashing monitors	Expanded: High – 1 session plus regular input from peer monitors	Expanded: continuous supply
Graves (2011) [27]	Poster design competition	Low – 1 session only	No soap provided
Gyorkos (2013) [28]	60-minute class on STH transmission and prevention and poster display	High – initial 1-hour session followed by 30 minute refresher activities every 2 weeks throughout length of intervention	No soap provided
Nicholson (2014) [29]	Fun activities (songs, poems and stories), environmental cues (wall hanger, etc.), HWWS rewards (stickers, toys, animals etc.), children encouraged to advocate HWWS at home), HWWS pledges for children and mothers, 'Best Mums' club.	High – activities throughout length of intervention	Soap provided
Pickering (2013) [30]	Distribution of hygiene promotion kits for teacher use (posters, stickers, classroom activities, DVD, promotional songs)	Unclear	Soap schools: liquid soap provided Sanitiser schools: liquid hand sanitiser provided
Talaat (2011) [31]	Fun activities (e.g. games), poster displayed near sinks, songs. Supervised HWWS twice daily.	High – activities repeated throughout length of intervention (at least one activity per week)	Soap provided

practising handwashing in the intervention group was three-and-a-half times higher than the proportion of parents practising handwashing in the control group, both before eating (odds ratio [OR] 3.5, 95% confidence interval [CI]: 1.9–6.4), and after using the toilet (OR 3.5, 95% CI: 1.7–7.1). Soap was supplied in this intervention and the odds of HWWS was six-and-a-half times higher in the parents in the intervention group, compared to parents in the control group (95% CI: 3.2–13.1). Gyorkos (2013) [28] found no statistically significant difference (at the 5% significance level) between proportions of children washing their hands before eating or after visiting the toilet at the 16-week follow-up, and no difference in children using soap to wash their hands. Bieri (2013) [25] found a statistically significant increase in the number of children who washed their hands after toilet use in the intervention group *vs*. the control group (44.6% increase, 95% CI: 10.1%–79.1%, $P = 0.005$) at 36-week follow-up. Graves (2011) [27] reported no significant difference in the proportion of children practising handwashing after toilet use, at 16-week follow-up; the mean difference in the proportion of students washing their hands was 0.07 (95% CI: −0.13, 0.27). Pickering (2013) [30] reported no significant differences in handwashing at intervention schools compared to control schools after toilet use (prevalence ratio = 1.0, 95% CI: 0.3–3.8) and before eating (prevalence ratio = 1.2, 95% CI: 0.7–2.0). Nicholson (2014) [29] reported a median soap consumption of 45 g per household in the control group, compared to 235 g per household in the intervention group.

Soil-transmitted helminth infection

Three studies reported the effect of hygiene promotion interventions, which included messages around handwashing, on STH infections [24, 25, 28].

Although Al-delaimy (2014) [24] showed a significant decrease in hookworm infection rates in the intervention

Table 3 Study outcomes and effects

Outcome	Study	Outcome measurement	Outcomes measured	Positive effect
Behaviour	Al-delaimy (2014) [24]	KAP survey	Washing hands before eating	✔
			Washing hands after defecation	✔
			Washing hand with soap	✔
	Bieri (2013) [25]	Observations	Washing hands after toilet	✔
	Graves (2011) [27]	Observations	Handwashing	✗
	Gyorkos (2013) [28]	KAP survey	Washing hands after toilet	✗
			Using soap when washing hands after toilet	✗
			Washing hands before eating	✗
			Using soap when washing hands before eating	✗
	Nicholson (2014) [29]	Soap wrapper collection	Soap consumption	✔
	Pickering (2013) [30]	Observations	Soap Intervention	
			Hand cleaning after toilet use	✗
			Hand cleaning before eating	✗
			Hand Sanitiser Intervention	
			Hand cleaning after toilet use	✔
			Before eating	✗
Diarrhoea	Bowen (2007) [26]	Teacher records	Standard Intervention	
			Diarrhoea Incidence	✗
			Expanded Intervention	
			Diarrhoea Incidence	✗
	Nicholson (2014) [29]	Caregiver interviews	Predictive relative risk reduction (Intention-to-treat analysis)	
			Target children	✗
			Children aged ≤ 5 (non-target)	✔
			Children 6-15 (non-target)	✔
			Whole families	✔
	Pickering (2013) [30]	Student interviews	Soap Intervention	
			Diarrhoea prevalence	✗
			Sanitiser Intervention	
			Diarrhoea prevalence	✗
	Talaat (2011) [31]	Teacher records	School absence due to diarrhoea	✔
STH	Al-delaimy (2014)[24]	Laboratory analysis	*A. lumbricoides* re-infection	✗
			A. lumbricoides infection intensity	✔
	Bieri (2013)[25]	Laboratory analysis	STH Incidence	✔
			STH infection intensity	✗
	Gyorkos (2013)[28]	Laboratory analysis	*A. lumbricoides prevalence*	✗
			A. lumbricoides infection intensity	✔
Knowledge	Al-delaimy (2014)[24]	KAP survey	Knowledge of handwashing as a STH infection preventative measure	✔
	Bieri (2013)[25]	KAP survey	Knowledge of handwashing as a STH infection preventative measure	✔
	Gyorkos (2013)[28]	KAP survey	Knowledge of handwashing as a STH infection preventative measure	✔

group compared to the control group 24 weeks after deworming (75.5% *vs.* 39.6%, $P < 0.05$), the reduction in *A. lumbricoides* infection rates in the intervention group was not significant (82.3% *vs.* 63.3% $P > 0.05$). This study did, however, show a significant decrease in the intensity of *A. lumbricoides* at the 24-week follow-up, assessed as the mean *A. lumbricoides* egg count per gram of faeces. Bieri (2013) [25] reported significant reductions in incidence of STH infections, 36 weeks after deworming, between the intervention group and control group (OR 0.50, $P < 0.001$), but not in the intensity of infections (OR 1.12, $P = 0.12$), assessed as the geometric mean number of eggs per gram of faeces. Although researchers present results as ‘all STHs’, 100% of the infections detected were *A. lumbricoides* and thus were amenable to the handwashing promotion intervention

[25]. Gyorkos (2013) [28] showed no significant difference in *A. lumbricoides* infection between the intervention group and the control group 16 weeks post-deworming (adjusted OR 0.88, 95% CI: 0.57–1.34); however, the intensity of *A. lumbricoides* infection was significantly lower in the intervention group (adjusted incidence rate ratio 0.42, 95% CI: 0.21–0.85).

Diarrhoea

Four studies measured the effect of handwashing on diarrhoea [26, 29–31]. Talaat (2011) [31] measured the incidence of school absence due to diarrhoea among children (in the first three grades of primary school) and reported incidence was 33% lower in the intervention school compared to the control school ($P < 0.0001$, no 95% CI given). This intervention included a 'Hand Hygiene Team' comprising three teachers who supervised children to ensure handwashing was being practised, a method that may account for the pronounced effect of the intervention. Bowen (2007) [26] also measured diarrhoea incidence using teacher records of school absence due to diarrhoea, as well as diarrhoea reported during school time; however, the incidence of diarrhoea was reported to be zero in control, standard intervention and expanded intervention groups, and thus, no significant difference was reported. Pickering (2013) [30] measured prevalence of diarrhoea, as reported in interviews with children, and found no significant effect in either the soap intervention group (risk ratio 0.84, 95% CI: 0.58–1.22, $P = 0.36$) or the waterless hand sanitiser group (risk ratio 0.89, 95% CI 0.61–1.30, $P = 0.56$) at 8-week follow-up, although the authors highlight that the study was not designed to have adequate power to detect effects on health outcomes. Nicholson (2014) [29] reported the effect of the intervention on diarrhoea incidence in the target children (age 5), and in household members stratified by different age groups (under-5s, ages 6–15 and adults), measured by interviews with caregivers. In the per-protocol analysis, the target children in the intervention group were reported to have a predictive relative risk reduction (PRRR) of 21.3% (95% CI: 36.6%–2.3%); however, in the intention-to-treat (ITT) analysis the PRRR was no longer significant. The PRRRs for the under-5s, 6- to 15-year-olds and whole families were similar to that of the target children; however, all remained significant in the ITT analysis.

Knowledge

The three studies that focused on education around STH also measured changes in knowledge as a secondary outcome, along with STH infection and handwashing behaviour, and all reported statistically significant increases in knowledge [24, 25, 28]. Bieri (2013) [25] reported a 32.8 percentage point increase (95% CI: 28.9%–36.8%, $P < 0.001$) in the KAP scores (measuring knowledge of STH transmission, symptoms, prevention and treatment) of the intervention group compared to the control group; however, these results may be biased as KAP scores were also higher in the intervention group at baseline. Gyorkos (2013) [28] reported significantly higher KAP scores in the target children in the intervention group compared to the control group (OR 18.4, 95% CI: 12.7–26.6) and Al-delaimy (2014) [24] measured knowledge of handwashing as a STH infection preventative measure in parents of the target children, using KAP surveys, and recorded significantly higher scores from parents in the intervention group compared to parents in the control group (OR 2.5, 95% CI: 1.5–4.1).

Quality assessment

Judgements about the risk of bias are summarised in Figure 2 and Figure 3. The full-quality assessment is presented in Appendix S5.

The random sequence was judged to be adequately generated in five of the seven cluster-RCTs and these studies were classed as having a 'low risk' of bias [25, 26, 28, 29, 31]. In the other two cluster-RCTs the sequence generation was unclear [27, 30]. The method of allocation concealment was classed as 'low risk' in Gyorkos (2013) [28], whilst the risk was 'unclear' in all other cluster-RCTs. Five of the studies were at 'low risk' of confounding bias [24, 28–31] and the other three studies were classed as 'high risk' because of differences in soap availability (Graves [2011]) [27], KAP scores (Bieri [2013]) [25], household water and sanitation and student age (Bowen [2007]) [26], at baseline. Data were collected contemporaneously and classed as 'low risk', in all studies except for Bowen (2007) [26], which was classed as 'high risk' due to the replacement of some schools in the study during the second week of data collection. Seven studies were judged to have a 'high risk' of performance bias as neither of the participants nor the personnel were blinded [24–30], whilst the blinding status of participants or personnel could not be determined in Talaat (2011) [31]. Seven of the studies had a 'high risk' or 'unclear risk' of detection bias as the outcome assessors were not blinded to intervention status or blinding was unclear [24–27, 29–31], whilst Gyorkos (2013) [28] was judged to have a 'low risk' of detection bias as the laboratory technologists testing STH in stool samples were blinded to the intervention. In four of the studies, over 80% of

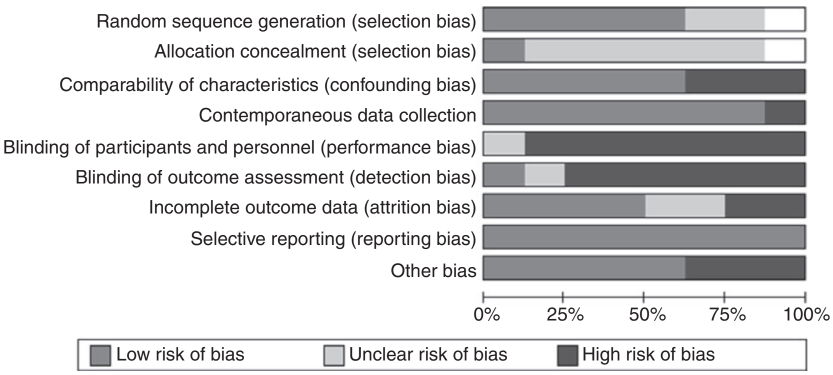

Figure 2 Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

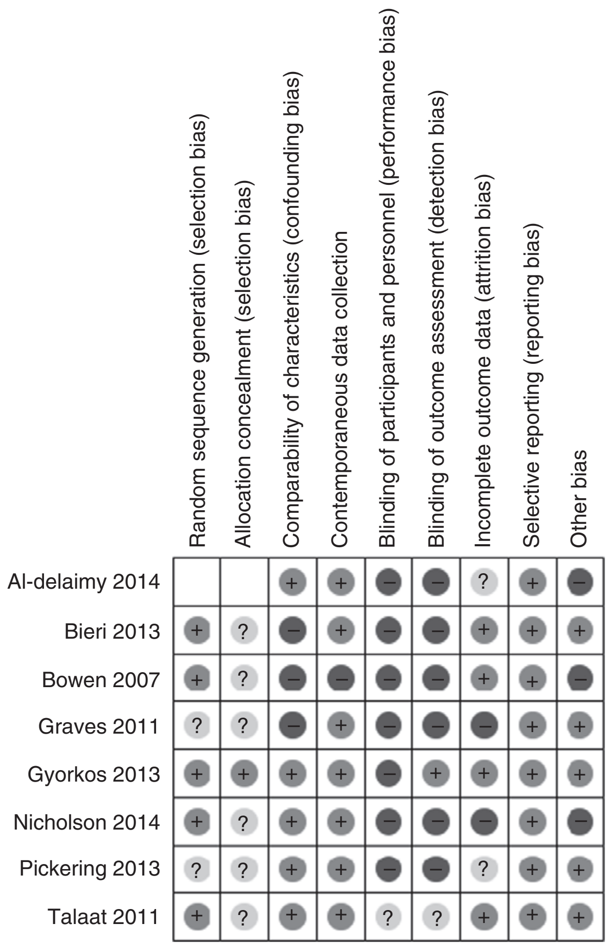

Figure 3 Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

those allocated to the study were included in the analysis and these studies were classed as 'low risk' of attrition bias [25, 26, 28, 31]. Al-delaimy (2014) [24] and Pickering (2013) [30] did not report loss to follow-up, and hence, the risk of attrition bias was unclear. Graves (2011) [27] and Nicholson (2014) [29] were classed as 'high risk' of attrition bias, with less than 80% of participants allocated to the study, included in the analysis. Other sources of bias identified in the studies were lack of adjustment for clustering in the analysis (Nicholson [2014] [29] and Al-delaimy [2014] [24]) and misrepresentation of the source population (Bowen [2007] [26] and Al-delaimy [2014] [24]).

Discussion

The main finding from the review is that the evidence base for child-focussed handwashing promotion in LMICs is extremely scarce; only eight relevant studies were found [24–31] and meta-analysis was not deemed possible due to heterogeneity in the interventions and measurement of outcomes across the studies. This was also evident in a recent review of the effect of handwashing promotion on diarrhoea, in which only three trials were identified that were conducted in schools or day-care centres in LMICs [1]. Studies also suffered from a number of design limitations which compromised the validity of their findings. The heterogeneity of the results, however, reflects the 'real-world' circumstance of handwashing promotion and hence a qualitative approach to synthesising the evidence is necessary.

Our review showed mixed evidence on the effectiveness of handwashing promotion, targeted at children, on infection with the STH, *A.lumbricoides*. Only one of the three studies identified showed a statistically significant reduction in *A.lumbricoides* infection in children [25], whilst two of the studies showed a significant reduction in *A.lumbricoides* intensity [24, 28]. These studies, however, may have been affected by bias due to a lack of blinding of the assessors. In one study that did blind the laboratory technologists assessing STH infection, and therefore was at a low risk of detection bias, no significant effect on *A.lumbricoides* infection was recorded [28].

Handwashing promotion targeted at children was only reported to have a significant effect on diarrhoea in the intervention target children in one study, in which handwashing was obligatory and teacher-supervised, potentially masking the true effects of the other hygiene promotion activities in this study [31]. No other significant effects on diarrhoea incidence were reported in the other studies; however, incidence of diarrhoea was measured by self-report or through caregiver reports across all studies. As the responders were not blinded to the intervention, these reports are at high risk of response bias, influenced by perceived social desirability, and thus, diarrhoea is likely to be under-reported and may not accurately represent the effectiveness of the interventions [32]. A meta-analysis in Ejemot's (2015) review did show handwashing promotion to have a positive effect on the diarrhoea incidence of children within child day-care centres or schools in LMICs (rate ratio 0.66, 95% CI: 0.43-0.99); however, this meta-analysis only included two trials which were both graded as low quality [1].

All three of the studies in this review which used hygiene-related knowledge as a secondary outcome measure of intervention effect recorded a significant increase in knowledge post-intervention [24, 25, 28]. However, although knowledge is quick and easy to measure, it is not a good proxy indicator of behaviour change as it does not necessarily translate into behaviour change [33], as evident in Gyorkos' (2013) [28] study where children in receipt of the intervention scored significantly higher on a STH-related knowledge survey, but no significant change in handwashing behaviour was recorded. This intervention also had no significant effect on *A. lumbricoides* infection. By contrast, Bieri (2013) [25] and Al-delaimy (2014) [24] did both show a significantly higher increase in knowledge as well as change in behaviour in the intervention group compared to the control group. However, all studies measured behaviour outcomes in different ways – observations of target children's handwashing in Bieri (2013) [25], self-report of target children's handwashing in Gyorkos (2013) [28] and self-report of parent's handwashing in Al-delaimy (2014) [24] – and hence, comparisons should be made with caution. Although knowledge is necessary for behaviour change, it is not always sufficient and thus studies assessing the effect of handwashing promotion interventions should also include direct measures of behaviour change wherever possible.

Only three of the eight studies in our review used direct observations to measure handwashing behaviour change [25, 27, 30], whilst the remaining studies measuring handwashing behaviour used self-report, via KAP surveys [24, 28], or soap consumption as a proxy measure [29]. Whilst using self-reported behaviour and soap consumption to measure handwashing may be easier and less expensive than direct observations as less enumerator time and training is required, the validity of these measures is questionable. Participant awareness of the social desirability of handwashing, coupled with possible courtesy bias, is likely to lead to an overestimation of self-reported handwashing behaviour [32] and proxy measures such as soap consumption do not necessarily correlate with actual practice or prevalence of handwashing [34]. Direct observation of behaviours is considered the current 'gold standard' for measuring handwashing [34], although it is still at risk of bias; the presence of an observer has been shown to introduce reactivity and observed individuals may over-perform, leading to overestimates of actual behaviour [35, 36]. However, only one of the studies with observed handwashing behaviour [25] saw an overall statistically significant increase in the handwashing practices of children post-intervention compared to pre-intervention, which may suggest the effect of reactivity bias in schools was minimal. Although Nicholson (2014) [29] did record an increase in hand cleaning after using the toilet in the hand sanitiser intervention, no such effect was recorded in the soap intervention group.

The range of methods used to assess changes in behaviours across the studies made direct comparisons of findings difficult. Meta-analysis would be facilitated if future studies used more consistent measures of behaviour change to enable comparison. Direct observation should be the outcome measure selected where possible to improve the validity of results. Furthermore, a standard unit of measurement, such as the proportion of participants HWWS at a specified moment, for example after defecation, would better enable comparative analysis. The use of covert video cameras in both schools and homes has become increasingly common; however, video surveillance has also been shown to introduce reactivity [37] and remains logistically difficult and expensive.

All of the handwashing promotion interventions identified in this review were targeted at children attending primary school, between the ages of five and twelve. There is a clear lack of handwashing promotion interventions targeting teenagers, who may represent a potentially very important group in the disruption of the pathogen transmission considering the high adolescent fertility rate in low-income settings, which may indicate a large number of teenagers in caregiving roles [38]. Another overlooked target group, identified by this review, is children who do not attend school, the numbers of whom are substantially higher in LMICs than in high income countries [38]. The findings of Ejemot's (2015) review also highlights this, with no trials included which were focussed on teenagers or out-of-school children [1].

A lack of good-quality evidence exists to prioritise specific handwashing promotion interventions targeted at children in LMICs. A variety of intervention methods are being employed to promote handwashing among children and not one accepted method of implementation or outcome measure has yet come to the forefront as the most effective. Due to the limited number of studies and heterogeneity of interventions, we were not able to assess the relationship between intervention effectiveness and the duration or intensity of the intervention. However, a recent systematic review of school-based interventions to modify dietary behaviour found no relationship between intervention intensity and effectiveness [39].

There has been some recent innovation in the science of changing handwashing behaviour. The Behaviour Centred Design (BCD) framework offers a new generalised approach to behaviour change which incorporates both a theory of change for behaviour and a practical process for designing and evaluating interventions [40]. BCD aims to change behaviour through surprise, revaluation and disruption of performance rather than traditional 'messaging' and has been used successfully in the design and evaluation of handwashing interventions, for example the SuperAmma programme in rural India [41]. Central to the BCD framework is changing both the environment and the brain (cognitive processes related to a specific behaviour). Pilot research in Bangladesh found large, sustained changes in handwashing behaviour associated with nudges – environmental changes in schools that included brick paths and painted symbols that prompted handwashing behaviours [42]. Larger trials examining the effect of environmental modification on handwashing outcomes in schools are underway [43]. Whilst more evidence is needed, environmental modification may present a viable approach to changing handwashing behaviours in schools.

This review has some limitations. Firstly, because the studies were judged too heterogeneous to conduct a meaningful meta-analysis, no quantitative conclusions could be drawn. Due to the heterogeneity of the studies, it was also not feasible to assess publication bias; however, many of the studies did report negative findings indicating that publication bias was not an important bias in this review. One potential method of reducing publication bias would be to include unpublished studies, although unpublished studies may be of lower quality and do not always reduce the publication bias but often alter the effect size [44]. Whilst this review only included concurrently controlled trials, there may also be some useful information to gain from those uncontrolled studies excluded from this review, especially as in low-income settings, RCTs and non-randomised controlled trials are often considered ethically or financially challenging. Inclusion of these lower quality studies, however, may have resulted in inclusion of evidence with an unacceptably high risk of bias. Additionally, the exclusion of non-English language studies from this review may limit the generalisability of the findings as we may have excluded valid international work. A final limitation of this review is the exclusion of studies where the effect of the handwashing promotion intervention could not be distinguished from the effect of other WASH improvements. Whilst this was necessary to assess the effectiveness of handwashing promotion interventions, it does not reflect the best approaches to improving health through hygiene where access to water, improved water quality and sanitation also play an important role. Organisational support is a key factor in the sustainability of health service interventions [45]. In the school-based handwashing promotion interventions identified in our review, soap supply, WASH infrastructure and maintenance, along with other organisational aspects of handwashing, over which children have very little agency, will impact the sustainability of these interventions and are important considerations.

Whilst regular handwashing with soap is regarded as an effective and cost-effective public health measure, no previous reviews have assessed whether interventions targeting children are effective in changing handwashing behaviours nor health outcomes. Our review found just eight studies that evaluated such interventions and those identified were heterogeneous in nature and had various methodological limitations. As much of the hygiene attributable disease burden is concentrated among children, it is plausible that interventions which succeed in changing children's handwashing practices will lead to significant health impacts. The current paucity of evidence in this area, however, does not permit any recommendations to be made as to the most effective route to increasing handwashing with soap practice among children in LMIC.

References

1. Ejemot-Nwadiaro RI, Ehiri JE, Arikpo D, Meremikwu MM, Critchley JA. Hand washing promotion for preventing diarrhoea. *Cochrane Database Syst Rev* 2015; **9**: CD004265.
2. Liu L, Oza S, Hogan D *et al.* Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: an updated systematic analysis. *Lancet* 2015: **385**: 430–440.

3. Aiello AE, Coulborn RM, Perez V, Larson EL. Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am J Public Health* 2008: **98**: 1372–1381.
4. Pruss-Ustun A, Bartram J, Clasen T *et al*. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Med Int Health* 2014: **19**: 894–905.
5. Rabie T, Curtis V. Handwashing and risk of respiratory infections: a quantitative systematic review. *Trop Med Int Health* 2006: **11**: 258–267.
6. Curtis V, Cairncross S. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect Dis* 2003: **3**: 275–281.
7. Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis* 2005: **5**: 42–52.
8. Cairncross S, Hunt C, Boisson S *et al*. Water, sanitation and hygiene for the prevention of diarrhoea. *Int J Epidemiol* 2010: **39**(Suppl 1): i193–i205.
9. Freeman MC, Stocks ME, Cumming O *et al*. Hygiene and health: systematic review of handwashing practices worldwide and update of health effects. *Trop Med Int Health* 2014: **19**: 906–916.
10. Jamieson D, Bremen J, Measham A, Alleyne G, Claeson M. *Disease Control Priorities in Developing Countries*. Oxford University Press: Oxford, 2006.
11. Humphrey JH. Child undernutrition, tropical enteropathy, toilets, and handwashing. *Lancet* 2009;**374** North American Edition: 1032–1035, 4p.
12. United Nations. *Transforming our World: The 2030 Agenda for Sustainable Development*. United Nations: New York, 2015.
13. World Health Organisation, The United Nations Children's Fund. *End Preventable Deaths: Global Action Plan for Prevention and Control of Pneumonia and Diarrhoea*. WHO Press: Geneva, Switzerland, 2013.
14. Hotez PJ, Bundy DAP, Beegle K *et al*. Helminth Infections: soil-transmitted Helminth Infections and Schistosomiasis. In: Jamison DT, Breman JG, Measham AR, *et al*. (eds). *Disease Control Priorities in Developing Countries* (2nd edn). The International Bank for Reconstruction and Development/The World Bank: Washington, DC, 2006.
15. Pullan RL, Smith JL, Jasrasaria R, Brooker SJ. Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. *Parasit Vectors* 2014: **7**:37.
16. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLoS Med* 2014: **11** (3): e1001620.
17. Nikolay B, Brooker SJ, Pullan RL. Sensitivity of diagnostic tests for human soil-transmitted helminth infections: a meta-analysis in the absence of a true gold standard. *Int J Parasitol* 2014: **44**: 765–774.
18. World Bank. World Bank Country and Lending Groups: country classification 2016 [Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
19. The World Health Organisation. Soil-Transmitted Helminth Infections: Fact Sheet 2016 (Available from: http://www.who.int/mediacentre/factsheets/fs366/en/).
20. Bresee S, Caruso BA, Sales J, Lupele J, Freeman MC. 'A child is also a teacher': exploring the potential for children as change agents in the context of a school-based WASH intervention in rural Eastern Zambia. *Health Educ Res* 2016: **31**: 521–534.
21. Moher D, Liberati A, Tetzlaff J, Altman DG, The PG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009: **6**: e1000097.
22. Higgins JP, Altman DG, Gotzsche PC *et al*. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011: **343**: d5928.
23. Clasen TF, Alexander KT, Sinclair D *et al*. Interventions to improve water quality for preventing diarrhoea. *Cochrane Database Syst Rev* 2015; (9): CD004794.
24. Al-Delaimy AK, Al-Mekhlafi HM, Lim YAL *et al*. Developing and evaluating health education learning package (HELP) to control soil-transmitted helminth infections among Orang Asli children in Malaysia. *Parasit Vectors* 2014: **7** (no pagination): 416.
25. Bieri FA, Gray DJ, Williams GM *et al*. Health-education package to prevent worm infections in Chinese schoolchildren. *N Engl J Med* 2013: **368**: 1603–1612.
26. Bowen A, Ma H, Ou J *et al*. A cluster-randomized controlled trial evaluating the effect of a handwashing-promotion program in Chinese primary schools. *Am J Trop Med Hyg* 2007: **76**: 1166–1173.
27. Graves JM, Daniell WE, Harris JR, Obure AF, Quick R. Enhancing a safe water intervention with student-created visual aids to promote handwashing behavior in Kenyan primary schools. *Int Q Community Health Educ* 2011: **32**: 307–323.
28. Gyorkos TW, Maheu-Giroux M, Blouin B, Casapia M. Impact of health education on soil-transmitted helminth infections in schoolchildren of the Peruvian Amazon: a cluster-randomized controlled trial. *PLoS Negl Trop Dis* 2013: **7**: e2397.
29. Nicholson JA, Naeeni M, Hoptroff M *et al*. An investigation of the effects of a hand washing intervention on health outcomes and school absence using a randomised trial in Indian urban communities. *Trop Med Int Health* 2014: **19**: 284–292, 9p.
30. Pickering AJ, Davis J, Blum AG *et al*. Access to waterless hand sanitizer improves student hand hygiene behavior in primary schools in Nairobi, Kenya. *Am J Trop Med Hyg* 2013: **89**: 411–418.
31. Talaat M, Afifi S, Dueger E *et al*. Effects of hand hygiene campaigns on incidence of laboratory-confirmed influenza

and absenteeism in schoolchildren, Cairo Egypt. *Emerg Infect Dis* 2011: **17**: 619–625.
32. Contzen N, De Pasquale S, Mosler HJ. Over-reporting in handwashing self-reports: potential explanatory factors and alternative measurements. *PLoS ONE* 2015: **10** (8): e0136445.
33. Curtis VA, Danquah LO, Aunger RV. Planned, motivated and habitual hygiene behaviour: an eleven country review. *Health Educ Res* 2009: **24**: 655–673.
34. Biran A, Rabie T, Schmidt W, Juvekar S, Hirve S, Curtis V. Comparing the performance of indicators of hand-washing practices in rural Indian households. *Trop Med Int Health* 2008: **13**: 278–285.
35. Ram PK, Halder AK, Granger SP *et al.* Is structured observation a valid technique to measure handwashing behavior? Use of acceleration sensors embedded in soap to assess reactivity to structured observation. *Am J Trop Med Hyg* 2010: **83**: 1070–1076.
36. Pedersen DM, Keithly S, Brady K. Effects of an observer on conformity to handwashing norm. *Percept Mot Skills* 1986: **62**: 169–170.
37. Pickering AJ, Blum AG, Breiman RF, Ram PK, Davis J. Video surveillance captures student hand hygiene behavior, reactivity to observation, and peer influence in Kenyan primary schools. *PLoS ONE* 2014: **9** (3): e92571.
38. World Bank Group. *World Development Indicators*. International Bank for Reconstruction and Development/The World Bank: Washington, DC, 2016.
39. Racey M, O'Brien C, Douglas S, Marquez O, Hendrie G, Newton G. Systematic review of school-based interventions to modify dietary behavior: does intervention intensity impact effectiveness? *J Sch Health* 2016: **86**: 452–463.
40. Aunger R, Curtis V. Behaviour centred design: towards an applied science of behaviour change. *Health Psychol Rev* 2016: **10** (4): 425–446.
41. Biran A, Schmidt WP, Varadharajan KS *et al.* Effect of a behaviour-change intervention on handwashing with soap in India (SuperAmma): a cluster-randomised trial. *Lancet Global Health* 2014: **2**: e145–e152.
42. Dreibelbis R, Kroeger A, Hossain K, Venkatesh M, Ram PK. Behavior change without behavior change communication: nudging handwashing among primary school students in Bangladesh. *Int J Environ Res Public Health* 2016: **13** (1): e129.
43. University of Oklahoma. Nudging Handwashing: A Cluster-Randomized Trial in Bangladesh. In: ClinicalTrials.gov: Bethesda (MD): National Library of Medicine (US). 2000; [cited 2016 11th October]. Available from: https://clinicaltrials.gov/ct2/show/NCT02703974 NLM identifier: NCT02703974.
44. Song F, Hooper L, Loke Y. Publication bias: what is it? How do we measure it? How do we avoid it? *Open Access J Clinical Trials* 2013: **5**: 71–81.
45. Scheirer MA, Dearing JW. An agenda for research on the sustainability of public health programs. *Am J Public Health* 2011: **101**: 2059–2067.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Detailed Search Strategy and Hits – Medline.
Appendix S2. PRISMA Checklist.
Appendix S3. Characteristics of Excluded Studies.
Appendix S4. Characteristics of Included Studies.
Appendix S5. Risk of Bias.

Corresponding Author Julie Watson, Department for Disease Control, Faculty of Infectious Tropical Diseases, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK. E-mail: julie.watson@lshtm.ac.uk