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Interventions to increase personal protective behaviours to limit the spread of respiratory viruses: A rapid evidence review and meta-analysis

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Abstract

Purpose: Changing human behaviour is critical for stopping the spread of respiratory viruses, including SARS-CoV-2. This includes increasing personal protective behaviours: we need evidence to inform how to achieve this. We aimed to evaluate the acceptability, practicability, effectiveness, affordability, spill-over effects and equity impact of interventions to increase personal protective behaviours to limit the spread of respiratory viruses.

Methods: We used standard best practice for rapid evidence reviews. We searched Ovid MEDLINE and Scopus to identify interventions designed to change six personal protective behaviours: hand hygiene; avoiding touching the 'T-Zone'; catching droplets in tissues; face mask use; disinfecting surfaces; and maintaining physical distancing. Primary research studies conducted in adults or children with active or passive comparators were included. A narrative synthesis and random-effects meta-analyses were conducted.

Results: We identified 39 studies conducted across 15 countries. Interventions targeted hand hygiene (n = 30) and/or face mask use (n = 12) and used two- or three-arm study designs with passive comparators. Interventions were typically delivered face-to-face and included a median of three behaviour change techniques. Interventions to increase hand hygiene had a medium, positive effect (d = 0.62, 95% CI = 0.43-0.80, $p < .001$, I^2 = 81.2%). Interventions targeting face mask use had mixed results, with an imprecise pooled estimate (OR = 4.14, 95% CI = 1.24-13.79, $p < .001$, I^2 = 89.67%). Between-study heterogeneity was high.

Conclusions: We found positive effects of interventions targeting hand hygiene, with unclear results for interventions targeting face mask use.

Introduction

Respiratory viruses such as SARS-CoV-2 enter the body through the eyes, nose and mouth (the 'T-Zone')[1]. Changing human behaviour is critical for stopping the spread of the SARS-CoV-2 virus and for supporting the easing of financially and psychologically costly physical distancing measures[2–5]. Personal protective behaviours, including hand washing, disinfecting fomites such as clothes or furniture, and face mask wearing, are advocated for limiting the spread of SARS-CoV-2[6,7]. Simply advising people to adopt these behaviours has been found to be insufficient, just as has explaining what to do and why these behaviours are necessary[8]. Directly relevant evidence on interventions to promote adherence to personal protective behaviours in community-dwelling children and adults is sparse but there is an urgent need to identify and synthesise what evidence does exist. Policymakers need evidence to inform the development of public health guidance and decide which interventions to prioritise. We adopted best practice for rapid evidence reviews to evaluate the acceptability, practicability, effectiveness, affordability, spill-over effects (unintended consequences) and equity impact (the 'APEASE' criteria[9]) of interventions to increase personal protective behaviours.

During pandemics of respiratory viruses, multipronged approaches involving both pharmacological (e.g. vaccination) and behavioural measures (e.g. hand washing, physical distancing) are required to bring the reproductive number below 1[2–4,10]. Vaccination of populations will take months, even years, to roll out, especially in low- and middle-income countries. Hence, physical distancing and other behavioural measures will be required, possibly permanently. Population-wide restrictions are costly from financial, social and psychological perspectives: the world economy has been projected to shrink by approximately 4.9% in 2020[11], with an additional 88 million people globally being pushed into extreme poverty (i.e. living on less than $1.90/day)[12], and prolonged periods of social isolation are associated with increases in domestic violence[13] and negative mental health effects, such as post-traumatic stress disorder, confusion and anger[14]. Less costly, yet highly effective[15], personal protective behaviours are thus important for supporting the easing of lockdown measures to ensure long-term suppression of viral transmission and preparedness for new viral waves and future pandemics[3,5,10]. To successfully block transmission, personal protective behaviours must be adopted across the population. Although systematic reviews of interventions to change hand hygiene in healthcare professionals are available[16–20], generalisability to community settings is limited. There also appears to be little evidence about interventions to change behaviours such as not touching the T-Zone (eyes, nose and mouth), which would have a significant effect if adopted[21] and carry little or no costs to people or society. If adopted at scale across the population including disadvantaged communities, such interventions have the potential to reduce health inequalities. Here, we aimed to conduct a rapid evidence review to evaluate the acceptability, practicability, effectiveness, affordability, spill-over effects and equity of interventions to increase personal protective behaviours that limit the spread of respiratory viruses.

Methods

Study design

The study protocol was pre-registered on the Open Science Framework (https://osf.io/7cphy). During ongoing pandemics, the World Health Organization recommends the use of rapid evidence reviews for swift knowledge generation[22]. We

adopted acknowledged best practice for rapid evidence reviews, which involved completing the review in a timely fashion, limiting the search to main databases and the published literature, and having one reviewer extract data and another verify[23,24].

Criteria for considering studies for this review

Population

We included studies that recruited as participants community-dwelling children or adults (as opposed to qualified or trainee healthcare professionals in hospital or care home settings).

Intervention

We included reports of evaluations of interventions designed to increase at least one of six personal protective behaviours to block transmission of respiratory viruses (see Figure 1, coloured rectangles).

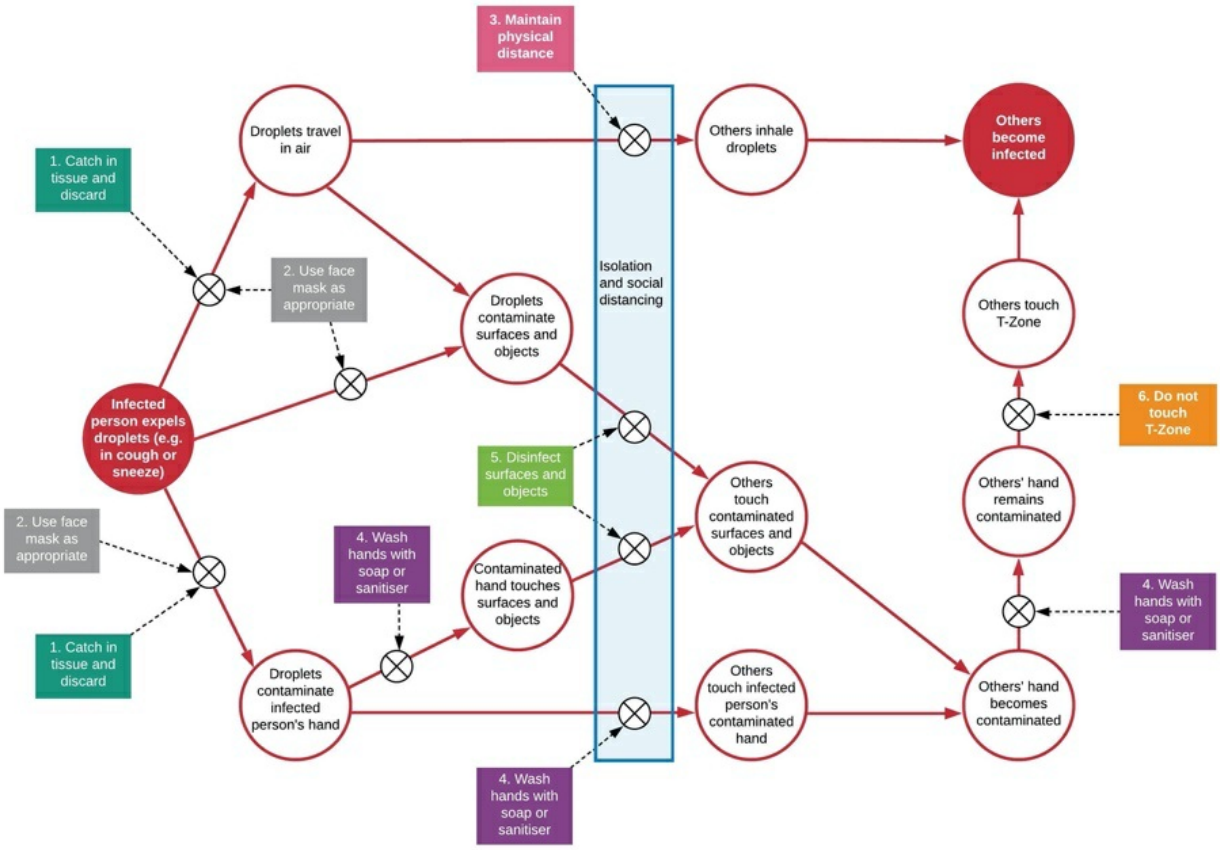

Figure 1. Map of personal protective behaviours relevant for blocking transmission of SARS-CoV-2: hand washing and use of hand sanitizers; avoiding touching the 'T-Zone'; catching droplets in tissues and discarding these; face mask use; disinfecting surfaces; and maintaining physical distancing. Reproduced with permission from the authors[25].

Comparison

We included studies with an active or passive (e.g. wait-list control, baseline) comparator.

Outcomes

We included studies that reported as outcome either the acceptability, practicability, effectiveness, affordability, spill-over effects and/or equity of interventions, measured via self-report or direct observation.

Study designs

We included primary research studies that used experimental (e.g. randomised controlled trial) or quasi-experimental (e.g. pre- and post-test) study designs, providing that they were conducted under free-living (as opposed to laboratory) conditions. In line with rapid review guidelines, we only included studies that were published in peer-reviewed journals and written in English[22,23].

Search methods for identification of studies

Electronic searches

We searched Ovid MEDLINE and Scopus. Search terms for each behaviour (e.g. 'hand hygiene', 'hand washing', 'face mask') were piloted and refined to achieve balance between sensitivity and specificity (see Supplementary file 1).

Searching for other sources

Expertise within the review team and consultation with topic experts was used to identify additional articles of interest. We had specified the use of reference chaining in the review protocol; however, given the rapid focus of the review and large number of identified studies, reference chaining was not performed.

Data collection and analysis

Selection of studies

Two reviewers (OP, DS) independently screened i) titles and abstracts and ii) full texts against the inclusion criteria. Discrepancies were discussed and resolved through consulting with a third reviewer (EC) if necessary.

Data extraction and management

A data extraction form was developed on the basis of the Behaviour Change Intervention Ontology (www.humanbehaviourchange.org) and Cochrane's PICO ontology (https://linkeddata.cochrane.org/pico-ontology). Ontologies are classification systems which enable researchers to specify entities and their inter-relationships, thus facilitating systematic knowledge synthesis[26]. We extracted data on study design, intervention content (i.e. behaviour change techniques (BCTs), coded against the BCT Taxonomy v1[27]), mode of delivery, population, setting, and mechanism(s) of action[28,29]. As an intervention may be effective but have negative spill-over effects to other behaviours, or be impracticable and/or unacceptable to key stakeholders, we extracted data pertaining to the APEASE criteria (see Table 1)[9]. Data were extracted by one reviewer (OP or DS). In the review protocol, we had specified that extracted data would be verified by a second reviewer to assess accuracy and completeness. However, given the large number of identified studies, a second reviewer (EC) verified 10% of studies.

Table 1. APEASE criteria for evaluating intervention approaches or components[9].

Criterion	To what extent …
Acceptability	…is the intervention judged to be acceptable by all key stakeholders
Practicability	…can the intervention be delivered as intended at the scale intended and in the context intended
Effectiveness	…will the intervention deliver the desired outcome in the target population
Affordability	…can the intervention be afforded within an acceptable budget
Spill-over effects	…is the intervention likely to have additional negative or positive consequences
Equity	…is the intervention likely to increase or decrease inequalities in society

Quality appraisal

The methodological rigour of included evaluation reports was assessed by one reviewer (OP or DS) using Cochrane's risk of bias tool[30]. A second reviewer (EC) verified 10% of studies.

Stakeholder involvement

We solicited input from key stakeholders, including patient and public representatives recruited via panels convened by Public Health England (n = 282) and the University of East Anglia (n = 3), and UK policymakers and academic researchers contacted via a mailing list on the research objectives, target behaviours and outcomes assessed. Feedback from patient and public representatives (n = 20) was incorporated into the review protocol; we did not receive any suggestions for improvement or clarification from the policymakers and academic researchers. The rapid review results will be disseminated to stakeholders via an infographic.

Data synthesis

A narrative (descriptive) synthesis was conducted for each of the six personal protective behaviours. We had specified in the review protocol that meta-analyses would be conducted if practicable and appropriate (i.e. >5 studies with homogeneous study designs and outcome variables). After inspection of study designs and outcome variables, however, we deemed it useful to conduct a meta-analysis with k = 4 studies. Random-effects meta-analyses to estimate a pooled odds ratio (OR) or the standardised mean difference (*d*) were conducted in RStudio v.1.2.5033 with the *metafor* package[31]. Cohen's conventions for small (*d* = 0.2), medium (*d* = 0.5) and large (*d* = 0.8) effects were used in the interpretation of the results[32]. Where studies reported more than one hand hygiene outcome (e.g. hand washing and hand sanitizer use), only the first reported outcome was included in the meta-analysis, so as not to violate the assumption of independence[33]. Where studies did not report sufficient detail to calculate effect sizes, study authors' own description/interpretation of results were grouped into 'positive' effects (i.e. a significant difference between intervention and control groups, favouring the intervention group, was detected), 'no difference' (i.e. a significant difference between groups was not detected), 'negative' effects (i.e. a significant difference between groups, favouring the control group, was detected) or 'indeterminate' (i.e. differences between groups were not reported or could not be computed given the study design). To aid interpretation, for behaviours where a majority of positive or negative results were observed, overall results were categorised as either 'positive' or 'negative', respectively, and were categorised as 'mixed' if a clear majority was not observed or where the majority of results were categorised as 'indeterminate'.

Results

Study selection

After removing duplicates, 5,594 records were identified, with 158 studies carried forward to the full text screening. Of the 39 studies included in the narrative evidence synthesis, 10 were included in meta-analyses (see Figure 2).

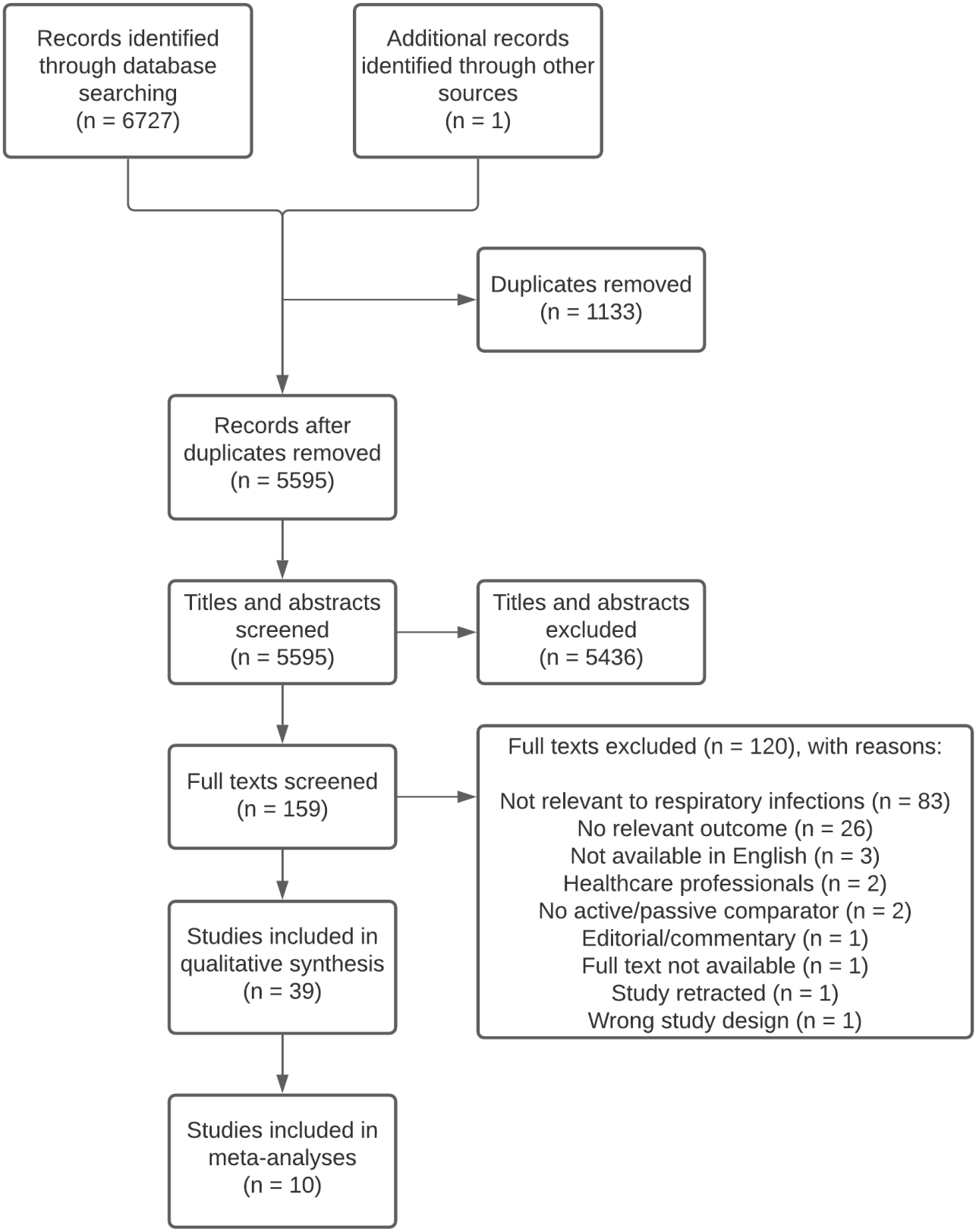

Figure 2. PRISMA flow chart of included studies.

Study characteristics

Studies were conducted in the United States (13/39; 33%)[34–46], China (5/39; 13%)[47–51], Germany (3/39; 13%)[52–54], Thailand (3/39; 13%)[55–57], Australia (2/39; 5%)[58,59], Denmark (2/39; 5%)[60,61], Spain (2/39; 5%)[62,63], the United Kingdom (2/39; 5%)[64,65], with one study each in Australia/Saudi Arabia[66], Bangladesh[67], Costa Rica[68], Finland[69], France[70], the Netherlands[71], and Turkey[72] (see Table 2). Studies had a median of 419 participants (range: 96 to 20,066).

The majority of studies (28/39; 72%) targeted hand hygiene, with the remaining studies targeting a combination of hand hygiene and/or face mask use (9/39; 23%)[37,38,43,48,49,52,53,55,59], face mask use only (3/39; 8%)[61,66,70] or a combination of catching of droplets in tissues and hand hygiene (1/39; 3%)[50] (see Table 2). Interventions were delivered in participants' own homes (12/39; 31%), nurseries/schools (10/39; 26%), university residence halls/public areas (5/39; 13%), offices (4/39; 10%), online (2/39; 5%), outpatient clinics (1/39; 3%), or an army training centre (1/39; 3%). Four studies did not state the setting for intervention delivery. Studies targeted children and adult household members (16/39; 41%), pre- or school children and/or teachers (8/39; 21%), university staff and/or students (5/39; 13%), office workers (4/39; 10%), community-dwelling adults (3/39; 8%), Hajj pilgrims (1/39; 3%), military trainees (1/39; 3%) or adult members of a social service centre (1/39; 3%).

Study designs used were two-arm, cluster RCTs (11/39; 28%), three-arm, cluster RCTs (10/39; 26%), two-arm RCTs (5/39; 13%), single-arm, pre- and post-intervention studies (5/39; 13%), two-arm, non-randomised cohort studies (2/39; 5%), three-arm RCTs (2/39; 5%), two-arm, pilot RCTs (1/39; 3%) or randomised, cross-over studies (1/30; 3%).

Intervention characteristics

Intervention durations ranged from one day (i.e. one-off interventions) to three years (see Table 3). In studies using a two- or three-arm design (33/39; 85%), comparators included no intervention/usual care (19/33; 58%), educational materials (9/33; 27%), the provision of soap/hand sanitizer (3/33; 9%) or a combination of educational materials and soap/hand sanitizer (2/33; 6%). Interventions were delivered via face-to-face sessions (23/39; 59%), written materials (including books and newsletters) (14/39; 36%), posters/bulletin boards/cue cards (8/39; 21%), cartoons/games (4/39; 10%), videos (4/39; 10%), telephone (3/39; 8%) and/or websites (2/39; 5%). Five studies did not clearly report on the mode of intervention delivery. Where reported, participants received a flat payment for study completion[34,37,49,52,53,55,73], payment per survey completed[40], points for study completion[36] or points per survey completed[39].

We coded 15 different BCTs across interventions (see Figure 3); however, details on intervention content were typically lacking. Interventions included a median of three BCTs (range: 0 to 6). The most frequently coded BCTs were '12.5 Adding objects to the environment' (17/39; 44%), '4.1 Instruction on how to perform the behaviour' (16/39; 41%) and '5.1 Information about health consequences' (10/39; 26%). Few studies reported targeting a specific mechanism of action. Where reported, interventions were designed to target intentions[64], attitudes[35,64], subjective norms[35,64], perceived behavioural control[47,64], perceived risk of infection/disease severity[35,47,64], action control[68], coping planning[68],

knowledge[47,51] or skills[51].

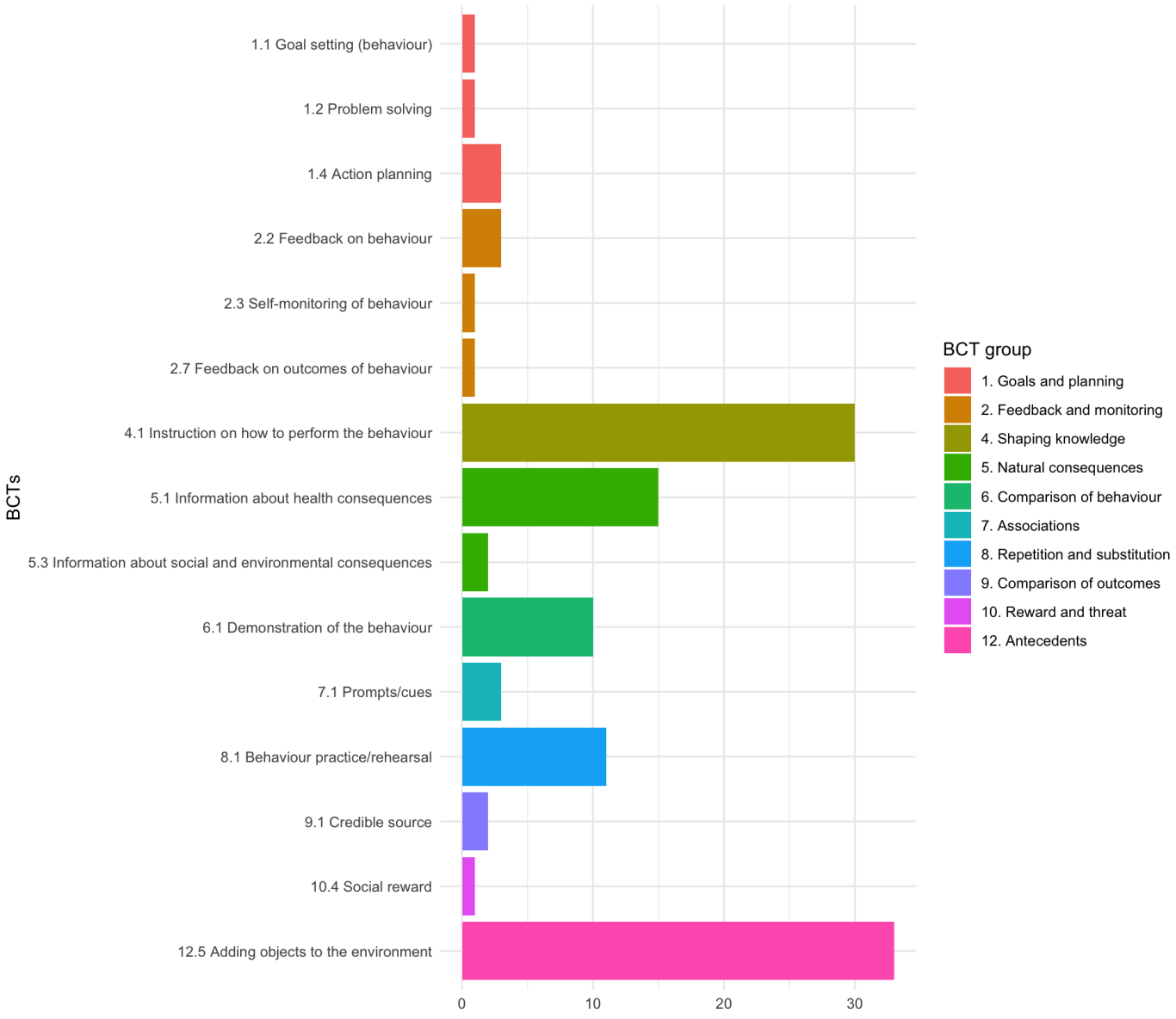

Figure 3. Frequencies of behaviour change techniques (BCTs) coded in included interventions.

Acceptability

Fourteen studies reported on the acceptability of interventions. Indicators assessed included mask comfort[38,52,53,59,66,70], skin problems/irritation[41,60,62,63,65], adverse events[49], liking/positive impressions[36] and ease of understanding[35], with a small number of participants experiencing discomfort or irritation in the majority of studies that reported these outcomes (see Table 4).

Practicability

One study[59] considered the practicability of scaling up mask fit testing outside the study setting and decided against including routine fit testing as part of the intervention (see Table 4).

Effectiveness

Studies relied on self-report (25/39; 64%), direct observation (7/39; 18%), a combination of self-report and direct observation (5/39; 13%) or photos/video (2/39; 5%) to examine intervention effectiveness (see Table 4). Outcome variables were heterogeneous across studies (e.g. the frequency or amount of hand sanitizer/soap use per day, the rate of compliance with hand hygiene, or the rate of compliance with face mask use).

Hand hygiene

Overall, the 30 studies pertaining to hand hygiene behaviours (including hand washing and/or hand sanitizer/soap use) had positive results, with 19 studies reporting positive effects[34–36,38,40,42,44,47,49–52,55–57,64,71,72,74], three studies reporting negative effects[42,44,74], six studies reporting no difference[38,39,43,45,48,68] and six studies with indeterminate results[41,54,58,60,67,69] (see Figure 4). It should be noted that some studies reported more than one hand hygiene outcome (e.g. hand washing and hand sanitizer use).

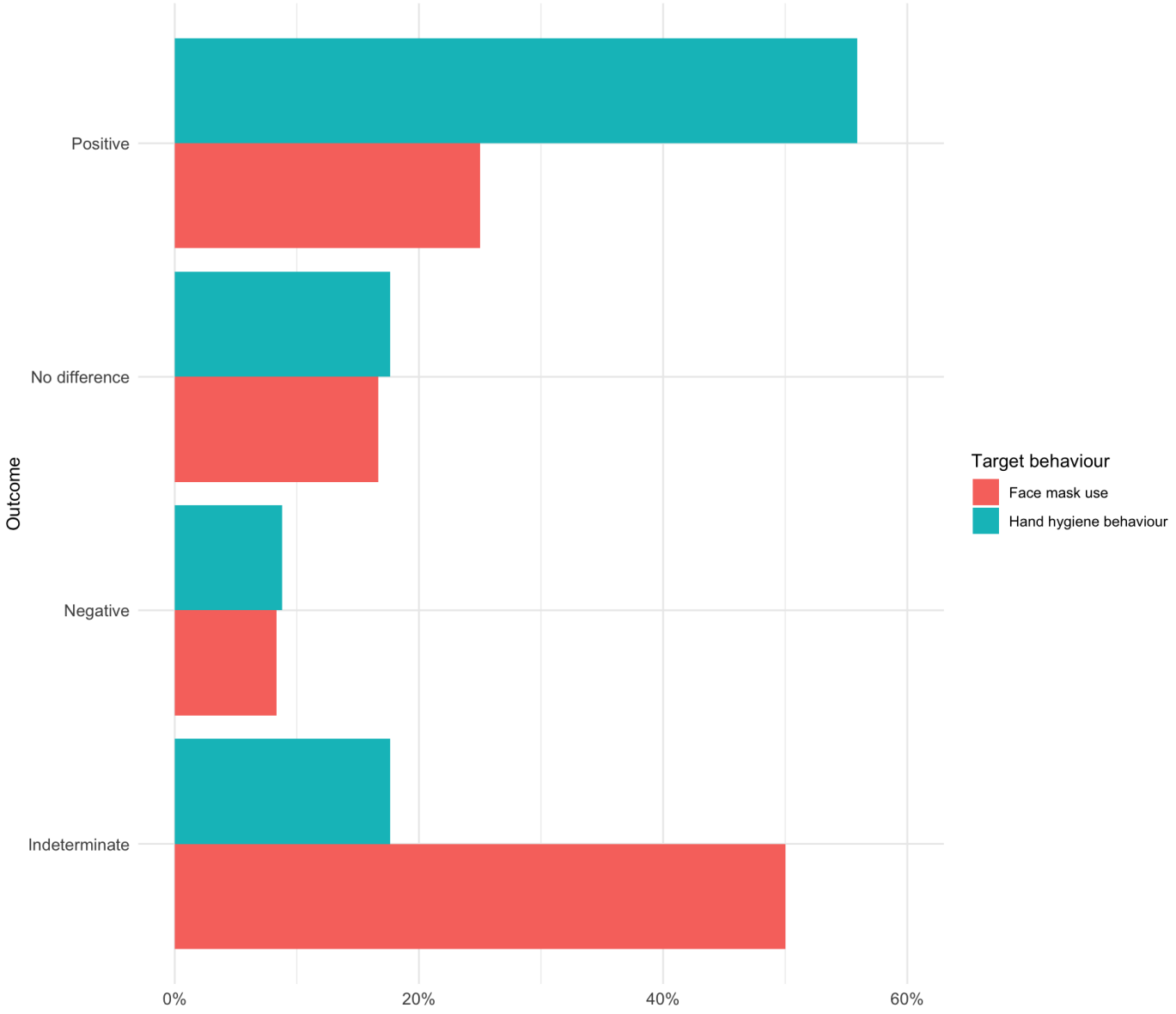

Figure 4. Proportions of reported effects (i.e. positive, negative, no difference or indeterminate) of interventions targeting hand hygiene behaviour and face mask use.

A random-effects meta-analysis (k = 6) found a medium, positive effect of interventions on the average frequency of hand hygiene behaviour, $d = 0.62$, 95% CI = 0.43-0.80, $p < .001$ (see Figure 5). However, between-study heterogeneity was high ($I^2 = 81.2\%$).

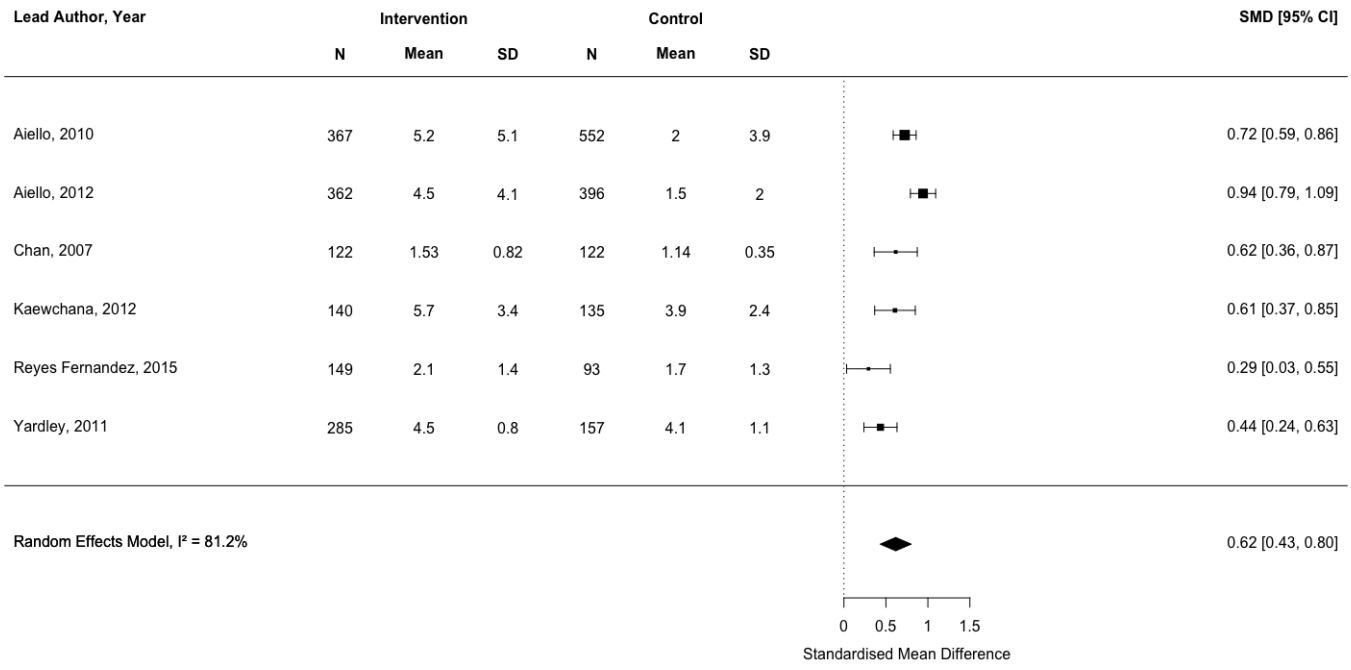

Figure 5. Forest plot for the standardised mean difference (*d*) in the frequency of hand hygiene behaviour in intervention and control or pre- and post-study comparisons. The comparison in Chan[50] pertains to a pre- and post-study comparison; the remaining studies were two- or three-arm RCTs.

Face mask use

Overall, the 12 studies pertaining to face mask use reported mixed results, with three studies reporting positive effects[48,49,66], two studies reporting no difference[38,59], one study reporting negative effects[37] and six studies with indeterminate results[43,52,53,55,61,70] (see Figure 4).

A random-effects meta-analysis (k = 4) found a large, positive effect of interventions on the odds of compliance with face mask use, OR = 4.14, 95% CI = 1.24-13.79, $p < .001$ (see Figure 6). However, between-study heterogeneity was high (I^2 = 89.67%) and the confidence interval for the pooled effect was wide.

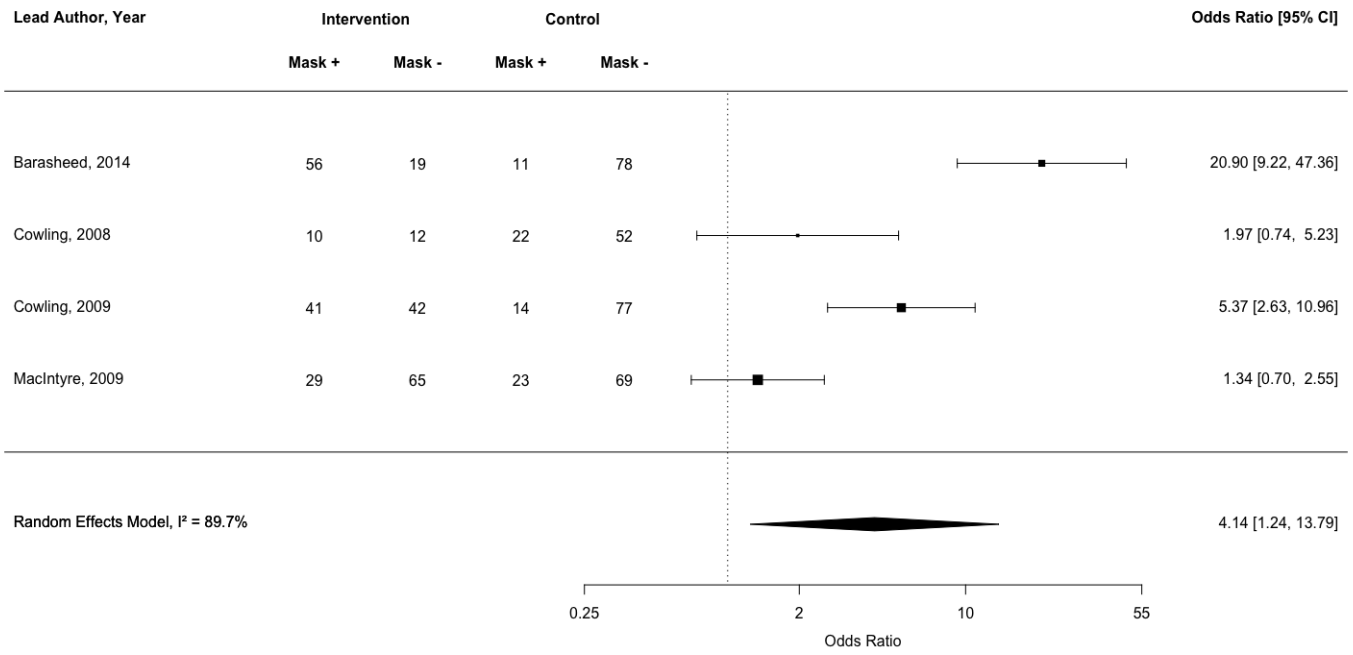

Figure 6. Forest plot for the odds of compliance with face mask use in intervention compared with control arms. The comparison in MacIntyre[59] pertains to the surgical mask (intervention) versus the P2 mask arm (control) at the longest point of follow-up.

Affordability

Two studies considered the affordability of interventions, with one study discussing the cost of face masks[61], which may act as a barrier for wider roll-out, and a second study[71] reporting that although they wanted to provide hand hygiene products to all day care centre groups, they could only afford to do so for a maximum of two groups per centre due to budget restrictions, thus indicating that the selected intervention was not affordable at scale (see Table 4).

Spill-over effects

Three studies reported on secondary behaviour change (i.e. positive or negative spill-over to other behaviours), with one study[71] assessing teachers' supervision of children's hand washing (in addition to their own hand washing), a second[42] assessing the impact of the intervention on military leaders' hand sanitizer use (in addition to trainees') and a third[44] examining multiple hand hygiene behaviours in the same group of participants. The first study reported no change, the second a significant increase in hand sanitizer use and the third a negative impact on hand washing with soap (see Table 4).

Equity

Four studies reported on the equity of interventions, with one study[64] reporting that the intervention was equally effective for participants from high and low socioeconomic status groups and three studies[44,46,62] reporting differential intervention effectiveness by educational attainment, parental income or ethnicity, with better outcomes reported in those with high educational attainment, high parental income and from a Black ethnic background (see Table 4).

Quality of included studies

One study received an overall rating of 'low risk of bias', with 16 studies rated as 'some concern', 18 as 'high risk of bias' and for four studies, a rating could not be applied (see Table 5).

Table 2. Characteristics of included studies.

Lead author (year)	Country	Target behaviour(s)	Study design	Population	Sample size	Mean age (*SD*)	% Female	% Post-16 educational qualifications	Setting	Recru strate
1) Aiello (2010)	United States	Face mask use and hand hygiene	Three-arm, cluster RCT	University students in residence halls	1297 (face mask + hand hygiene = 367; face mask = 378; control = 552)	18.7 *(0.8)*	66%	100%	University residence halls	Not re
2) Aiello (2012)	United States	Face mask use and hand hygiene	Three-arm, cluster RCT	University students in residence halls	1178 (face mask + hand hygiene = 362; face mask = 420; control = 396)	19.0 *(0.9)*	55%	100%	University residence halls	Not re
3) Apisarnthanarak (2009)	Thailand	Hand hygiene	Single arm, pre- and post-intervention study	Preschool children	240	5.0 *(1.7)*	49%	0%	Private kindergarten	Not re
4) Arbogast (2016)	United States	Hand hygiene	Two-arm, cluster RCT	Office workers	1386 (intervention = 604; control = 782)	47.0 *(0.4)*	78%	Not reported	Office buildings	E-mai emplo
5) Azman (2013)	United States	Hand hygiene	Two-arm, cluster RCT	Households	3360	Not reported	Not reported	0%	Schools	Not re
6) Azor-Martinez (2016)	Spain	Hand hygiene	Two-arm RCT	School children	1341	8.0 *(2.3)*	68%	0%	Schools	Not re
7) Azor-Martinez (2018)	Spain	Hand hygiene	Three-arm, cluster RCT	Households with a child at a day care centre	911 children	Unclear	Unclear	Unclear	Day care centres	Not re

8) Barasheed (2014)	Australia/Saudi Arabia	Face mask use	Two-arm, pilot RCT	Hajj pilgrims	164	Not reported	Not reported	Not reported	Not reported	Study broch distrib mosq Islami and p semir in hot Mecc
9) Bundgaard (2020)	Denmark	Face mask use	Two-arm RCT	Community-dwelling adults	6304	47.2 *(13.5)*	64%	Not reported	Participants' own homes	Media adver and th conta privat comp public organ
10) Canini (2010)	France	Face mask use	Two-arm, cluster RCT	Households in three regions of France with an index patient	105	26.5 *(16.0)*	Not reported	Not reported	GP offices	GPs
11) Chan (2007)	China	Catching droplets in tissues and hand hygiene	Single arm, pre- and post-intervention study	Registered members of a government subsidised social service centre	122	Not reported	63%	20%	Participants' own homes	Telep calls
12) Cowling (2008)	China	Face mask use and hand hygiene	Three-arm, cluster RCT	Households with an index patient	198	Not reported	56%	Not reported	Participants' own homes	Outpa clinics
13) Cowling (2009)	China	Face mask use and hand hygiene	Three-arm, cluster RCT	Households with an index patient	407 index patients	Not reported	51%	Not reported	Participants' own homes	Outpa clinics
14) Hübner (2010)	Germany	Hand hygiene	Two-arm RCT	Office workers	134	44.6 *(-)*	86%	Not reported	Office buildings	E-mai
15) Kaewchana (2012)	Thailand	Hand hygiene	Two-arm RCT	Households with an index paediatric patient	275 (frequency assessment) + 330 (quality assessment) households	34.7 *(13.8)*	58%	Not reported	Participants' own homes	Not re
16) Koep (2016)	United States	Hand hygiene	Two-arm, non-randomised cohort study	School children	260	Not reported	46%	0%	Schools	Not re
17) Larson (2009)	United States	Hand hygiene	Single arm, pre- and post-intervention study	Households	422 households	Not reported	Not reported	60%	Participants' own homes	Neigh snowl techn (e.g. c schoo
18) Larson (2010)	United States	Face mask use and	Three-arm	Households	509	Not	52%	54%	Participants'	Neigh snowl techn

[illegible]	[illegible]	hand hygiene	RCT	[illegible]	[illegible]	reported	[illegible]	[illegible]	own homes	(e.g. c schoo
19) Little (2015)	United Kingdom	Hand hygiene	Two-arm RCT	Community-dwelling adults	20,066	56.6 *(13.6)*	56%	Not reported	Online	Maile invita throu surge
20) Liu (2019)	China	Hand hygiene	Single arm, pre- and post-intervention study	Kindergarten teachers	361	29.0 *(8.7)*	95%	Not reported	Schools	Not re
21) MacIntyre (2009)	Australia	Face mask use and hand hygiene	Three-arm, cluster RCT	Households with an index paediatric patient	145 families, 290 caregivers	Not reported	Not reported	Not reported	Not reported	Paedi waitin
22) Mott (2007)	United States	Hand hygiene	Three-arm, non-randomised cohort study	Military trainees	2728	20.2 *(-)*	0%	Unclear	US army training centre	Not re
23) Nandrup-Bus (2009)	Denmark	Hand hygiene	Two-arm, cluster RCT	School children	652	Not reported	51%	0%	Schools	Parer sent v study inform
24) Or (2020)	China	Hand hygiene	Single arm, pre- and post-intervention study	Households with a child in kindergarten	58 parents; 60 children	Not reported	Parents = 93%; children = 40%	Not reported	Not reported	Letter princi kinde to invi and c partic
25) Ram (2015)	Bangladesh	Hand hygiene	Two-arm, cluster RCT	Households	377 index cases; 384 household compounds	121.2 months *(181.7)*	40%	Not reported	Participants' own homes	Outpa clinics
26) Reyes Fernández (2015)	Costa Rica	Hand hygiene	Two-arm, cluster RCT	University students	242	21.0 *(3.9)*	61%	100%	University classrooms	Not re
27) Roberts (2000)	Australia	Hand hygiene	Two-arm, cluster RCT	Pre-school children and day care staff	232 childcare centres; 558 children	Not reported	Not reported	0%	Childcare centres	Direct care were
28) Sandora (2005)	United States	Hand hygiene	Two-arm, cluster RCT	Households with a child at a day care centre	292 families	36.7 *(9.5)*	Not reported	91%	Participants' own homes	Direct care were recrui letter to par
29) Savolainen-Kopra (2012)	Finland	Hand hygiene	Three-arm, cluster RCT	Office workers	683	Not reported	Not reported	Not reported	Office buildings	E-mai
30) Simmerman (2011)	Thailand	Face mask use and hand hygiene	Three-arm RCT	Households	442 index cases; 1147 household contacts	Not reported	59%	Not reported	Participants' own homes	Outpa clinics
31) Stebbins (2010)	United States	Hand hygiene	Two-arm, cluster RCT	School children and teachers	151 teachers	Not reported	Not reported	Not reported	Schools	Not re
32) Stedman-Smith (2015)	United States	Hand hygiene	Two-arm, cluster RCT	Office workers	324	Not reported	84%	100%	Office buildings	E-mai

33) Suess (2011)	Germany	Face mask use and hand hygiene	Three-arm, cluster RCT	Households with an index patient during the H1N1 pandemic	147	Index cases = 7.9 *(3.3)*; household contacts = 30.0 *(14.2)*	52%	Not reported	Participants' own homes	Outpa clinics
34) Suess (2012)	Germany	Face mask use and hand hygiene	Three-arm, cluster RCT	Households with an index patient during the H1N1 pandemic	302	Not reported	Not reported	Not reported	Participants' own homes	Outpa clinics
35) Updegraff (2011)	United States	Hand hygiene	Randomised cross-over study	University students and staff	65 units	Not reported	Not reported	Not reported	Public areas of a university	No ac recrui
36) White (2003)	United States	Hand hygiene	Two-arm, cohort study*	University students	430	18.3 *(0.7)*	62%	0%	University residence halls	Not re
37) Yardley (2011)	United Kingdom	Hand hygiene	Two-arm, pilot RCT	Community-dwelling adults	517	49.8 *(11.4)*	64%	Not reported	Online	Maile invita GP su
38) Zomer (2016)	The Netherlands	Hand hygiene	Two-arm, cluster RCT	Households with a child at a day care centre	71 centres	Not reported	Not reported	Not reported	Not reported	Not re
39) Öncü (2019)	Turkey	Hand hygiene	Three-arm, cluster RCT	School children	96	9.2 *(1.0)*	54%	0%	School laboratory	Not re

Note. * Unclear if randomised.

Table 3. Characteristics of interventions to change personal protective behaviours.

Lead author (year)	Comparator	Intervention	Intervention duration	BCTs (comparator arm)	BCTs (intervention arm)	Intervention mode of delivery	Theoretical mechanism(s) of action of the intervention	Incenti structu study partici
1) Aiello (2010)	Educational materials	The face mask group received face masks; written instructions on how to use, store and safely discard masks. The face mask + hand hygiene group also received hand sanitizer	6 weeks	4.1. Instruction on how to perform the behaviour	4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Video link, written materials	Not reported	Those with int like illn were o $25 for providi throat specim
2) Aiello (2012)	Educational materials	The face mask group received face masks; written instructions on how to use, store and safely discard masks. The face mask + hand hygiene group also received hand sanitizer	6 weeks	4.1. Instruction on how to perform the behaviour	4.1. Instruction on how to perform the behaviour; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Written materials	Not reported	Not rep

3) Apisarnthanarak (2009)	NA	Children, teachers and parents received hand hygiene (including sanitizer) education via cartoons and workshops. A single dispenser of alcohol-based hand rub was placed in each nursery room	3 years	NA	2.2 Feedback on behaviour; 2.7 Feedback on outcomes of behaviour; 4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Face-to-face workshop, cartoons, written materials	Not reported	Not rep
4) Arbogast (2016)	An educational video about hand hygiene; soap and hand sanitizer provided in toilets	Same as the control group in addition to hand sanitizers being provided in different areas of the office building	13.5 months	4.1. Instruction on how to perform the behaviour; 12.5. Adding objects to the environment	4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 12.5. Adding objects to the environment	Videos	Not reported	25 'we points' were o to emp who comple both th baselir post-st survey
5) Azman (2013)	Hand sanitizer	Same as control group in addition to a live demonstration of hand washing behaviour. Information about hand hygiene was sent home	Not reported	12.5. Adding objects to the environment	4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 12.5. Adding objects to the environment	Face-to-face workshop, written materials	Not reported	Not rep
6) Azor-Martinez (2016)	No intervention	Handwashing workshop; hand hygiene practices were periodically reinforced in the classroom; younger children were supervised during hand hygiene procedures; provision of hand sanitizer	8 months	NA	4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Face-to-face workshop	Not reported	Not rep
7) Azor-Martinez (2018)	No intervention	Hand hygiene workshop with instruction on how to correctly perform the behaviour; use of stories, songs, posters; provision of hand sanitizer in one group and liquid soap in the other group; written materials on hand hygiene	8 months	NA	4.1. Instruction on how to perform the behaviour; 6.1. Demonstration of the behaviour; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Face-to-face workshop, written materials	Not reported	Not rep
8) Barasheed (2014)	Hygiene information	In addition to the general hygiene information, face masks and written and verbal instructions on how to use these were provided	5 days	Not reported	4.1. Instruction on how to perform the behaviour; 12.5. Adding objects to the environment	Face-to-face instructions, written materials	Not reported	Not rep
	Weekly e-mails	Instructions to wear a mask when outside the			4.1 Instruction on			

9) Bundgaard (2020)	encouraging participants to follow current COVID-19 recommendations	mask when outside the home during the next month; provision of 50 three-layer, disposable, surgical face masks with ear loops	1 month	NA	4.1 Instruction on how to perform the behaviour; 12.5 Adding objects to the environment	Written materials	Not reported	Not rep
10) Canini (2010)	No intervention	Provision of face masks and demonstration of how to use them	3 weeks	NA	6.1. Demonstration of the behaviour; 12.5. Adding objects to the environment	Face-to-face instructions	Not reported	Not rep
11) Chan (2007)	NA	Health education	7 days	NA	Not reported	Telephone calls with trained nursing students	Not reported	Not rep
12) Cowling (2008)	No intervention (education about healthy diet and lifestyle)	The face mask group received face masks, information about the efficacy of masks and instruction on how to use and safely dispose of masks; the hand hygiene group received hand sanitizer, liquid soap, information about the efficacy of hand hygiene and demonstration of hand hygiene behaviour	9 days	NA	4.1. Instruction on how to perform the behaviour; 5.1. Information about health consequences; 6.1. Demonstration of the behaviour; 12.5. Adding objects to the environment;	Not reported	Not reported	At the f home v housel were reimbu their particip with a supern vouche approx US $2(
13) Cowling (2009)	No intervention (education about healthy diet and lifestyle)	Hand hygiene; surgical face masks plus hand hygiene	6 days	NA	5.1. Information about health consequences; 12.5. Adding objects to the environment	Not reported	Not reported	At the f home v housel were reimbu their particip with a supern vouche approx US $2(
14) Hübner (2010)	No intervention	Provision of hand sanitizer and instruction on how and when to use it at work	12 months	NA	4.1. Instruction on how to perform the behaviour; 12.5. Adding objects to the environment	Not reported	Not reported	Not rep
15) Kaewchana (2012)	30-minute routine health education on influenza infection, nutrition, physical activity, and smoking cessation	30-minute intensive hand washing education; individual training on hand washing; provision of liquid soap; self-monitoring diary; written materials on hand washing techniques	3 months	4.1. Instruction on how to perform the behaviour; 5.1. Information about health consequences	2.3. Self-monitoring of behaviour; 4.1. Instruction on how to perform the behaviour; 5.1. Information about health consequences; 5.3. Information about social and environmental consequences; 8.1. behaviour practice/rehearsal;	Face-to-face workshop	Not reported	Not rep

					12.5. Adding objects to the environment			
16) Koep (2016)	No intervention	Educational intervention with information about microorganisms; provision of liquid soap and hand sanitizer in toilets and classrooms	Unclear	NA	4.1. Instruction on how to perform the behaviour; 5.1. Information about health consequences; 12.5. Adding objects to the environment	Face-to-face with trained teachers	Not reported	Not rep
17) Larson (2009)	NA	Educational intervention focused on infection control; question and answer fact sheets; two groups of households were randomised to receive hand sanitizer, face masks or both	2 to 20 months	NA	4.1. Instruction of how to perform the behaviour; 5.1. Information about health consequences; 8.1. Behaviour practice/rehearsal; 12.5. Adding objects to the environment	Face-to-face with trained researchers	Not reported	Not rep
18) Larson (2010)	Educational materials on infection control	The hand sanitizer group received education plus hand sanitizer; the hand sanitizer and face mask group received the same interventions plus face masks	19 months	Not reported	4.1. Instruction on how to perform the behaviour; 5.1. Information about health consequences; 8.1. behaviour practice/rehearsal; 12.5. Adding objects to the environment	Face-to-face with trained researchers	Not reported	Not rep
19) Little (2015)	No intervention	Four weekly web-based sessions with new content focused on the role of hand washing, setting up a plan to wash hands, reinforcement of helpful attitudes and norms, addressing negative beliefs, tailored feedback and prompts to login to the website	4 months	NA	1.4. Action planning; 2.2. Feedback on behaviour; 4.1. Instruction on how to perform the behaviour; 7.1 Prompts/cues; 8.1. Behaviour practice/rehearsal	Website	Not reported	Not rep
20) Liu (2019)	NA	Hand hygiene training and information booklet; provision of soap, towels, posters, stickers, books, memory games and diplomas	6 months	NA	4.1 Instruction on how to perform the behaviour; 10.4 Social reward; 12.5 Adding objects to the environment	Face-to-face sessions, posters, stickers, books	Knowledge, perceived susceptibility, perceived severity, perceived behavioural control	Not rep
21) MacIntyre (2009)	No intervention	Information about infection control; provision of either P2 or surgical face masks	Unclear	NA	12.5 Adding objects to the environment	Not reported	Not reported	Not rep
		In the PI group, hand sanitizer dispensers were installed throughout the training						

		environment; provision of personal hand sanitizer bottles; posters were placed in training facilities to encourage hand hygiene and foster a sense of pride in staying healthy; instruction on hand hygiene; weekly reminders by drill sergeants to carry, use and refill hand sanitizer bottles. The SI group received personal hand sanitizer bottles and instruction on hand hygiene only						
22) Mott (2007)	Hand sanitizer and instructions to wash or sanitize hands after key events (e.g. coughing, sneezing)		Not reported	12.5 Adding objects to the environment	4.1 Instruction on how to perform the behaviour; 9.1 Credible source; 12.5 Adding objects to the environment	Face-to-face sessions, posters	Not reported	Not rep
23) Nandrup-Bus (2009)	NA	Children were required to wash their hands three times per day; training on hand washing and infection control was provided; posters with step-by-step hand washing instructions placed by wash basins; parents were asked to remind children to wash their hands before the first lesson each day	3 months	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences	Face-to-face sessions, posters	Not reported	Not rep
24) Or (2020)	No intervention	Children attended 4 weekly sessions with information about infection control and hand hygiene techniques; parents attended a separate session with similar content	4 weeks	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences	Face-to-face sessions with an infection control nurse	Knowledge, skills	Not rep
25) Ram (2015)	No intervention	Household compounds were provided with a hand washing station (e.g. water container with a tap, soap); information on infection control and skills training; cue cards placed in a common area in compound courtyards	Tailored; daily intervention visits until 10 days following the resolution of the index case patient's symptoms	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences; 12.5 Adding objects to the environment	Face-to-face sessions, cue cards	Not reported	Not rep
26) Reyes Fernández (2015)	No intervention	Instructions on how and when to clean hands and a planning task to help students set action and coping plans	One-off	NA	1.2 Problem solving; 1.4 Action planning; 4.1 Instruction on how to perform the behaviour	A face-to-face session with research assistants, pamphlets	Action control, coping planning	Not rep
		Staff received training in hand washing and were asked to teach the techniques to the			4.1 Instruction on			

27) Roberts (2000)	No intervention	techniques to the children in their care via songs about hand washing to the melodies of nursery rhymes; training was reinforced with fortnightly visits and newsletters	Not reported	NA	4.1 Instruction on how to perform the behaviour; 6.1 Demonstration of the behaviour	Face-to-face training sessions, newsletters	Not reported	Not rep
28) Sandora (2005)	No intervention (educational materials about healthy eating; participants were asked not to use hand sanitizer during the study period)	Provision of alcohol-based hand sanitizer; educational materials (e.g. fact sheets, games, toys) about hand hygiene	5 months	NA	12.5 Adding objects to the environment	Fact sheets, games, toys	Not reported	Not rep
29) Savolainen-Kopra (2012)	No intervention	Both groups received information on infection control. In the soap and water group, toilets were equipped with liquid hand soap. In the hand sanitizer arm, toilets were equipped with both liquid hand soap and alcohol-based hand rub	18 months	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences; 12.5 Adding objects to the environment	Not reported	Not reported	Not rep
30) Simmerman (2011)	No intervention (nutritional, physical activity, and smoking cessation education)	The hand washing group received education, instruction on hand washing techniques and a hand washing kit with liquid hand soap. The hand washing + face mask group received the same interventions as the hand washing group in addition to paper surgical face masks, training on how to use them appropriately and information about benefits of use	7 days	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences; 12.5 Adding objects to the environment	Face-to-face sessions with trained study nurses	Not reported	House were compe with approx US $60 Thai ba
31) Stebbins (2010)	No intervention	Students and staff received training in hand hygiene behaviors; schools placed and maintained supplies of alcohol-based hand sanitizer in all classrooms and common areas; parents and guardians received educational materials on hand hygiene and home isolation practices	Not reported	NA	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences; 12.5 Adding objects to the environment	Face-to-face sessions, videos	Not reported	Teache were o $5 gift comple each s
32) Stedman-	A brief training video to promote more effective communication with health care providers	A brief training video on infection control and demonstration of effective hand washing/gel techniques; hand sanitizer and	Not reported	Not reported	4.1 Instruction on how to perform the behaviour; 12.5	Video,	Not reported	Points health promot items v an emp wellne

Smith (2015)	providers; branded key chains, brochures and posters with information about the programme	hand sanitizer and motivational/educational hand hygiene posters were placed in break rooms, kitchens and conference rooms	Not reported	Not reported	behaviour; 12.5 Adding objects to the environment	posters	Not reported	Wellne progra provide each s comple
33) Suess (2011)	Educational materials about infection control and recommendation to sleep in a different room than the index patient	Participants in the mask + hand hygiene and mask groups were provided with surgical face masks with ear loops and written information on their correct use; participants in the mask + hand hygiene group were provided with alcohol-based hand rub and instructions on correct use	8 days	Not reported	4.1 Instruction on how to perform the behaviour; 12.5 Adding objects to the environment	Written materials, telephone, face-to-face visits by trained study personnel	Not reported	€150 fo particip
34) Suess (2012)	Educational materials about infection control and recommendation to sleep in a different room than the index patient	Participants in the mask + hand hygiene and mask groups were provided with surgical face masks with ear loops and written information on their correct use; participants in the mask + hand hygiene group were provided with alcohol-based hand rub and instructions on correct use	8 days	Not reported	4.1 Instruction on how to perform the behaviour; 6.1 Demonstration of the behaviour; 12.5 Adding objects to the environment	Written materials, telephone, face-to-face visits by trained study personnel	Not reported	€150 fo particip
35) Updegraff (2011)	Hand sanitizer	Four signs were placed above hand sanitizer units. The perceived susceptibility headline read “Germs are out to get you. Get them first!”; the social norms headline read “Everybody is doing it. Are you?”; the gain-framed headline read “Stay healthy this season. Sanitize your hands”; and the loss-framed headline read “H1N1. Getting it is as easy as passing me by.” Each sign contained a “fact box” with more detailed information reinforcing the theme	12 weeks	12.5 Adding objects to the environment	5.1 Information about health consequences; 5.2 Information about social and environmental consequences; 12.5 Adding objects to the environment	Foam boards	Perceived susceptibility, social norms, and attitudes toward the behavior	Not rep
36) White (2003)	No intervention	Alcohol-gel dispensers were installed in every room, washroom, and dining hall in residence halls; a hand washing message campaign was implemented with bulletin boards and weekly messages to	10 weeks	NA	12.5 Adding objects to the environment	Bulletin boards	Not reported	Cash incenti totallin maxim $65

		encourage hand washing						
37) Yardley (2011)	No intervention	Four weekly web-based sessions with information about the medical team behind the advice (to enhance credibility), infection control, expert recommendations for hand washing frequency and technique, and instructions for picking up a free supply of hand gel from one's local GP practice; a hand washing plan to promote intention formation with situational cueing; tailored feedback to help participants improve their plan; reinforcement of positive attitudes and norms; addressing common negative beliefs; e-mail prompts to login to the website	4 weeks	NA	1.4 Action planning; 2.2 Feedback on behaviour; 5.1 Information about health consequences; 7.1 Prompts/cues; 9.1 Credible source; 12.5 Adding objects to the environment	Website	Intention to wash hands, attitude, subjective norms, perceived behavioural control, perceived risk of infection	Not rep
38) Zomer (2016)	Usual care	Four components: 1) free hand hygiene products with refills for 6 months (e.g. soap, hand sanitizer); 2) a handwashing exercise with 'UV Glow Cream' and an information booklet with the training content; 3) two team training sessions focused on goal setting and identifying hand hygiene improvement activities; 4) posters and stickers placed in day care centres acting as reminders to practice hand hygiene	6 months	Not reported	1.1 Goal setting (behaviour); 7.1 Prompts/cues; 8.1 Behavioural practice/rehearsal; 12.5 Adding objects to the environment	Face-to-face sessions, posters, stickers, booklets	Not reported	Not rep
39) Öncü (2019)	Hand gel and 'photo shoots' before and after handwashing	The first group received the same intervention as the control group plus information about getting rid of microbes on hands if washing hands 'properly'; the second group received the same interventions as the first plus a 30-minute hand hygiene educational and training session on types of microbes and diseases caused by microbes, in	4 weeks	12.5 Adding objects to the environment	4.1 Instruction on how to perform the behaviour; 5.1 Information about health consequences; 8.1 Behavioural practice/rehearsal; 12.5 Adding objects to the environment	Face-to-face session	Not reported	Not rep

		addition to WHO's 9-stage handwashing programme							

Note. NA = not applicable.

Table 4. APEASE criteria, reach and engagement.

Lead author (year)	Acceptability	Practicability	Affordability	Spill-over effects	Equity	Reach	Engagement	How primary outcome was assessed	Effecti
1) Aiello (2010)	Not reported	Not reported	Not reported	Not reported	Not reported	7/15 residence halls were included in the study	Not reported	Self-report	On ave mask o wore m hours p = 3.3) v hours p = 2.4) i and ha group. hours v signific in the n group c with the hand h group a point e: week 4 The ma group v hands day (SI versus per day in the n hand h group a times p 9.3) in t group. scale, t and ha group v hands fewer ti than th group f through mask o used h 2.3 time (SD = 3 5.2 time (SD = 5 mask a hygien 2.0 time (SD = 3 control the log particip

									mask a hygien reporte signific use of h sanitize to the n and co at each (p's<.0 were n differer betwee only gr control frequer sanitize
2) Aiello (2012)	On average, participants in the two intervention groups rated mask comfort as 4.7/10 (SD = 0.2)	Not reported	Not reported	Not reported	Not reported	5/15 residence halls were included in the study	Not reported	Self-report and observation of mask wearing by trained staff	Particip face ma hand h group a mask o wore m averag per day and 5.0 day (SD respect (p>.05) mask a hygien the face group r averag hand s times p 4.1) an per day respect (p<.05) compar times p 2.3) in t group. mask a hygien face ma group v hands s 3.3) an 3.3) tim respect control washed an aver times (S per day
3) Apisarnthanarak (2009)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Observation of hand hygiene and cough etiquette with a Web camera 1 hour, twice	The ob of hand compli increas 21% (5 period (170/24 2 (p<.0

								weekly	69% (1 period
4) Arbogast (2016)	Employees in the intervention group were significantly more likely than those in the control group to have a positive impression of the programme because of the presence of alcohol-based hand sanitizers in the workplace (80% vs 69%, p < 0.001). 88% of employees in the intervention group reported liking the products provided	Not reported	Not reported	Not reported	Not reported	1386/1609 employees agreed to participate	Not reported	Self-report	Self-rep washin improv signific time in interve (p<.05) reporte sanitize every a assess includi eating, sneezi coughi money restroo to their interac others sick (p'
5) Azman (2013)	Not reported	Not reported	Not reported	Not reported	Age and ethnicity were significant risk factors for self-reported influenza-like illness (p<.05)	Not reported	Not reported	Self-report	Not rep
6) Azor-Martinez (2016)	One child showed worsening of existing atopic dermatitis due to hand sanitizer gel use and was excluded from the study	Not reported	Not reported	Not reported	Predictors of a lower rate of absenteeism due to respiratory illness included older age, higher parental income, and correct handwashing technique (p<.05)	1616/1640 children were randomised	Not reported	Self-report	Not rep
7) Azor-Martinez (2018)	One child showed worsening of existing localized atopic dermatitis due to hand sanitizer gel use and was excluded from the study	Not reported	Not reported	Not reported	Not reported	25/52 day care centres contacted were randomised	Not reported	Self-report	Not rep
	The most commonly								Compli

8) Barasheed (2014)	reported reason for not wearing face masks was discomfort (15% of participants)	Not reported	Not reported	Not reported	Not reported	164/4200 pilgrims took part	Not reported	Self-report	face ma 76% (5 interve and 12 the con (p<.001
9) Bundgaard (2020)	Not reported	Not reported	The authors note that costs and availability may reduce the efficacy of face masks to prevent SARS-CoV-2 infection	Not reported	Not reported	17,258/6304 of those responding to recruitment adverts were randomised	Not reported	Self-report	46% of in the i arm wo as reco 47% pr as reco and 7% recomm Particip an aver masks weekda per we
10) Canini (2010)	75% of participants in the intervention arm reported discomfort with mask use. The three main causes of discomfort were warmth (45%), respiratory difficulties (33%) and humidity (33%). Children wearing child size face masks reported feeling pain more frequently than those wearing adult face masks (p=.036)	Not reported	Not reported	Not reported	Not reported	95/105 randomised households completed the study		Self-report	Index p interve househ reporte total of 7.2) ma 4.0 (SD with an use of 1.3) ma and a c use of 2.7) ho
11) Chan (2007)	Not reported	Not reported	Not reported	Not reported	Not reported	182/295 registered members were successfully contacted; 122/182 took part	Not reported	Self-report	Signific improv observ regards hands sneezi (M_{befor} = 0.44; 1.65, S washin with liq (M_{befor} = 0.35; 1.53, S and we in publi 1.31, S

								M_{after} = 1.12) (a p's<.00
12) Cowling (2008)	There were no reported adverse events requiring medical attention	Not reported	Not reported	Not reported	Not reported	198/944 index patients were randomised	Not reported	Self-report	In the fa group, of inde reporte mask o always with 30 and 28 the con hand h groups respect face ma 21% (1 househ reporte mask o always with 1% and 4% the con hand h groups respect cases i mask g median masks wherea househ used a masks 20). 63 index c (house contact hand h group r washin hands (always sneezi or clea nose, c with 63 and 31 the face control respect hand h group, used a 56 g (IC of alcol automa and a r g (IQR liquid h over th the stu
								The pro index c

13) Cowling (2009)	Not reported	Not reported	Not reported	Not reported	Not reported	407/2750 index patients and their households were randomised	Not reported	Self-report
14) Hübner (2010)	Not reported	Not reported	Not reported	Not reported	Not reported	134/850 participants were randomised	Not reported	Self-report
15) Kaewchana (2012)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Self-report

									34% (5 88% (1 (p<.001
16) Koep (2016)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Self-report and objective measure of soap and sanitizer use	No sign differen soap co were ol across (estima reporte sanitize increas in the ir school 0.06 tin student grades (p's>.05
17) Larson (2009)	Not reported	Not reported	Not reported	Hand sanitizer use increased but hand washing with soap decreased	Respondents with college degrees had higher knowledge scores than the other groups, adjusting for baseline scores (p =.04)	Not reported	Not reported	Self-report (questionnaire administered by trained researchers) and objective measures of hand sanitizer and mask use	A signi greater of parti reporte hand sa the enc (282/42 compar baselin but a lo proport using a soap at the stu compar baselin
18) Larson (2010)	Not reported	Not reported	Not reported	Not reported	Not reported	617/672 households that expressed interest in participation met eligibility criteria; 509/617 completed the initial home visit	Not reported	Self-report (questionnaire administered by trained researchers) and objective measures of hand sanitizer and mask use	Particip hand sa group u of 12.1 ounces those ir sanitize mask g mean c ounces (p=.36) househ case of reporte masks hours c onset. T used m reporte two masks/ (range:
	Minor self-reported skin irritation increased among those who did not report								

19) Little (2015)	problems at baseline. Among individuals who had a skin complaint at baseline, reported skin complaints did not significantly increase over time	Not reported	Not reported	Not reported	Not reported	20,066/80,4897 who received a mailed invitation were randomised	Not reported	Self-report	Not rep
20) Liu (2019)	Not reported	Not reported	Not reported	Not reported	Not reported	12/213 kindergarten clusters received the intervention	Not reported	Self-report	The av reporte compli hand h guideli signific after th interve IQR = 0 compa baselin = 0.47) Teache signific hand w behavi with ba coughi blowin changi contact fluids a textiles the toil the nos wiping bottom helping food (p
21) MacIntyre (2009)	There were no significant differences in difficulties with mask use between the P2 and surgical mask groups, but >50% reported concerns, the main one being that wearing a face mask was uncomfortable. Other concerns were that the child did not want the parent wearing a mask. Some participants mentioned that	Fit testing for P2 masks was not conducted because this was judged unlikely to be feasible in the general community during a pandemic	Not reported	Not reported	Not reported	145/401 families assessed for eligibility took part	Not reported	Self-report	On day use, 38 the sur users a (42/92) mask u that the wearin “most o time” (p Adhere droppe (29/94) (23/92) respect 5 of ma

	the mask did not fit well and that it was not practical to wear at mealtime or while asleep								
22) Mott (2007)	Not reported	Not reported	Not reported	Hand sanitizer use increased in leaders in both intervention groups (from 3.0 to 13.4 times/day and from 3.2 to 4.7 times/day, respectively)	Not reported	Not reported	Not reported	Self-report	Post-in there w decrea daily fr hand w the SI g 4.4 to 2 times/d change group (5.0 time Hand s increas interve (from 3 times/d 4.0 to 6 times/d respect
23) Nandrup-Bus (2009)	Three children withdrew from the intervention arm due to skin problems	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Objective measure of soap use	School showed monthl consun 2.5 litre soap a interve During interve consun increas liquid s accurat measu not pos soap w continu repleni reliable measu soap c in the c school availab
24) Or (2020)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Self-report and observation of hand washing with fluorescent stain gel and photos	After th progra percen properl areas c hands i signific particul (from 0 p<.001
						377/766		The intervention staff weighed the soap each	A medi capita s consun

25) Ram (2015)	Not reported	Not reported	Not reported	Not reported	Not reported	eligible index cases took part	Not reported	day and replaced it if the bar weighed <20 grams	g (IQR was ob the first the pro
26) Reyes Fernández (2015)	Not reported	Not reported	Not reported	Not reported	Not reported	242/440 students completed the study	Not reported	Self-report	Self-rep frequer sanitize day, me a 5-poi scale, i both th (from M 0.9 to M 1.3) an interve (from M 1.3 to M 1.4), p=
27) Roberts (2000)	Not reported	Not reported	Not reported	Not reported	Not reported	23/26 eligible childcare centres took part	Not reported	Observation by trained researchers	Hand w compli childre divided groups corresp interve with a s (53%-6 centres (70%-7 centres (>80%; compli
28) Sandora (2005)	Forty-five families reported 112 adverse events related to hand sanitizer use. Seventy-one (63%) of the adverse events were in relation to “dry skin,” and 20 (18%) were related to “irritation.” Other reported adverse events included “stinging”, “smells bad”, “dislike it”, “allergic reaction”, and “too slippery”	Not reported	Not reported	Not reported	Not reported	292/647 families assessed for eligibility took part	Not reported	Self-report	Primary reporte hand s a medi frequer times/d
29) Savolainen-Kopra (2012)	Not reported	Not reported	Not reported	Not reported	Not reported	683/1270 employees considered for eligibility took part	Not reported	Assessment by study nurses	The av amoun disinfe particip g and 6 active g
									Particir

30) Simmerman (2011)	Not reported	Not reported	Not reported	Not reported	Not reported	465/20,537 paediatric outpatients with influenza-like illness took part	Not reported	Self-report
31) Stebbins (2010)	Not reported	Not reported	Not reported	Not reported	Not reported	151/167 enrolled teachers took part	Not reported	Self-report
32) Stedman-Smith (2015)	Not reported	Not reported	Not reported	Not reported	Not reported	324/1708 enrolled office workers took part	Not reported	Self-report
	The majority (60%) of participants did not report any problems when wearing face masks. Of those who							

33) Suess (2011)	reported having removed their masks in transmission-prone situations, 'feeling hot' was the main reason. Other problems mentioned less frequently were pain when wearing the mask and shortness of breath. The majority of adult household contacts in the control and intervention groups perceived wearing face masks as well as intensified hand hygiene as an effective means of preventing transmission of influenza	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Self-report	81% of and 71 household member combin groups mask 'a 'most o when i room w healthy person Particip cases a combin mask p group washed their ha signific frequen compa those i and co combin (p=.007
34) Suess (2012)	The majority of participants (62%) did not report any problems with mask wearing. This proportion was significantly higher in adults (71%) than children (50%) (p = 0.005). The main problem stated by participants (adults as well as children) was "heat/humidity", followed by "pain" and "shortness of breath" when wearing a face mask	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	The amount of remaining intervention materials was assessed at the end of the study period	Particip mask g median (IQR = masks individu Particip mask p group u median (IQR = masks. of hand disinfe day wa 4.1 in i in the 2 2010/1 respect numbe disinfe day wa 7.5 in h contact 2009/1 2010/1 respect
									All sign signific hand s

35) Updegraff (2011)	There were no significant differences between the four signs in how easy they were to understand. The loss-framed and perceived susceptibility signs elicited significantly more negative affect than the gain-framed and norms signs (p's <.01).	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Grams of sanitizer used per day, measured with a digital scale	compa no sign but the equally Dispen gain-fra had the hand s with 66 use tha dispen signs (Loss-fr were a with a 5 increas compa sign (p social r (44.3% and the suscep (40.6% were a with so lower i usage with the framed framed both le signific use tha (both p
36) White (2003)	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Not reported	Self-report	Over th the stu produc washe 10.4% frequer control times/h times/h frequer sanitize also sig greater produc times/h times/h
37) Yoxall (2011)	Not reported	Not reported	Not reported	Not reported	Moderator analyses indicated that the intervention was similarly	517/8150 of	Of the 324 participants who were randomly assigned to the intervention, 251 (77.5%) progressed to the second session, 219 (67.6%) completed	Self-report	Signific differen betwee hand w frequer measu point s observ

37) Yardley (2011)	Not reported	Not reported	Not reported	Not reported	effective for those from higher and lower socioeconomic status groups.	those invited participated	three sessions, and 188 (58.0%) completed all four sessions. The free hand gel was collected by 170/324 (52.5%) eligible participants.	Self-report	weeks = 0.9 vs SD = 0. d = 0.4 weeks = 1.1 vs SD = 0. d = 0.3
38) Zomer (2016)	Not reported	Not reported	Due to budget restrictions, hand hygiene products were only provided for two groups within each day care centre, even if the centre had more than two groups.	No significant effect of the intervention was found on supervising children's hand hygiene (36% vs. 32%)	Not reported	71/122 day care centres participated	Of 274 caregivers, 21% (54/261) attended none of the training sessions, 25% (66/261) attended one training session, 29% (75/261) attended two training sessions and 25% (66/261) attended all three sessions.	Direct observation by trained researchers	Hand h compli interve care ce 66% vs control = 6.33, 3.71–1
39) Öncü (2019)	Not reported	Not reported	Not reported	Not reported	Not reported	96/552 children	Not reported	Photos examined by researchers not directly involved in the study	In the n intensi interve post-in hand w effectiv scores signific all regi hands

Note. + = positive effect; - = negative effect; / = no change; @ = indeterminate; NA = not applicable.

Table 5. Quality appraisal.

Lead author (year)	1) Bias arising from the randomisation process	2) Bias due to deviations from the intended interventions	3) Bias due to missing outcome data	4) Bias in measurement of the outcome	5) Bias in selection of the reported result	Overall rating
1) Aiello (2010)	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Low risk of bias	Some concerns
2) Aiello (2012)	Some concerns	Low risk of bias	Some concerns	Some concerns	Low risk of bias	Some concerns

3) Apisarnthanarak (2009)	NA	NA	NA	NA	NA	NA
4) Arbogast (2016)	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Some concerns	Some concerns
5) Azman (2013)	Some concerns	Some concerns	Low risk of bias	Some concerns	Some concerns	Some concerns
6) Azor-Martinez (2016)	Some concerns	Some concerns	Some concerns	Some concerns	Low risk of bias	High risk of bias
7) Azor-Martinez (2018)	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Low risk of bias	Some concerns
8) Barasheed (2014)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
9) Bundgaard (2020)	Some concerns	Some concerns	Some concerns	Some concerns	Low risk of bias	High risk of bias
10) Canini (2010)	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Low risk of bias	Some concerns
11) Chan (2007)	NA	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
12) Cowling (2008)	Some concerns	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Some concerns
13) Cowling (2009)	Some concerns	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Some concerns
14) Hübner (2010)	Some concerns	Some concerns	Low risk of bias	Some concerns	Some concerns	High risk of bias
15) Kaewchana (2012)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
16) Koep (2016)	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
17) Larson (2009)	NA	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
18) Larson (2010)	Some concerns	Some concerns	Low risk of bias	Some concerns	Some concerns	High risk of bias
19) Little (2015)	Some concerns	Some concerns	Some concerns	Low risk of bias	Some concerns	High risk of bias
20) Liu (2019)	NA	NA	NA	NA	NA	NA
21) MacIntyre (2009)	Some concerns	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Some concerns
22) Mott (2007)	NA	NA	NA	NA	NA	NA
23) Nandrup-Bus (2009)	Some concerns	Some concerns	Some concerns	Some concerns	Low risk of bias	High risk of bias
24) Or (2020)	NA	NA	NA	NA	NA	NA
25) Ram (2015)	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Low risk of bias	Some concerns
26) Reyes Fernández (2015)	Some concerns	Some concerns	Some concerns	Some concerns	Low risk of bias	High risk of bias
27) Roberts (2000)	Some concerns	Some concerns	Some concerns	Low risk of bias	Some concerns	High risk of bias
28) Sandora (2005)	Low risk of bias	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
29) Savolainen-						High risk

Kopra (2012)	Some concerns	Some concerns	Some concerns	Some concerns	Low risk of bias	of bias
30) Simmerman (2011)	Low risk of bias	Low risk of bias	Some concerns	Some concerns	Low risk of bias	Some concerns
31) Stebbins (2010)	Some concerns	Some concerns	Low risk of bias	Some concerns	Some concerns	High risk of bias
32) Stedman-Smith (2015)	Low risk of bias	Low risk of bias	Some concerns	Some concerns	Some concerns	Some concerns
33) Suess (2011)	Low risk of bias	Low risk of bias	Some concerns	Some concerns	Some concerns	Some concerns
34) Suess (2012)	Low risk of bias	Some concerns	Some concerns	Some concerns	Some concerns	High risk of bias
35) Updegraff (2011)	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias
36) White (2003)	High risk of bias	Low risk of bias	Some concerns	Some concerns	Some concerns	High risk of bias
37) Yardley (2011)	Low risk of bias	Low risk of bias	Some concerns	Some concerns	Low risk of bias	Some concerns
38) Zomer (2016)	Low risk of bias	Some concerns	Low risk of bias	Some concerns	Low risk of bias	Some concerns
39) Öncü (2019)	Some concerns	Some concerns	Low risk of bias	Low risk of bias	Some concerns	Some concerns

Note. NA = not applicable.

Discussion

This rapid review of interventions to increase personal protective behaviours to limit the spread of respiratory viruses identified 39 studies conducted across 15 countries. The majority of interventions targeted hand hygiene and/or face mask use, with one intervention targeting the catching of droplets in tissues in addition to hand hygiene. None of the identified interventions focused on avoiding touching the T-Zone, disinfecting surfaces or maintaining physical distancing. Interventions were typically delivered in participants' own homes or in nurseries/schools, targeting children/adult household members or pre- or school children/teachers. Two- or three-arm study designs with passive comparators were typically used. The overall quality of included studies was low, with only one study rated as 'low risk of bias'. The majority of interventions had a face-to-face component and delivered a median of three BCTs; the most frequent were 'Adding objects to the environment', 'Instruction on how to perform the behaviour' and 'Information about health consequences'. Where investigated, interventions were considered acceptable by participants, with a minority reporting issues with mask wear discomfort or skin irritation from hand hygiene products. Few studies reported the practicability, affordability, spill-over effects or equity of interventions. In a narrative synthesis, interventions targeting hand hygiene behaviour were found to have positive effects and those targeting face mask use had a mixture of positive and negative effects. Random-effects meta-analyses of a small number of studies found positive effects of interventions targeting hand hygiene behaviour and face mask use. However, between-study heterogeneity was high and the confidence interval for the pooled effect of interventions targeting face mask use was wide, partly due to the small number of studies included in the comparison.

Strengths and limitations

This review was conducted rapidly (July-December 2020) with input on the research questions and review scope from public health and behavioural science experts and lay members as part of a written stakeholder consultation. However, the review has several limitations. First, given the expected large number of hand hygiene studies related to gastrointestinal infections, we limited the review to studies explicitly studying behaviour change in relation to respiratory viruses. However, data from interventions targeting personal protective behaviours to prevent gastrointestinal illness are likely to add to our understanding of the acceptability, effectiveness and equity of hand hygiene interventions. Second, data extraction was performed by a single reviewer, with a proportion verified by a second reviewer. Third, although most of identified studies were two- or three-arm RCTs, they were typically designed to study rates of respiratory infection as their primary outcome, with behaviour change outcomes less clearly reported. This hindered quantitative synthesis, with only a small number of included studies contributing to meta-analyses. Future studies specifically designed to examine the effectiveness of interventions on behavioural outcomes are needed. Fourth, in line with guidelines[75], we only coded BCTs when there was clear evidence of their presence; interventions may have included additional BCTs not documented in this review.

Implications for policy and practice

Although we caution against drawing firm conclusions due to the low quality of the evidence, positive effects of interventions targeting hand hygiene behaviour and face mask use were observed, with the majority of interventions providing free hand hygiene products and/or face masks to participants in addition to instructions on how to perform the behaviour and information about health consequences. As far as is practicably feasible, authorities should aim to provide free products to staff, clients and visitors during respiratory viral epidemics. The limited range of BCTs included in interventions suggests a missed opportunity for harnessing techniques indicated by relevant behaviour change theory and evidence. We encourage policymakers and healthcare practitioners to work collaboratively with behavioural scientists to incorporate techniques that theory or evidence predicts are effective for enabling personal protective behaviours[15], such as techniques targeting motivational or self-regulatory processes.

Avenues for future research

Findings highlight the need for evaluations of interventions to support people to avoid touching the T-Zone, disinfect surfaces, maintain physical distancing and ensure efficient ventilation. Ventilation is increasingly seen as an important personal protective behaviour but was missed from the present review as it was planned during an earlier epidemic phase when the emphasis was on viral transmission via droplets rather than aerosols[76,77]. In addition, we need studies designed to detect effects on behavioural outcomes and data on the affordability and equity of interventions to increase personal protective behaviours, particularly in low- and middle-income countries. Although the provision of hand hygiene products and face masks may offset costs related to primary and secondary care or work absenteeism for those with severe respiratory viral illness, the provision of free products at scale may be prohibitively costly. Future research involving health

and social care economists should evaluate the cost-effectiveness of different types of interventions to enable personal protective behaviours, including those targeting motivational and self-regulatory processes. We also need further evidence from studies evaluating interventions to improve adherence to face mask use, with unclear results observed at present.

Conclusions

This rapid review identified 39 studies across 15 countries with interventions targeting hand hygiene and/or face mask use. Positive effects of interventions targeting hand hygiene were observed, with unclear results for interventions targeting face mask use.

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Declaration of interests

OP, DS, EC, LS, RW and SM have no conflicts of interest to declare.

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