



## Effectiveness of behaviour change techniques used in hand hygiene interventions targeting older children – A systematic review

Julie Watson<sup>a,\*</sup>, Oliver Cumming<sup>a</sup>, Amy MacDougall<sup>b</sup>, Alexandra Czerniewska<sup>a</sup>, Robert Dreibelbis<sup>a</sup>

<sup>a</sup> Department of Disease Control, London School of Hygiene and Tropical Medicine, Keppel St, Bloomsbury, London, WC1E 7HT, UK

<sup>b</sup> Department of Medical Statistics, London School of Hygiene and Tropical Medicine, Keppel St, Bloomsbury, London, WC1E 7HT, UK

### ARTICLE INFO

#### Keywords:

Systematic review  
Hygiene promotion  
Hand washing  
Hand hygiene  
Children  
Behaviour change  
Behaviour change techniques

### ABSTRACT

**Background:** Promoting good hand hygiene in older children is an important measure to reduce the burden of common diseases such as diarrhoea and acute respiratory infections. The evidence around what works to change this behaviour, however, is unclear.

**Objectives:** To aid future intervention design and effective use of resources, this review aims to identify the individual components used in hand hygiene interventions and assesses their contribution to intended behavioural change.

**Methods:** We systematically searched seven databases for experimental studies evaluating hand hygiene interventions targeting children (age 5–12) and quantitatively reporting hand hygiene behaviour. Interventions in each study were categorised as ‘promising’, or ‘non-promising’ according to whether they led to a positive change in the targeted behaviour. Behaviour change techniques (BCTs) were identified across interventions using a standard taxonomy and a novel promise ratio calculated for each (the ratio of promising to non-promising interventions featuring the BCT). ‘Promising’ BCTs were those with a promise ratio of  $\geq 2$ . BCTs were ranked from most to least promising.

**Results:** Our final analysis included 19 studies reporting 22 interventions across which 32 unique BCTs were identified. The most frequently used were ‘demonstration of the behaviour’, ‘instruction on how to perform the behaviour’ and ‘adding objects to the environment’. Eight BCTs had a promise ratio of  $\geq 2$  and the five most promising were ‘demonstration of the behaviour’, ‘information about social and environmental consequences’, ‘salience of consequences’, ‘adding objects to the environment’, and ‘instruction on how to perform the behaviour’.

**Conclusions:** Our findings suggest that hand hygiene interventions targeting older children should employ a combination of promising BCTs that ensure children understand the behaviour and the consequences of their hand hygiene habits, appropriate hardware is available, and social support is provided. Researchers are encouraged to consistently and transparently describe evaluated interventions to allow promising components to be identified and replicated.

### 1. Introduction

Hand hygiene is a critical measure for the prevention of communicable disease. Handwashing with soap alone can reduce both diarrhoea and acute respiratory infections (ARIs) by over 20% (Aiello et al., 2008; Cairncross et al., 2010; Freeman et al., 2014; Wolf et al., 2018) and has been linked to the reduction of certain neglected tropical diseases such as trachoma (Stocks et al., 2014) and some soil-transmitted helminth

infections (Strunzet al., 2014).

Older children - children age 5–14 as often defined in Global Burden of Disease studies (Kyuet al., 2018) - are an important target group for hand hygiene interventions. Although the greatest burden of diarrhoea and ARIs is borne by children under-five, these diseases are also some of the leading causes of mortality among older children; they account for over 19% of all deaths in this age group globally (World Health Organization, 2020).

\* Corresponding author.

E-mail address: [julie.watson@lshtm.ac.uk](mailto:julie.watson@lshtm.ac.uk) (J. Watson).

<https://doi.org/10.1016/j.socscimed.2021.114090>

Received in revised form 23 May 2021; Accepted 27 May 2021

Available online 31 May 2021

0277-9536/© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Evidence suggests that improving hand hygiene among older children may also reduce school absenteeism (Nandrup-Bus, 2009; Talaat et al., 2011; Willmott et al., 2015). By the age of five, children have typically begun attending school; then, they are expected to practice hand hygiene independently and can subsequently act as agents of change, passing on hygiene messages they receive to their family and peers (Adair et al., 2013; Bresee et al., 2016; Onyango-Ouma et al., 2005). Furthermore, many habits established during childhood years can persist through to adulthood (Kelder et al., 1994; Movassagh et al., 2017; Pressman et al., 2014). For these reasons, effective interventions targeting older children which aim to improve their hand hygiene behaviour are likely to achieve significant public health impacts.

The rationale for targeting hand hygiene interventions at children is strong but the evidence around which intervention approaches work best is unclear (Mbakaya et al., 2017; Watson et al., 2017). Hand hygiene is influenced by different social, environmental, and behavioral determinants, which may vary from context to context, and different approaches are needed to address these determinants and change behaviour (Curtis et al., 2009; White et al., 2020). Published studies, however, often do not report which components of their interventions were successful, making it difficult to assess what works and how to best allocate resources. To aid future design and implementation of hand hygiene interventions, and to ensure the most efficient use of resources, it is important to identify the individual components of interventions that positively contribute to targeted changes in behaviour. In the behaviour change literature, these individual components are often labelled *behaviour change techniques* (BCTs) – the smallest observable and replicable components of behaviour change interventions that on their own have the potential to change behaviour; they can be used individually or in combination (Michie and Johnston, 2012).

Michie and colleagues have validated a 93-item hierarchically structured BCT Taxonomy (BCTTv1) of consensually agreed (by expert opinion), clear and distinct BCTs for specifying components of behaviour change interventions, for example, goal setting, social comparison, and habit formation (Michie et al., 2013). This taxonomy has been used to specify intervention techniques across a wide range of public health behavioural domains such as physical activity and healthy eating (Craddock et al., 2017; Samdal et al., 2017), sedentary behaviour (Gardner et al., 2016), gestational weight management (Soltaniet al., 2016), smoking (Brown et al., 2019a), cardiac rehabilitation (Heron et al., 2016), and HIV and STI prevention (De Vasconcelos et al., 2018). Although the taxonomy has been used recently to specify techniques in hand hygiene and environmental-disinfection interventions in settings likely to include children (Stanford and Schmidtke, 2020), to our knowledge the BCTTv1 has not yet been used to assess the effectiveness of specific BCTs across hand hygiene interventions specifically targeted at older children.

In this systematic review, we aim to use the BCTTv1 to identify and classify the individual techniques used across hand hygiene interventions targeted at older children, assess their contribution to intended intervention outcomes, and determine their relative effectiveness. To navigate the problems consistently faced by past systematic reviews of hygiene interventions (Mbakaya et al., 2017; Watson et al., 2017) – namely finding too much heterogeneity across studies to perform meta-analyses or make conclusive recommendations – we have included interventions in low-, middle-, and high-income countries as well as experimental study designs both with and without a control group. We then employed a novel approach to determining effectiveness – the promise ratio – first developed by Gardner et al. (2016). The promise ratio allows synthesis of heterogeneous data by categorising interventions according to whether they are promising or not – i.e., whether they achieved a significant change in the intended outcome – and using these categories to assess the contribution of individual BCTs to ‘intervention promise’.

## 2. Methods

The current systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Moher et al., 2009) and a complete PRISMA checklist is available in Appendix S1.

### 2.1. Search strategy

Electronic searches were performed on 26 April 2020, by one reviewer (JW), using seven bibliographic databases: Medline (OvidSP interface), Embase (OvidSP interface), Global Health (OvidSP interface), IBSS, Africa-Wide Information (Ebsco Interface), CINAHL (Ebsco Interface), and Web of Science Core Collection (Web of Science interface).

The search strategy incorporated terms related to three concepts: (1) hand hygiene behaviour; (2) promotion; and (3) children. Medical Subject Headings (MeSH) terms and keywords were originally developed for the Medline database and subsequently adapted for use in the other databases using database-specific controlled vocabulary terms and search filters. A full description of the search strategy and search terms for the Medline database is included (Appendix S2). In addition to the search strategy described above, the reference lists of included articles were also hand searched for any relevant articles.

### 2.2. Inclusion criteria

Studies were eligible for inclusion if they met the following criteria:

**Publication and language:** Studies published in peer-reviewed journals on any date up to 26 April 2020 and available in English.

**Types of study design:** Randomised controlled trials (RCTs), non-randomised controlled trials (NRCTs), controlled before-after studies (CBAs), and before-after studies without a control group (BAs). For controlled studies, if there were multiple intervention arms and/or the control arm received an active comparator intervention, each study arm was reclassified as an individual BA study for analysis purposes.

**Control group:** RCTs, NRCTs, and CBAs were included if the control group received no intervention or basic standard care, or if the control group received another active comparator intervention and baseline and endline data were available to reclassify each study arm as an individual BA study. If these data were not available these studies were excluded.

**Types of participants:** Interventions targeting children aged 5–12 years. Note that although the term ‘older children’ typically refers to children age 5–14 we restricted our inclusion criteria to children age 5–12 as this range is the typical primary school age and intervention techniques adopted in primary and secondary school settings are likely highly heterogeneous.

**Types of settings:** Studies in household, community, or school settings, in any country.

**Types of interventions:** Interventions aiming to change hand hygiene (defined as hand washing with soap or disinfecting hands with sanitiser).

**Types of outcomes:** Studies reporting a quantitative frequency measure for hand hygiene practice. Both observed and self-reported measurements were eligible for inclusion. Measures of hand hygiene technique were not an outcome of interest.

Observational studies, conference abstracts, editorials, commentaries, perspectives, short reports, case series, dissertations, and qualitative studies were not eligible for inclusion in this review. Studies with any number of children outside of the 5–12 age range were excluded. Studies specifically targeting children with an illness or disability (e.g., those with hearing impairments or learning difficulties) and studies in healthcare facilities or in any other non-school institution were also excluded to increase the generalisability of our findings. Studies in which the intervention was not well described, and where this information could not be obtained by contacting the author, were also excluded.

### 2.3. Data collection and analysis

#### 2.3.1. Selection of studies

According to PRISMA guidelines, study screening and data extraction were initially conducted by one reviewer (JW) and a second reviewer (AC) cross-checked a sample of records and the extracted data for all studies. All studies retrieved from the database searches were imported into Endnote X8 (Thomson Reuters, New York, USA) and duplicates removed. Studies were screened for relevance by title and abstract, with non-eligible studies excluded. The full texts of the remaining eligible studies were subsequently assessed for inclusion and, in the case of any discrepancies, consensus was reached by discussion between the two reviewers (JW and AC). Where consensus could not be reached, a third reviewer (RD) arbitrated.

#### 2.3.2. Data extraction and management

Data were extracted from each study in a pre-specified table recording the following information: (i) Author/s and Publication Date; (ii) Study Title; (iii) Study Design; (iv) Setting/Country; (v) Intervention Description; (vi) Study Population and Sample Size; (vii) Intervention Intensity (i.e. how much it was repeated); (viii) Length of Follow-up; (ix) Outcome Measure and method of assessment (reported or observed); and (x) Results (note: only data on our outcomes of interest were extracted).

#### 2.3.3. Risk of bias assessment

To accommodate the multiple study designs included in the review, the risk of bias of each individual included study was assessed using an adapted combination of the tools developed by the National Heart, Lung and Blood Institute for controlled intervention studies and before-after studies with no control group (Nhlbi, 2018). Our adapted risk of bias assessment tool includes 14 items (detailed in Appendix S3). For each study, each of these 14 items were scored as 1 = 'yes', 0.5 = 'partially' (where applicable), and 0 = 'no' or 'not applicable'. The overall risk of bias in each study was subsequently calculated by summing up individual item scores, producing a risk of bias index of 0–14, with a score of

$$\text{BCT Promise Ratio} = \frac{\text{Number of 'promising' interventions featuring specific BCT}}{\text{Number of 'non - promising' interventions featuring specific BCT}}$$

0 indicating the highest possible risk of bias and a score of 14 the lowest possible risk of bias. This scoring system restricted BA study designs to a maximum score of 10, as only ten items (items 1–10) were applicable. For BCT coding (see below), the overall risk of bias score for each study was converted to a percentage of the maximum possible score and expressed as a decimal.

#### 2.3.4. Coding of behaviour change techniques

We used Michie's BCTTv1 framework (Michie et al., 2013) (Appendix S4), to identify and code the BCTs used in intervention and control arms of the studies. Two reviewers (JW and AC), both who had successfully completed online training for use of the BCTTv1 ([www.bct-taxonomy.com](http://www.bct-taxonomy.com)), independently coded the technical content of intervention and control groups and rated each of the 93 BCTs as either present or absent. The frequency at which individual BCTs were delivered within an intervention was not coded. The target of BCTs identified with the BCTTv1 was hand hygiene, as defined above. Where interventions targeted other behaviours, only the BCTs related to the relevant target behaviour were coded. Cohen's  $\kappa$  was calculated to measure inter-coder agreement (McHugh, 2012). Any disagreement over BCT coding between the researchers (JW and AC) was resolved by researcher consensus and where consensus could not be reached, a third researcher

(RD), also experienced in BCT coding, mediated the decision.

#### 2.3.5. Analysis of behaviour change techniques

The analysis of BCTs took place in four consecutive steps.

**Step 1:** The intervention/s in each study was given an 'intervention promise rating' according to potential to improve the specified outcome. Interventions were rated as: (i) 'Promising' (= 1) if, in studies with a control group, there was a statistically significant (at  $p < 0.05$ ) increase in the targeted handwashing behavioral outcome in the intervention group compared to the control group at endline, or, if, in studies without a control group (including studies with only comparator intervention groups, which we redefined as before-after studies) there was a statistically significant ( $p < 0.05$ ) increase in the handwashing behavioral outcome at the endline relative to baseline; (ii) 'Non-promising' (= 0) if there was no statistically significant change at  $p < 0.05$ , or a negative change in the handwashing behavioral outcome. This scale is adapted from that used by Gardner et al. (2016). Unlike traditional meta-analyses which require the same outcome to be measured in the same way across studies, it enables comparison of different outcome measures across studies. Instead of using Gardener's 3-point scale ('very promising', 'quite promising' and 'non-promising'), however, we only categorised interventions as 'promising' or 'non-promising' since our additional step of weighting promise ratio by the individual study's risk of bias (see below) naturally accounts for a lack of control group. Note that if more than one measure of the behavioral outcome was reported, only the most objective outcome was used in the rating (i.e., we selected observed measures over self-reported measures).

**Step 2:** Following the approach by Gardener et al. (2016), after coding, a 'promise ratio' was calculated for each BCT identified across the interventions of the included studies by dividing the number of 'promising' interventions featuring a specific BCT by the number of 'non-promising' interventions featuring that BCT:

Note that, for any given controlled study, we considered only those BCTs that featured exclusively in the intervention group (i.e., they did not also feature in the control group), because intervention 'promise' could not be confidently associated with a BCT if it featured in both intervention and control group.

BCTs must have been present in at least three interventions to be included in the promise ratio analysis. This was decided because, for a BCT to be considered 'promising', it must have been used in at least twice as many promising as non-promising interventions (i.e., promise ratio  $\geq 2$ ), and when weighting BCT promise ratios by risk of bias (see next step), it would be impossible for BCTs used at a low-frequency (in  $\leq 2$  interventions) to be rated as 'promising' unless both studies had a perfect risk of bias rating. Where BCTs were used in only promising interventions (three or more), the number of interventions in which they were used was reported as the promise ratio.

**Step 3:** To account for the different study designs and the reporting and analysis of studies, BCT promise ratios were weighted according to the risk of bias across the individual studies in which they were present. Each BCT promise ratio was multiplied by the mean risk of

bias score (on a scale of 0–1) across all interventions in which that BCT was present to give the weighted BCT promise ratio.

**Step 4:** BCTs were then ranked from the most promising to least promising according to their weighted BCT promise ratio.

### 2.4. Additional analyses

The association between an intervention’s promise rating and the number of BCTs used in that intervention was assessed using Firth’s penalized maximum likelihood logistic regression (firthlogit) to account for the small number of interventions and the skewedness in the intervention promise ratings. The firthlogit technique uses Firth’s method to impose a bias term on the standard likelihood function that is sensitive to a small number of events, ultimately reducing the estimates towards zero (Devikaet al., 2016; Firth, 1993; Gim and Ko, 2017; Heinze and Schemper, 2002; Rojas, 2018). A Welch’s two-sample t-test was performed to determine if there was a statistically significant difference ( $p < 0.05$ ) between the number of BCTs used in non-promising interventions compared to promising interventions.

Co-occurrence patterns of promising BCTs were described using network plots. The number of times each pair of promising BCTs occurred within the same intervention was counted. These co-occurrences were then visualised in a network plot, in which each BCT was represented by a node. The width of each edge (line joining nodes) was proportional to the total number of co-occurrences of BCTs. The size of each node was proportional to the ‘promise ratio’.

### 2.5. Sensitivity analysis

We excluded studies without a control group (i.e., BA studies) in a sensitivity analysis to check if this affected our results.

## 3. Results

### 3.1. Search results

Database searches identified a total of 5207 articles from Medline (751), Embase (1,412), Global Health (738), IBSS (76), AWI (456), CINHAL (719), and Web of Science (1,055). No further articles were identified through reference list screening. After de-duplication, a total of 3360 articles were screened by title and abstract and 94 articles were selected for full-text screening. Applying the pre-defined inclusion criteria, 19 articles were included in the final analysis, detailing 22 interventions. The flow diagram in Fig. 1 outlines the results of the database searches and the screening process, according to PRIMSA guidelines (Moheret al., 2015). Reasons for excluding the remaining 75 articles on full-text screening are given in Appendix S5.

#### 3.1.1. General characteristics of included studies and interventions

The Appendix summarises study characteristics; full details of the characteristics of included studies can be found in online supplemental Appendix S6.

### 3.2. Settings

Fifteen (79%) of the included studies were conducted in low- and middle-income countries (LMICs) and the remaining 4 studies (21%) were conducted in high-income countries (HICs), classified as such by the World Bank (World Bank, 2019). Eighteen (95%) of the 19 included studies were implemented in schools and the one remaining study was a household-level intervention in an internally displaced camp in Northern Iraq. Eleven (58%) studies were conducted in rural settings, 7 (37%) in urban settings, and 1 (5%) study in a mix of urban and rural settings. The skewedness towards rural settings was more pronounced when looking at studies in LMICs only (11 studies in rural settings vs 3 studies in urban settings) whereas all 4 studies in HICs were conducted in urban

settings.

### 3.3. Study design

Of the 19 included studies, 9 were RCTs (6 with a cluster design), 1 was a NRCT with a cluster design, 4 were CBAs, and 5 were BAs. For BCT coding and analysis, Grover et al., 2018 (Grover et al., 2018a), a cluster RCT, was redefined as two separate BA studies due to an active comparator group. Two of the studies: Pickering et al. (2013) and Snow et al. (2008) were multi-arm trials in which all intervention arms targeted hand hygiene behaviour, as defined in this review. The intervention arms in each of these studies were analysed individually and the effect of each intervention (compared to the control group) noted for each intervention arm.

### 3.4. Intervention

Intervention intensity varied from a single hygiene promotion session or initial infrastructure improvements only, to repeated sessions every two weeks over a six-month period. Length of follow-up ranged from one day to one year.

### 3.5. Outcomes

Observation was considered the most rigorous measure of hand hygiene behaviour and was used in 14 (74%) of the included studies. In the remaining 5 studies (26%), hand hygiene behaviour was measured via self-reporting. Of the 22 interventions tested across the 19 included studies, 19 (86%) of these were classified as promising interventions (i.e., reported an increased frequency of hand hygiene behaviour). The remaining 3 (14%) interventions did not have a positive effect on hand hygiene behaviour and were classed as non-promising interventions.

### 3.6. Risk of bias assessment

Only one study (Lewis et al., 2018) was awarded the highest possible overall risk of bias rating of 14 (i.e., was at the lowest risk of bias). The other 18 studies had overall risk of bias ratings ranging from 4 to 11, with a mean of 7.84. Fig. 2 shows the proportion of studies at low, unclear, or high risk of bias (i.e., ‘yes’, ‘partially’, or ‘no/not applicable’),

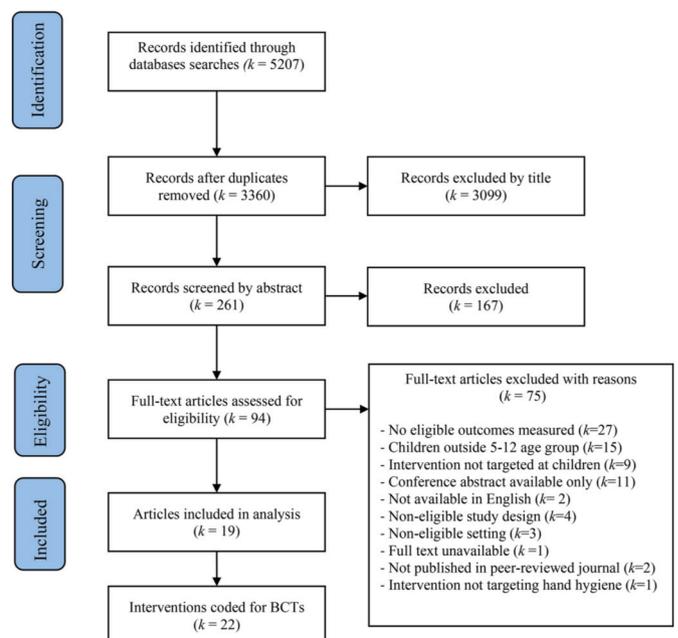


Fig. 1. Flow of studies into the systematic review.

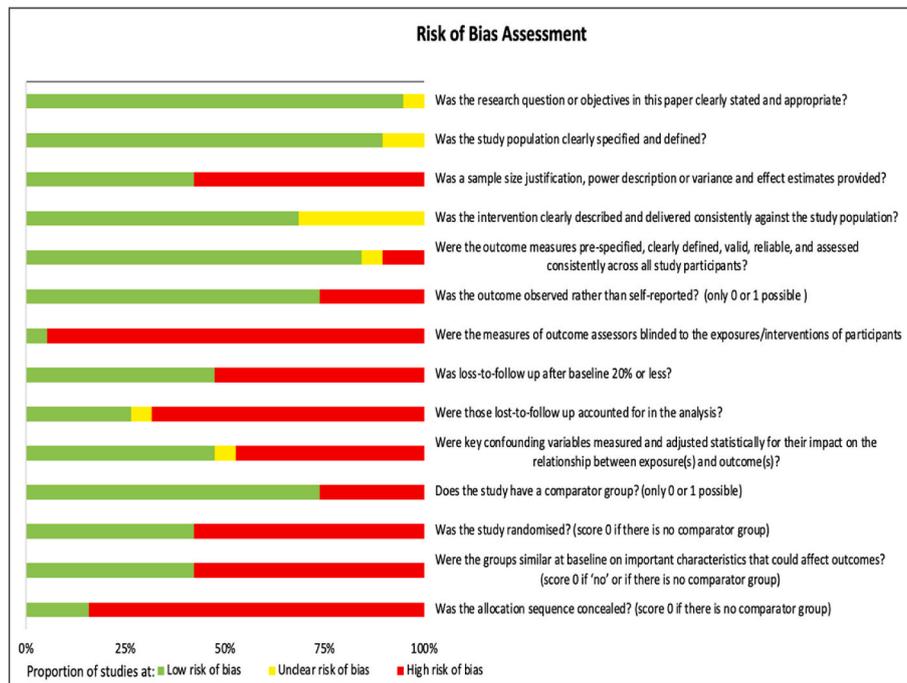


Fig. 2. Risk of bias assessment.

respectively, were the answers to the risk of bias items) for each of the 14 risk of bias items. The full assessment can be found in Appendix S7. Lack of blinding of assessors to the exposures/interventions of participants, no sample size justification, high loss-to-follow-up rates and not accounting for loss-to-follow-up in the analysis were common sources of potential bias across the studies. For controlled studies, a lack of randomisation, baseline imbalance between groups and allocation concealment were also common sources of bias.

### 3.7. Behaviour change techniques

We identified 32 unique BCTs from the 22 interventions included in this review, belonging to 13 of the 16 hierarchical clusters of the BCTTv1. Inter-coder agreement was almost perfect ( $\kappa = 0.87$ ). Details of the BCTs coded in each intervention can be found in Appendix S8. The most frequently employed BCTs (coded in  $\geq 25\%$  of interventions (Brown et al., 2019)) were ‘instruction on how to perform the behaviour’ (14 interventions; 64%), ‘adding objects to the environment’ (13 interventions; 59%), ‘demonstration of the behaviour’ (12 interventions; 55%), ‘information about social and environmental consequences’ (8 interventions; 36%), ‘prompts/cues’ (8 interventions; 36%), ‘salience of consequences’ (7 interventions; 32%), ‘behavioural practice/rehearsal’ (7 interventions; 32%), ‘restructuring the social environment’ (7 interventions; 32%), and ‘information about health consequences’ (6 interventions; 27%).

The number of BCTs identified in a single intervention ranged from 2 to 16 with a mean of 6.4 (CI 6.2–6.6) BCTs per intervention. Firth’s penalized maximum likelihood logistic regression analysis showed that the number of BCTs used in an intervention was negatively associated with the intervention promise rating (i.e., intervention effectiveness) (OR 0.92  $p < 0.01$ ), however this association was no longer statistically significant when adjusted for risk of bias in studies (OR = 0.98,  $p = 0.33$ ). There was also a significant difference between the mean number of BCTs used in non-promising interventions (7.7 CI 7.0–8.3) and in promising interventions (6.2 CI 6.0–6.4) (Welch’s 2-sample  $t$ -test ( $df = 321.6$ ) = 4.3,  $p < 0.01$ ).

It was possible to report promise ratios for 17 of the BCTs identified. The remaining 15 BCTs were excluded from the promise ratio analysis as

they were used at too low a frequency across interventions (i.e., used in only one or two interventions). After adjusting for study quality, a total of 8 individual BCTs had a promise ratio of  $\geq 2$  and were therefore considered as ‘promising’, or most likely to enhance effectiveness of interventions to improve hand hygiene among children. The BCTs with the highest promise ratios (i.e., the most promising BCTs) were: ‘demonstration of the behaviour’ (adjusted promise ratio (aPR) 6.12); ‘information about social and environmental consequences’ (aPR = 4.31); ‘salience of consequences’ (aPR = 3.73); ‘adding objects to the environment’ (aPR = 3.22); and ‘instruction on how to perform the behaviour’ (aPR = 3.22).

The 8 BCTs we found to be promising belonged to 6 of the hierarchical clusters of the BCTTv1. ‘Natural Consequences’ was the cluster with the highest number of promising BCTs ( $k = 3$ ). The remaining 5 clusters had 1 promising BCT each. Table 1 shows the frequency of occurrence of each BCT identified across the interventions and their promise ratios.

### 3.8. Sensitivity analysis

Omitting studies without a control group ( $k = 5$ ) in our sensitivity analysis revealed a few disparities between the promise ratio analyses across all studies compared to controlled studies only, but the highest ranked BCTs were similar indicating that including studies without a control group did not substantially change our results (Fig. 3).

### 3.9. Co-occurrence patterns of promising BCTs

Visual inspection of the co-occurrence network plot of promising BCTs suggests that three of the most promising BCTs, ‘demonstration of the behaviour’, ‘instruction on how to perform the behaviour’ and ‘adding objects to the environment’ all co-occur frequently with one another (Fig. 4). ‘Information about social and environmental consequences’ also appears to co-occur frequently with the BCTs ‘demonstration of the behaviour’ and ‘instruction on how to perform the behaviour’. No other clear co-occurrence relationships were observable from visual inspection.

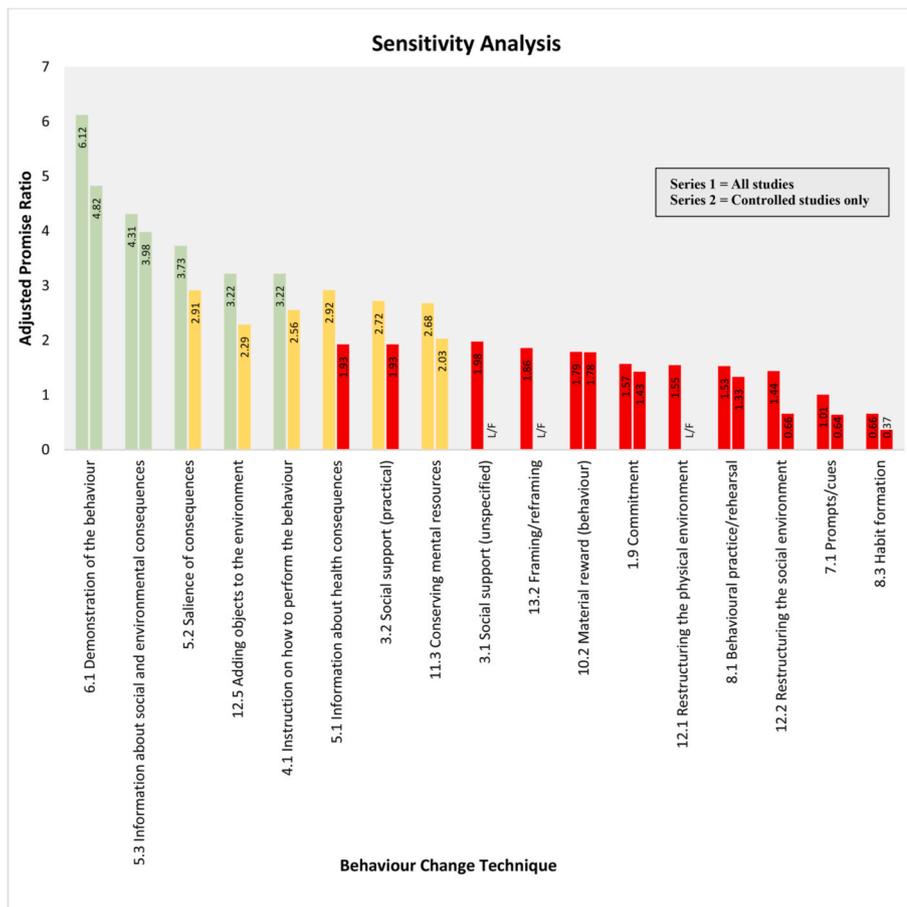
**Table 1**  
Behaviour change technique analysis.

Behaviour Change Technique	BCT FAMILY	Total frequency across interventions	Frequency across promising interventions	Frequency across non-promising interventions	Promise ratio*	Mean Quality score	Adjusted Promise ratio**
6.1 Demonstration of the behaviour	Comparison of behaviour	12	11	1	11.00	0.556	6.12
5.3 Information about social and environmental consequences	Natural Consequences	8	7	1	7.00	0.616	4.31
5.2 Salience of consequences	Natural Consequences	7	6	1	6.00	0.622	3.73
12.5 Adding objects to the environment	Antecedents	13	11	2	5.50	0.585	3.22
4.1 Instruction on how to perform the behaviour	Shaping Knowledge	14	12	2	6.00	0.536	3.22
5.1 Information about health consequences	Natural Consequences	6	5	1	5.00	0.583	2.92
3.2 Social support (practical)	Social support	5	5	0	5.00	0.543	2.72
11.3 Conserving mental resources	Regulation	5	4	1	4.00	0.671	2.68
3.1 Social support (unspecified)	Social support	4	3	1	3.00	0.660	1.98
13.2 Framing/reframing	Identity	4	4	0	4.00	0.464	1.86
10.2 Material reward (behaviour)	Reward and threat	3	3	0	3.00	0.595	1.79
1.9 Commitment	Goals and Planning	3	2	1	2.00	0.785	1.57
12.1 Restructuring the physical environment	Antecedents	4	3	1	3.00	0.518	1.55
8.1 Behavioural practice/rehearsal	Repetition & Substitution	7	5	2	2.50	0.612	1.53
12.2 Restructuring the social environment	Antecedents	7	5	2	2.50	0.576	1.44
7.1 Prompts/cues	Associations	8	5	3	1.67	0.607	1.01
8.3 Habit formation	Repetition & Substitution	4	2	2	1.00	0.660	0.66
1.2 Problem Solving	Goals and Planning	1	1	0	L/F	0.643	L/F
1.5 Review behaviour goal(s)	Goals and Planning	1	1	0	L/F	0.643	L/F
13.1 Identification of self as a role model	Identity	1	1	0	L/F	0.428	L/F
15.3 Focus on past success	Self-belief	1	1	0	L/F	0.714	L/F
2.5 Monitoring of outcome(s) of behaviour	Feedback and monitoring	1	1	0	L/F	0.428	L/F
2.7 Feedback on outcome(s) of behaviour	Feedback and monitoring	1	1	0	L/F	0.286	L/F
5.6 Information about emotional consequences	Natural Consequences	1	1	0	L/F	0.714	L/F
6.3 Information about others approval	Comparison of behaviour	1	1	0	L/F	0.714	L/F
9.1 Credible source	Comparison of outcomes	1	1	0	L/F	0.71	L/F
10.1 Material incentive (behaviour)	Reward and threat	2	2	0	L/F	0.68	L/F
1.4 Action planning	Goals and Planning	2	2	0	L/F	0.54	L/F
1.1 Goal Setting (behaviour)	Goals and Planning	2	2	0	L/F	0.46	L/F
2.2 Feedback on behaviour	Feedback and monitoring	2	2	0	L/F	0.43	L/F
2.3 Self-monitoring of behaviour	Feedback and monitoring	2	1	1	L/F	0.64	L/F
2.1 Monitoring of behaviour by others without feedback	Feedback and monitoring	1	0	1	L/F	1.00	L/F

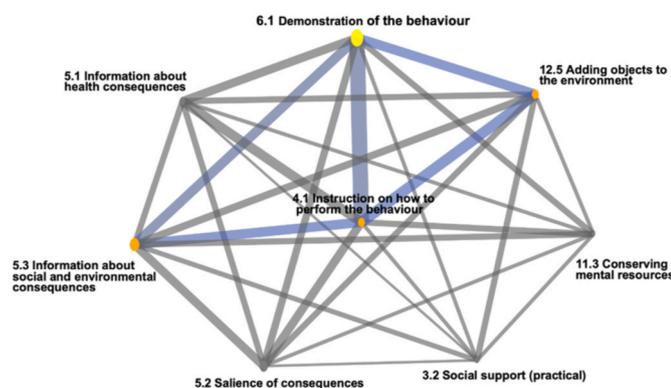
\* Promise ratio denotes the number of promising interventions in which a BCT is featured, divided by the number of non-promising interventions in which it is featured.

\*\* Adjusted promise ratio denotes the promise ratio weighted by risk of bias score. An adjusted promise ratio of 2 or above means the BCT can be classed as promising. Rows in green represent the most promising BCTs (promise ratio >3), rows in yellow represent BCTs with a promise ratio between 2-3, and rows in red represent non-promising BCTs.

L/F = low frequency, excluded from the promise ratio analysis.



**Fig. 3.** Sensitivity analysis excluding studies without a control group. *Note.* Adjusted promise ratio denotes the number of promising interventions in which a BCT is featured, divided by the number of non-promising interventions in which it is featured, weighted by risk of bias score. An adjusted promise ratio of 2 or above means the BCT can be classed as promising. Bars in green represent the most promising BCTs (promise ratio >3), bars in yellow represent BCTs with a promise ratio between 2 and 3, and bars in red represent non-promising BCTs. L/F = low frequency, excluded from the promise ratio analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



**Fig. 4.** Co-occurrence network plot of promising BCTs. *Note.* Nodes represent individual BCTs. The size of each node is proportional to the ‘promise ratio’. The width of each edge (line joining nodes) is proportional to the total number of co-occurrences of BCTs.

#### 4. Discussion

This is the first systematic review to identify behaviour change techniques used in hand hygiene interventions targeting older children. We identified 22 hand hygiene interventions and found evidence of the use of 32 unique BCTs from the BCTTv1. According to our promise ratio calculations, 8 of these BCTs contributed positively to intervention effectiveness in terms of increasing the frequency of children’s hand hygiene behaviour and were classed as ‘promising BCTs’.

Among the most promising BCTs were ‘demonstration of behaviour’, ‘instruction on how to perform the behaviour’ and ‘adding objects to the

environment,’ such as installing handwashing stations and providing soap. It is clear why these BCTs are important – children need to understand how to perform handwashing and require the right tools to do so – and our visual inspection of the co-occurrence network of promising BCTs indicates that these BCTs are commonly used in combination with one another. Several studies among both children and adults report that even when soap and water are available, handwashing rates are often still low (Biranet et al., 2012; Phillips et al., 2015; Watson et al., 2018, 2020), suggesting that while an enabling physical environment is necessary, adding objects to the environment is unlikely to lead to a substantial change in hand hygiene behaviour without complementary BCTs. We therefore recommend that the BCT ‘adding objects to the environment’ is used in combination with other promising BCTs to achieve the best possible outcome. Consideration should also be given to the placement and design of these objects as this may enhance their use without necessarily requiring additional resources. For example, handwashing stations may themselves serve as behavioural cues if installed in a child’s direct path of movement; ensuring taps and soap holders are in easy reach may encourage handwashing by minimising the effort required to perform the behaviour (Neal et al., 2016).

Encouragingly, we found that the three promising BCTs discussed above – ‘demonstration of behaviour’, ‘instruction on how to perform the behaviour’ and ‘adding objects to the environment’ – are also the BCTs that have been employed most frequently in child-targeted hand hygiene interventions. These BCTs should continue to be important considerations for inclusion in intervention design since BCTs with a high overall frequency of use are those most likely to be feasible, acceptable, and fit for purpose (Brown et al., 2019). The fact that these three BCTs were found to frequently co-occur with one another within an intervention further indicates their importance.

Our review also suggests that providing information about the

natural social, environmental, or health consequences of poor hand hygiene and using methods to emphasise these consequences are important techniques to change children's behaviour. Use of these techniques may involve informing children that their peers disapprove of dirty hands (approve of clean hands), visually showing them how dirty hands will lead to a dirty environment (e.g., using glitter), and explaining the link between dirty hands and diseases. Interestingly, our finding that knowledge of health consequences can contribute to a positive change in children's hand hygiene behaviour is contrary to recent studies, primarily among adults, that report health not to be a strong motivator of hand hygiene behaviour change (Biranet al., 2009; Curtis et al., 2009; White et al., 2020). Although a promising BCT, health messaging can be time-consuming and difficult to implement, requiring skilled and trained staff to deliver messages consistently (Contzenet al., 2015b; Greenland et al., 2017). As such, a better use of resources may be to instead provide children with information about social and environmental consequences, particularly since our analysis suggests that this BCT is more promising than providing information about health consequences.

The BCT 'social support (practical) – defined in the BCTTv1 as advising on, arranging, or providing practical help (e.g., from friends, relatives, colleagues, 'buddies' or staff) for performance of the behaviour – was also found to contribute to intervention promise. Other studies of hygiene behaviour among older children support this suggestion, for example; familial role (i.e. support from family members) was found to be an important determinant of older children's handwashing behaviour in an internally displaced camp in Northern Iraq (Watson et al., 2020). In schools in Bangladesh, after visiting the toilet, the presence of a student reminding their peers to handwash, leading them to the handwashing station, or demonstrating proper handwashing techniques was also found to positively impact older children's handwashing behaviour (Grover et al., 2018b). Hygiene programmes should continue to explore novel and age-appropriate strategies to foster active social support among children for positive hand hygiene behaviours.

We found that the number of BCTs used within an intervention was not associated with the intervention's promise rating, meaning that more BCTs does not necessarily equate to intervention effectiveness. In fact, on average, promising interventions employed fewer BCTs than non-promising interventions. Other reviews of BCTs have reported similar findings (Gardner et al., 2011; Hill et al., 2013; Michie et al., 2009a). An explanation for this may be that intervention quality and fidelity of delivery may be compromised by a large number of techniques. In light of this, when designing interventions to improve hand hygiene, programme designers and implementing organisations should focus time and resources on BCTs that positively contribute to intervention effectiveness, rather than the number of BCTs employed. This is particularly important in low-income settings where resources are scarcer and employing fewer BCTs may have positive effects on intervention feasibility, replicability and ability to be delivered at scale (Michie et al., 2009b).

The decision on which BCTs to employ in an intervention should be informed by the physical, social, and cultural aspects of the specific setting. For example, in contexts where there is already good access to handwashing infrastructure, providing further handwashing stations is unlikely to lead to an increase in handwashing behaviour; however, teaching children how to perform proper handwashing and encouragement and support by peers or family members may be more effective. Robust formative research to further understand the context-specific social, environmental, and behavioural drivers is still needed and can be guided by any number of behaviour change frameworks available (Aunger and Curtis, 2016; Coombes and Devine, 2010; Dreifelbis et al., 2013; Michie et al., 2011; Mosler, 2012).

We found no evidence of 61 (66%) BCTs in Michie's taxonomy being used in child-targeted hand hygiene interventions. In addition, even among the 32 BCTs we identified, almost half of these were used too infrequently to be included in promise ratio analyses. We are therefore

unable to determine if these BCTs could contribute to intervention promise, even though many of them were found to be present only in promising interventions. Newer, innovative approaches are less likely to have been widely adopted yet and therefore are more likely to fall into this category of low-frequency BCTs for which promise ratios cannot be calculated. Additionally, innovative approaches are likely to be tested in less rigorous studies, for example in smaller proof-of-concept studies employing simple before-after study designs, likely because funding for evaluation is initially limited for these new approaches. Our weighting by risk of bias will have penalized these approaches due the design of the study in which they are tested and therefore lowered BCT promise ratios (where these could be calculated). Researchers should however not be deterred from further evaluating these newer approaches or from developing their own innovative approaches. Future, more rigorous studies formally evaluating and reporting these unused, low-frequency, and innovative BCTs will shed further light on their ability to change children's hand hygiene behaviour.

Observation was used to measure the behavioural outcome of 74% of the interventions included in this review. For the remaining 26% of interventions, behaviour was assessed by self-report. Self-reported measures are well known to be at high risk of bias; awareness of the social desirability of good hygiene behaviour, coupled with possible courtesy bias, is likely to lead to overreporting of hygiene behaviour (Contzenet al., 2015a). This may contribute to the large proportion of interventions which reported a significant positive change in children's hand hygiene behaviour. We attempted to account for this bias in our BCT analysis by weighting the promise ratio by risk of bias score but nonetheless, care should still be taken when interpreting these results. To aid design of future interventions, practitioners should be encouraged to use observation over self-report wherever possible.

Finally, it should be noted, as found in a previous review of the effect of handwashing promotion targeted at children (Watson et al., 2017), that almost all hand hygiene interventions for children are implemented in a school setting; we found only one study in a non-school setting that met our inclusion criteria. Children spend only about a third of their day in school meaning we are likely missing other opportunities to promote and reinforce good hand hygiene when they are at home or in other community settings. Thus, children out-of-school are clearly a missed subpopulation when it comes to hand hygiene interventions. This may be especially important in low-income settings where children may leave school at an early age, and in humanitarian emergency contexts where schools are not yet established (typically in the early stages of the humanitarian response when camps are first opened and there is a rapid influx of people).

#### 4.1. Limitations

There are number of limitations of our review. First, we made the decision to include studies without a control group in our analysis to increase the depth of information and to reflect the available literature. Although we accounted for this by weighting our promise ratios by risk of bias score, which captured presence or absence of a control group, this study design is at high risk of bias and we cannot know for certain if reported changes in behaviour are bought about by promising BCTs. However, the sensitivity analysis performed indicates that excluding studies without a control group would not change our main results or overall conclusions.

Second, basing our BCT analysis on Gardner's technique (Gardner et al., 2016) allowed us to include heterogenous interventions in our review. This revealed which BCTs likely contributed to intervention effectiveness and their effect relative to other BCTs, but it did not allow quantification of the magnitude of effect of a given BCT. Furthermore, as all interventions employed more than one BCT we can only infer an association and not a causal relationship between an individual BCT and the intervention effect, since the effect of each individual BCT used in the intervention may be masked or modified by the other co-occurring

BCTs.

Third, using the BCTv1 to categorise intervention components and subsequently synthesising results according to Gardener’s technique allowed us to account for study quality, as discussed above, but not for the quality of individual BCTs. BCTs can be employed in different ways with varying quality, intensity and duration; however, in our approach, once an intervention component is coded as a specific BCT it is treated as equal to all components across studies that have also been coded with the same BCT label. The most evident example of this in our review was the BCT ‘prompts and cues’. Placing a poster above a handwashing facility (Lewis et al., 2018), a teacher verbally prompting students to wash their hands before lunch (Snow et al., 2008), and painting footpaths leading from the toilet to the handwashing station together with handprints on the station (Dreibelbis et al., 2016), were all intervention components we coded as ‘prompts and cues’. However, these prompts and cues are all rather different. The painted footpaths and handprints are likely to be much more noticeable than a single poster above a sink and therefore likely to act as a stronger cue to wash hands, and children may feel more compelled or obliged to wash their hands if prompted verbally by a teacher rather than by a simple poster. Beyond this, even the quality of posters, specifically their ability to catch attention and be clearly understood, can widely vary. Similarly, BCTs that have the same format may also be used at very different intensities, for example, the BCT ‘information about health consequences’ was delivered verbally in numerous interventions but in some it was delivered just in one session and in other interventions it was delivered repeatedly over weeks, months, or even years. In this review, as in others that have used similar approaches, there is a risk that some of our promise ratios may have been skewed. When deciding to employ a specific BCT care should also be taken to ensure the way in which that BCT is employed is of adequate quality and that consideration is also given to the duration and intensity of use.

Accounting for differences in intervention quality and intensity is further compounded by the overall low quality of reporting on the interventions used across the studies included in this review. While standard tools and formats exist for reporting on and assessing study quality (Critical Appraisal Skills Programme, 2019; Downs and Black, 1998; Jadad et al., 1996; National Heart Lung and Blood Institute, 2019; Sterne et al., 2016, 2019; Wells et al., 2019) there are fewer guidelines available for reporting on the specifics of intervention content, delivery mode, intensity, and duration. More standardised reporting of BCTs and intervention delivery and intensity would facilitate future comparisons that account for overall intervention quality. This low reporting quality may have also introduced biases in our own intervention coding. Where information was incomplete or absent with regard to BCTs, there is a risk that BCTs are miscoded or omitted.

The approach we used in this review is designed to identify individual BCTs that contribute to a positive change in hand hygiene. As such, we did not quantitatively assess if specific combinations of BCTs were important for intervention outcome. We did however conduct a visual assessment of the co-occurrence of promising BCTs and this

indicated some co-occurrence patterns suggesting that using certain promising BCTs in combination may be important for achieving an overall positive change in behaviour. As mentioned above, in all interventions, BCTs were used in combination so we cannot say for certain if the BCTs we identified as promising would achieve a significant change in hygiene behaviour if used independently. We have however published our data set and welcome further analyses by researchers who are interested in examining these characteristics.

Finally, by including only English language studies we may have missed key hand hygiene interventions published in other languages. There is also a strong risk of publication bias (whereby promising interventions are more likely to be published), indicated by the large proportion (86%) of interventions that were promising in our study, which may have skewed our results. Due to the nature of our analysis, it was not possible to formally evaluate the moderator effects of publication bias and specific methodological features of studies on our results, as is best practice (Johnson and Hennessy, 2019). However, by adjusting promise ratios by risk of bias we attempted to account for this as much as possible. Our protocol was not pre-registered in a standard repository.

**5. Conclusion**

This systematic review identified 8 promising BCTs for improving older children’s hand hygiene behaviour. We recommend that future child-targeted hand hygiene interventions include some of these promising BCTs in combination, particularly those that ensure children understand how to perform the behaviour and its associated consequences and those providing an enabling physical and social environment, which we find to be the most promising BCTs. To further our understanding of the most effective ways to improve the hand hygiene of older children, we also recommend that researchers always publish transparent and comprehensive descriptions of intervention techniques and that observed behavioural outcome measures are used whenever possible. We encourage further research quantitatively evaluating the effectiveness of hand hygiene interventions employing the less frequently used BCTs we have identified in this review in order for their efficacy to also be determined.

**Author contributions**

Julie Watson: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. Oliver Cumming: Supervision, Conceptualization, Methodology, Formal analysis, Writing – review & editing, Amy MacDougal: Formal analysis, Writing – review & editing, Alexandra Czerniewska: Formal analysis, Validation, Writing – review & editing. Robert Dreibelbis: Supervision, Conceptualization, Methodology, Formal analysis, Writing – review & editing

**Declaration of competing interest**

None.

**Appendix Intervention Characteristics**

Study	Study Design	Setting	Country	Behaviour Change Techniques *	Outcome measure	Effect (increased frequency of hand hygiene behaviour)
Al-Delaimy 2014	NRCT (cluster)	Rural schools	LMIC	- 3.1 Social support (unspecified) - 4.1 Instruction on how to perform the behaviour - 5.1 Information about health consequences - 6.1 Demonstration of the behaviour - 7.1 Prompts/cues - 8.1 Behavioural practice/rehearsal	Self-report	✓

(continued on next page)

(continued)

Study	Study Design	Setting	Country	Behaviour Change Techniques *	Outcome measure	Effect (increased frequency of hand hygiene behaviour)
Au 2010	RCT	Urban schools	HIC	<ul style="list-style-type: none"> <li>- 12.2 Restructuring the social environment</li> <li>- 12.5 Adding objects to the environment</li> <li>- 2.2 Feedback on behaviour</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.2 Saliency of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 8.3 Habit formation</li> <li>- 10.1 Material incentive (behaviour)</li> <li>- 10.2 Material reward (behaviour)</li> <li>- 11.3 Conserving mental resources</li> </ul>	Observed	✓
Beiri 2013	RCT (cluster)	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences**</li> <li>- 5.2 Saliency of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 5.6 Information about emotional consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 9.1 Credible source</li> <li>- 12.5 Adding objects to the environment</li> <li>- 15.3 Focus on past success</li> </ul>	Observed	✓
Chard and Freeman 2018	RCT (cluster)	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 7.1 Prompts/cues</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 8.3 Habit formation</li> <li>- 12.1 Restructuring the physical environment</li> <li>- 12.2 Restructuring the social environment</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	×
Dreibelbis 2016	BA	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 3.2 Social support (practical)</li> <li>- 7.1 Prompts/cues</li> <li>- 12.1 Restructuring the physical environment</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	✓
Early 1998	RCT (multi-arm) ***	Urban school s	HIC	<ul style="list-style-type: none"> <li>- 3.2 Social support (practical)</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 10.2 Material reward (behaviour)</li> <li>- 11.3 Conserving mental resources</li> <li>- 12.2 Restructuring the social environment</li> </ul>	Observed	✓
Graves 2011	CBA	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 7.1 Prompts/cues</li> <li>- 12.5 Adding objects to the environment**</li> </ul>	Observed	×
Grover 2018	RCT (cluster) (redefined as two BAs)	Rural schools	LMIC	<p>BA 1)</p> <ul style="list-style-type: none"> <li>- 1.1 Goal Setting (behaviour)</li> <li>- 1.2 Problem Solving</li> <li>- 1.4 Action planning</li> <li>- 1.5 Review behaviour goal(s)</li> <li>- 1.9 Commitment</li> <li>- 3.1 Social support (unspecified)</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 11.3 Conserving mental resources</li> <li>- 12.2 Restructuring the social environment</li> </ul> <p>BA 2)</p> <ul style="list-style-type: none"> <li>- 7.1 Prompts/cues</li> <li>- 12.1 Restructuring the physical environment</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	BA 1) ✓ BA 2) ✓

(continued on next page)

(continued)

Study	Study Design	Setting	Country	Behaviour Change Techniques *	Outcome measure	Effect (increased frequency of hand hygiene behaviour)
Lewis 2018	RCT (cluster)	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 1.9 Commitment</li> <li>- 2.1 Monitoring of behaviour by others without feedback</li> <li>- 2.3 Self-monitoring of behaviour</li> <li>- 3.1 Social support (unspecified)</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 5.2 Salience of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 7.1 Prompts/cues</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 8.3 Habit formation</li> <li>- 11.3 Conserving mental resources</li> <li>- 12.2 Restructuring the social environment</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	×
Pasewaldt 2018	BA	Urban & Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 1.4 Action planning</li> <li>- 2.5 Monitoring of outcome(s) of behaviour without feedback</li> <li>- 3.1 Social support (unspecified)</li> <li>- 3.2 Social support (practical)</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 5.2 Salience of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 8.3 Habit formation</li> <li>- 12.1 Restructuring the physical environment</li> <li>- 12.2 Restructuring the social environment</li> <li>- 12.5 Adding objects to the environment</li> <li>- 13.1 Identification of self as a role model</li> <li>- 13.2 Framing/reframing</li> </ul>	Self-report	✓
Patel 2012	CBA	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Self-report	✓
Pickering 2013	RCT (cluster, multi-arm)	Urban schools	LMIC	<ul style="list-style-type: none"> <li>1) <ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 12.5 Adding objects to the environment</li> <li>- 13.2 Framing/reframing</li> </ul> </li> <li>2) <ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 12.5 Adding objects to the environment</li> <li>- 13.2 Framing/reframing</li> </ul> </li> </ul>	Observed	1) ✓ 2) ✓
Saboori 2013	RCT (cluster)	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 3.2 Social support (practical)</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	✓
Snow 2008	RCT (multi-arm)	Urban schools	HIC	<ul style="list-style-type: none"> <li>1) <ul style="list-style-type: none"> <li>- 6.1 Demonstration of the behaviour</li> <li>- 7.1 Prompts/cues</li> </ul> </li> <li>2) <ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 5.2 Salience of consequences</li> <li>- 7.1 Prompts/cues</li> </ul> </li> </ul>	Observed	1) ✓ 2) ✓
Solehati 2017	BA	Rural schools	LMIC	<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 12.2 Restructuring the social environment</li> </ul>	Observed	✓
	CBA	Urban schools	LMIC	<ul style="list-style-type: none"> <li>- 1.9 Commitment</li> </ul>	Self-report	✓

(continued on next page)

(continued)

Study	Study Design	Setting	Country	Behaviour Change Techniques *	Outcome measure	Effect (increased frequency of hand hygiene behaviour)
Taware 2018				<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 6.3 Information about others approval</li> <li>- 8.1 Behavioural practice/rehearsal</li> </ul>		
Tousman 2007	BA	Urban schools	HIC	<ul style="list-style-type: none"> <li>- 1.1 Goal Setting (behaviour)</li> <li>- 2.2 Feedback on behaviour</li> <li>- 2.3 Self-monitoring of behaviour</li> <li>- 2.7 Feedback on outcome(s) of behaviour</li> <li>- 4.1 Instruction on how to perform the behaviour</li> <li>- 5.1 Information about health consequences</li> <li>- 5.2 Saliency of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 12.5 Adding objects to the environment</li> <li>- 13.2 Framing/reframing</li> </ul>	Self-report	✓
Watson 2019	CBA	Rural households	LMIC	<ul style="list-style-type: none"> <li>- 4.1 Instruction on how to perform the behaviour **</li> <li>- 5.2 Saliency of consequences</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.1 Demonstration of the behaviour **</li> <li>- 8.1 Behavioural practice/rehearsal</li> <li>- 10.1 Material incentive (behaviour)</li> <li>- 10.2 Material reward (behaviour)</li> <li>- 12.5 Adding objects to the environment **</li> </ul>	Observed	✓
Wichaidit 2019	BA	Urban schools	LMIC	<ul style="list-style-type: none"> <li>- 1.9 Commitment</li> <li>- 3.2 Social support (practical)</li> <li>- 5.3 Information about social and environmental consequences</li> <li>- 6.3 Information about others approval</li> <li>- 11.3 Conserving mental resources</li> <li>- 12.5 Adding objects to the environment</li> </ul>	Observed	✓

HIC = high-income country, LMIC = low or middle-income country, BA = before-after study, CBA = controlled before-after study, RCT = randomised controlled trial, NRCT = non-randomised controlled trial.

1) and 2) represent different intervention arms within a trial. Where an RCT has been redefined as two separate BA studies, BA 1) and BA 2) represent these separate studies.

\* Employed in the intervention group/s.

\*\* BCT also features in the control group and therefore was excluded from the analysis.

\*\*\* Only one intervention arm targeted the behaviour of interest.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.socscimed.2021.114090>.

### References

Adair, P.M., Burnside, G., Pine, C.M., 2013. Analysis of health behaviour change interventions for preventing dental caries delivered in primary schools. *Caries Res.* 47 (Suppl. 1), 2–12.

Aiello, A.E., Coulborn, R.M., Perez, V., Larson, E.L., 2008. Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am. J. Publ. Health* 98, 1372–1381.

Aunger, R., Curtis, V., 2016. Behaviour Centred Design: towards an applied science of behaviour change. *Health Psychol. Rev.* 10, 425–446.

Biran, A., Schmidt, W.-P., Zeleke, L., Emukule, H., Khay, H., Parker, J., Peprah, D., 2012. Hygiene and sanitation practices amongst residents of three long-term refugee camps in Thailand, Ethiopia and Kenya. *Trop. Med. Int. Health* 17, 1133–1141.

Biran, A., Schmidt, W.P., Wright, R., Jones, T., Seshadri, M., Isaac, P., Nathan, N.A., Hall, P., Mckenna, J., Granger, S., Bidinger, P., Curtis, V., 2009. The effect of a soap promotion and hygiene education campaign on handwashing behaviour in rural India: a cluster randomised trial. *Trop. Med. Int. Health* 14, 1303–1314.

Bresee, S., Caruso, B.A., Sales, J., Lupele, J., Freeman, M.C., 2016. '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.* 31, 521–534.

Brown, T.J., Hardeman, W., Bauld, L., Holland, R., Maskrey, V., Naughton, F., Orton, S., Ussher, M., Notley, C., 2019. A systematic review of behaviour change techniques within interventions to prevent return to smoking postpartum. *Addict. Behav.* 92, 236–243.

Brown, T.J., Hardeman, W., Bauld, L., Holland, R., Maskrey, V., Naughton, F., Orton, S., Ussher, M., Notley, C., 2019. A systematic review of behaviour change techniques within interventions to prevent return to smoking postpartum. *Addict. Behav.* 92, 236–243.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I.C., Schmidt, W.P., 2010. Water, sanitation and hygiene for the prevention of diarrhoea. *Int. J. Epidemiol.* 39 (Suppl. 1), i193–205.

Contzen, N., De Pasquale, S., Mosler, H.-J., 2015a. Over-reporting in handwashing self-reports: potential explanatory factors and alternative measurements. *PLoS One* 10, e0136445.

Contzen, N., Meili, I.H., Mosler, H.J., 2015b. Changing handwashing behaviour in southern Ethiopia: a longitudinal study on infrastructural and commitment interventions. *Soc. Sci. Med.* 124, 103–114.

- Coombes, Y., Devine, J., 2010. Introducing foam: a framework to analyze handwashing behaviours to design effective handwashing programs. Water and sanitation program: working paper. Global Scaling up Handwashing Project. Water and Sanitation Program, Washington, DC.
- Cradock, K.A., Ólaighin, G., Finucane, F.M., Gainforth, H.L., Quinlan, L.R., Ginis, K.A.M., 2017. Behaviour change techniques targeting both diet and physical activity in type 2 diabetes: a systematic review and meta-analysis. *Int. J. Behav. Nutr. Phys. Activ.* 14, 18–18.
- Critical Appraisal Skills Programme, 2019. CASP Checklists [Online]. Available:** <https://casp-uk.net/casp-tools-checklists/>. (Accessed 10 February 2021).
- Curtis, V.A., Danquah, L.O., Atunger, R.V., 2009. Planned, motivated and habitual hygiene behaviour: an eleven country review. *Health Educ. Res.* 24, 655–673.
- De Vasconcelos, S., Toskin, I., Cooper, B., Chollier, M., Ram, P.K., Blondeel, K., Troussier, T., Kiarie, J., 2018. Behaviour change techniques in brief interventions to prevent HIV, STI and unintended pregnancies: a systematic review. *PLoS One* 13, e0204088.
- Devika, S., Jayaseelan, L., Sebastian, G., 2016. Analysis of sparse data in logistic regression in medical research: a newer approach. *J. Postgrad. Med.* 62, 26–31.
- Downs, S., Black, N., 1998. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J. Epidemiol. Community Health* 52 (6), 377–384.
- Dreibelbis, R., Kroeger, A., Hossain, K., Venkatesh, M., Ram, P.K., 2016. Behavior change without behavior change communication: nudging handwashing among primary school students in Bangladesh. *Int. J. Environ. Res. Publ. Health* 13.
- Dreibelbis, R., Winch, P.J., Leontini, E., Hulland, K.R., Ram, P.K., Unicomb, L., Luby, S. P., 2013. The Integrated Behavioural Model for Water, Sanitation, and Hygiene: a systematic review of behavioural models and a framework for designing and evaluating behaviour change interventions in infrastructure-restricted settings. *BMC Publ. Health* 13, 1015.
- Firth, D., 1993. Bias reduction of maximum likelihood estimates. *Biometrika* 80, 27–38.
- Freeman, M.C., Stocks, M.E., Cumming, O., Jeandron, A., Higgins, J.P., Wolf, J., Pruss-Ustun, A., Bonjour, S., Hunter, P.R., Fewtrell, L., Curtis, V., 2014. Hygiene and health: systematic review of handwashing practices worldwide and update of health effects. *Trop. Med. Int. Health* 19, 906–916.
- Gardner, B., Smith, L., Lorenzatto, F., Hamer, M., Biddle, S.J., 2016. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol. Rev.* 10, 89–112.
- Gardner, B., Wardle, J., Poston, L., Croker, H., 2011. Changing diet and physical activity to reduce gestational weight gain: a meta-analysis. *Obes. Rev.* 12 e602-e620.
- Gim, T.-H.T., Ko, J., 2017. Maximum likelihood and Firth logistic regression of the pedestrian route choice. *Int. Reg. Sci. Rev.* 40, 616–637.
- Greenland, K., Chipungu, J., Chilekwa, J., Chilengi, R., Curtis, V., 2017. Disentangling the effects of a multiple behaviour change intervention for diarrhoea control in Zambia: a theory-based process evaluation. *Glob. Health* 13, 78.
- Grover, E., Hossain, M.K., Uddin, S., Venkatesh, M., Ram, P.K., Dreibelbis, R., 2018a. Comparing the behavioural impact of a nudge-based handwashing intervention to high-intensity hygiene education: a cluster-randomised trial in rural Bangladesh. *Trop. Med. Int. Health* 23, 10–25.
- Grover, E., Hossain, M.K., Uddin, S., Venkatesh, M., Ram, P.K., Dreibelbis, R., 2018b. Social Influence on Handwashing with Soap: Results from a Cluster Randomized Controlled Trial in Bangladesh. *The American Journal of Tropical Medicine and Hygiene*.
- Heinze, G., Schemper, M., 2002. A solution to the problem of separation in logistic regression. *Stat. Med.* 21, 2409–2419.
- Heron, N., Kee, F., Donnelly, M., Cardwell, C., Tully, M.A., Cupples, M.E., 2016. Behaviour change techniques in home-based cardiac rehabilitation: a systematic review. *Br. J. Gen. Pract.* 66, e747–e757.
- Hill, B., Skouteris, H., Fuller-Tyszkiewicz, M., 2013. Interventions designed to limit gestational weight gain: a systematic review of theory and meta-analysis of intervention components. *Obes. Rev.* 14, 435–450.
- Jadad, A.R., Moore, R.A., Carroll, D., Jenkinson, C., Reynolds, D.J.M., Gavaghan, D.J., M, H.J., 1996. Assessing the quality of reports of randomized clinical trials: is blinding necessary? *Contr. Clin. Trials* 17, 1–12.
- Johnson, B.T., Hennessy, E.A., 2019. Systematic reviews and meta-analyses in the health sciences: best practice methods for research syntheses. *Soc. Sci. Med.* 233, 237–251.
- Kelder, S.H., Perry, C.L., Klepp, K.I., Lytle, L.L., 1994. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *Am. J. Publ. Health* 84, 1121–1126.
- Kyu, H.H., Stein, C.E., Boschi Pinto, C., Rakovac, I., Weber, M.W., Dannemann Purnat, T., Amuah, J.E., Glenn, S.D., Cercy, K., Biryukov, S., Gold, A.L., Chew, A., Mooney, M. D., O’rouke, K.F., Sliagar, A., Murray, C.J.L., Mokdad, A.H., Naghavi, M., 2018. Causes of death among children aged 5–14 years in the WHO European Region: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Child & Adolescent Health* 2, 321–337.
- Lewis, H.E., Greenland, K., Curtis, V., Schmidt, W.P., 2018. Effect of a school-based hygiene behavior change campaign on handwashing with soap in Bihar, India: cluster-randomized trial. *Am. J. Trop. Med. Hyg.* 99, 924–933.
- Mbakaya, B.C., Lee, P.H., Lee, R.L.T., 2017. Hand hygiene intervention strategies to reduce diarrhoea and respiratory infections among schoolchildren in developing countries: a systematic review. *Int. J. Environ. Res. Publ. Health* 14, 371.
- Mchugh, M.L., 2012. Interrater reliability: the kappa statistic. *Biochem. Med.* 22, 276–282.
- Michie, S., Abraham, C., Whittington, C., McAteer, J., Gupta, S., 2009a. Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychol.* 28, 690–701.
- Michie, S., Jochelson, K., Markham, W.A., Bridle, C., 2009b. Low-income groups and behaviour change interventions: a review of intervention content, effectiveness and theoretical frameworks. *J. Epidemiol. Community Health* 63, 610–622.
- Michie, S., Johnston, M., 2012. Theories and techniques of behaviour change: developing a cumulative science of behaviour change. *Health Psychol. Rev.* 6, 1–6.
- Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M.P., Cane, J., Wood, C.E., 2013. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann. Behav. Med.* 46, 81–95.
- Michie, S., Van Stralen, M.M., West, R., 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement. Sci.* : ISCUS 6, 42–42.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., The, P.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 6, e1000097.
- Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., Group, P.-P., 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst. Rev.* 4, 1.
- Mosler, H.J., 2012. A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. *Int. J. Environ. Health Res.* 22, 431–449.
- Movassagh, E.Z., Baxter-Jones, A.D.G., Kontulainen, S., Whiting, S.J., Vatanparast, H., 2017. Tracking dietary patterns over 20 Years from childhood through adolescence into young adulthood: the saskatchewan pediatric bone mineral accrual study. *Nutrients* 9, 990.
- Nandrup-Bus, I., 2009. Mandatory handwashing in elementary schools reduces absenteeism due to infectious illness among pupils: a pilot intervention study. *Am. J. Infect. Contr.* 37, 820–826.
- National Heart Lung And Blood Institute, 2019. Study Quality Assessment Tools [Online]. Available: <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>. (Accessed 10 February 2021).
- Neal, D., Vujcic, J., Burns, J., Wood, W., Devine, J., 2016. Nudging and Habit Change for Open Defecation: New Tactics from Behavioral Science. World Bank.
- Nhlbi, 2018. Study Quality Assessment Tools. [Online]. National Heart, Lung, and Blood Institute, Bethesda, Maryland. Available: <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>. (Accessed 7 May 2018).
- Onyango-Ouma, W., Aagaard-Hansen, J., Jensen, B.B., 2005. The potential of schoolchildren as health change agents in rural western Kenya. *Soc. Sci. Med.* 61, 1711–1722.
- Phillips, R.M., Vujcic, J., Boscoe, A., Handzel, T., Aninyasi, M., Cookson, S.T., Blanton, C., S Blum, L., Ram, P.K., 2015. Soap is not enough: handwashing practices and knowledge in refugee camps, Maban County, South Sudan. *Conflict Health* 9, 39.
- Pickering, A.J., Davis, J., Blum, A.G., Scalmanini, J., Oyier, B., Okoth, G., Breiman, R.F., Ram, P.K., 2013. Access to waterless hand sanitizer improves student hand hygiene behavior in primary schools in Nairobi, Kenya. *Am. J. Trop. Med. Hyg.* 89, 411–418.
- Pressman, R.M., Owens, J.A., Evans, A.S., Nemon, M.L., 2014. Examining the interface of family and personal traits, media, and academic imperatives using the learning habit study. *Am. J. Fam. Ther.* 42, 347–363.
- Rojas, Y., 2018. Long-term Suicidogenic Effect of Being Mostly Alone as a Child in a Stockholm Birth Cohort - Restating the Role of Social Isolation in Suicide.
- Samdal, G.B., Eide, G.E., Barth, T., Williams, G., Meland, E., 2017. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *Int. J. Behav. Nutr. Phys. Activ.* 14, 42.
- Snow, M., White JR., G.L., Kim, H.S., 2008. Inexpensive and time-efficient hand hygiene interventions increase elementary school children’s hand hygiene rates. *J. Sch. Health* 78, 230–233.
- Soltani, H., Arden, M.A., Duxbury, A.M.S., Fair, F.J., 2016. An analysis of behaviour change techniques used in a sample of gestational weight management trials. *J. Pregnancy* 2016, 1085916. <https://doi.org/10.1155/2016/1085916>.
- Stanford, L.J., Schmidtke, K.A., 2020. A systematic review of hand-hygiene and environmental-disinfection interventions in settings with children. *BMC Publ. Health* 20, 195.
- Sterne, J., Hernán, M., Reeves, B., Savović, J., Berkman, N., Viswanathan, M., Henry, D., Altman, D., Ansari, M., Boutron, I., Carpenter, J., Chan, A., Churchill, R., Deeks, J., Hróbjartsson, A., Kirkham, J., Jüni, P., Loke, Y., Pigott, T., Ramsay, C., Regidor, D., Rothstein, H., Sandhu, L., Santaguida, P., Schünemann, H., Shea, B., Shrier, I., Tugwell, P., Turner, L., Valentine, J., Waddington, H., Waters, E., Wells, G., Whiting, P., Higgins, J., 2016. ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ* 355, i4919.
- Sterne, J., Savović, J., Page, M., Elbers, R., Blencowe, N., Boutron, I., Cates, C., Cheng, H.-Y., Corbett, M., Eldridge, S., Hernán, M., Hopewell, S., Hróbjartsson, A., Junqueira, D., Jüni, P., Kirkham, J., Lasserson, T., Li, T., Mcaleenan, A., Reeves, B., Shepperd, S., Shrier, I., Stewart, L., Tilling, K., White, I., Whiting, P., Higgins, J., 2019. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 366, i4898.
- Stocks, M.E., Ogden, S., Haddad, D., Addiss, D.G., Mcguire, C., Freeman, M.C., 2014. Effect of water, sanitation, and hygiene on the prevention of trachoma: a systematic review and meta-analysis. *PLoS Med.* 11, e1001605.
- Strunz, E.C., Addiss, D.G., Stocks, M.E., Ogden, S., Utzinger, J., Freeman, M.C., 2014. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLoS Med.* 11, e1001620.
- Talaat, M., Afifi, S., Dueger, E., El-Ashry, N., Marfin, A., Kandeel, A., Mohareb, E., El-Sayed, N., 2011. Effects of hand hygiene campaigns on incidence of laboratory-confirmed influenza and absenteeism in schoolchildren, Cairo, Egypt. *Emerg. Infect. Dis.* 17, 619–625.

- Watson, J., Cumming, O., Aunger, R., Deola, C., Chase, R.P., Dreibelbis, R., 2020. Child handwashing in an internally displaced persons camp in Northern Iraq: a qualitative multi-method exploration of motivational drivers and other handwashing determinants. *PloS One* 15, e0228482.
- Watson, J., Dreibelbis, R., Aunger, R., Deola, C., King, K., Long, S., Chase, R.P., Cumming, O., 2018. Child's play: harnessing play and curiosity motives to improve child handwashing in a humanitarian setting. *Int. J. Hyg Environ. Health* 222 (2), 177–182. <https://doi.org/10.1016/j.ijheh.2018.09.002>.
- Watson, J.A., Ensink, J.H.J., Ramos, M., Benelli, P., Holdsworth, E., Dreibelbis, R., Cumming, O., 2017. 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. *Trop. Med. Int. Health* 22, 526–538.
- Wells, G., Shea, B., O'connell, D., Peterson, J., Welch, V., Losos, M., Tugwell, P., 2019. *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analyses* [Online]. Ottawa Hospital Research Institute. Available: [http://www.ohri.ca/programs/clinical\\_epidemiology/oxford.asp](http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp). (Accessed 10 February 2021).
- White, S., Thorseth, A.H., Dreibelbis, R., Curtis, V., 2020. The determinants of handwashing behaviour in domestic settings: an integrative systematic review. *Int. J. Hyg Environ. Health* 227, 113512.
- Willmott, M., Nicholson, A., Busse, H., Macarthur, G.J., Brookes, S., Campbell, R., 2015. Effectiveness of Hand Hygiene Interventions in Reducing Illness Absence Among Children in Educational Settings: a Systematic Review and Meta-Analysis. *Archives of Disease in Childhood*.
- Wolf, J., Hunter, P.R., Freeman, M.C., Cumming, O., Clasen, T., Bartram, J., Higgins, J.P. T., Johnston, R., Medlicott, K., Boisson, S., Prüss-Ustün, A., 2018. Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. *Trop. Med. Int. Health* 23, 508–525.
- World Bank, 2019. *World Bank Country and Lending Groups: World Bank List of Economies (July 2019)* [Online]. Available: <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>. (Accessed 22 July 2020).
- World Health Organization, 2020. *Global Health Estimates 2020: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2019*. World Health Organisation, Geneva.