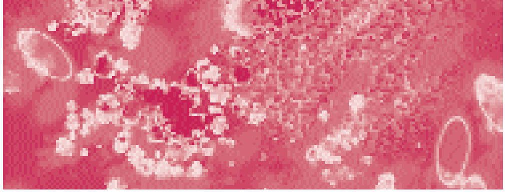

Effect of washing hands with soap on diarrhoea risk in the community: a systematic review

Val Curtis and Sandy Cairncross

We set out to determine the impact of washing hands with soap on the risk of diarrhoeal diseases in the community with a systematic review with random effects meta-analysis. Our data sources were studies linking handwashing with diarrhoeal diseases. Seven intervention studies, six case-control, two cross-sectional, and two cohort studies were located from electronic databases, hand searching, and the authors' collections. The pooled relative risk of diarrhoeal disease associated with not washing hands from the intervention trials was 1·88 (95% CI 1·31–2·68), implying that handwashing could reduce diarrhoea risk by 47%. When all studies, when only those of high quality, and when only those studies specifically mentioning soap were pooled, risk reduction ranged from 42–44%. The risks of severe intestinal infections and of shigellosis were associated with reductions of 48% and 59%, respectively. In the absence of adequate mortality studies, we extrapolate the potential number of diarrhoea deaths that could be averted by handwashing at about a million (1·1 million, lower estimate 0·5 million, upper estimate 1·4 million). Results may be affected by the poor quality of many of the studies and may be inflated by publication bias. On current evidence, washing hands with soap can reduce the risk of diarrhoeal diseases by 42–47% and interventions to promote handwashing might save a million lives. More and better-designed trials are needed to measure the impact of washing hands on diarrhoea and acute respiratory infections in developing countries.

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Diarrhoeal diseases are amongst the top three killers of children in the world today.[1] At least 20 viral, bacterial, and protozoan enteric pathogens, including *Salmonella spp*, *Shigella spp*, *Vibrio cholerae*, and rotavirus, multiply in the human gut, exit in excreta, and transit through the environment, causing diarrhoea in new hosts. Because diarrhoeal diseases are of faecal origin, interventions that prevent faecal material entering the domestic environment of the susceptible child are likely to be of greatest significance for public health.[2] The key primary barriers to the transmission of enteric pathogens are safe stool disposal and adequate handwashing (figure 1), especially after contact with faecal material during anal cleansing of adults and children.[3] Hands serve as vectors, transmitting pathogens to foodstuffs and drinks and to the mouths of susceptible hosts. In a 1997 review Huttly quoted five studies on handwashing with a median reduction in diarrhoea incidence of 35%.[4]

Figure 1. Handwashing, a barrier to transmission of enteric pathogens.

We carried out a systematic review of the effects of washing hands with soap on diarrhoea risk and estimated potential reductions in diarrhoea mortality.

Methods

Search strategy

We aimed to identify all studies published in English up to the end of 2002 relating handwashing to the risk of infectious intestinal or diarrhoeal diseases in the community. Medline, CAB Abstracts, Embase, Web of Science, and the Cochrane Library were systematically searched using appropriate textwords and thesaurus terms for papers relating to handwashing, use of soap, as well as disease terms such as diarrhoea, typhoid, enteric, cholera, shigellosis, dysentery, and mortality. Searches were also undertaken by hand with reference lists from these papers, the authors' own collections, and review articles. No limitations were placed on date or geographical location. In addition, researchers attending a hygiene conference were asked if they had unpublished data on handwashing, but no suitable data sets were identified.

Review strategy

Studies were retained for the meta-analysis if they provided point estimates and 95% CIs (or the means to

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Table 1. Characteristics and results of the 17 studies of handwashing and diarrhoea retained for the meta-analysis

Study	Location, setting	Type of study	Exposure/intervention	Age group	Methodological shortcomings*	Outcome	Relative risk (95% CI)	Soap use specified
Black et al, 1981[6]	US urban daycare	Intervention trial	Instructions for carers to wash hands with soap before handling food after carer or child toilet	Children aged 6–28 months	1,5,6	Diarrhoea	1·92 (1·32–2·81)	Yes
Khan, 1982[7]	Bangladesh, urban	Intervention trial	Soap and water pitchers provided. Handwashing with soap, after defecation and before eating	All ages	5	Diarrhoea Shigella	1·60 (0·90–2·86) 2·34 (1·26–4·33)	Yes Yes
Sircar et al, 1987[8]	India, urban slum	Intervention trial	Soap given with advice to wash hands after defecation and before handling food	All ages	1,2,5,6	Diarrhoea	1·02 (0·93–1·13)	Yes
Han and Hlaing 1989[9]	Myanmar, poor urban	Intervention trial	Mothers and children asked to wash hands with soap after defecation and before preparing main meals	Children aged 5–59 months	5	Diarrhoea Dysentery	1·43 (1·08–1·85) 1·08 (0·45–2·56)	Yes Yes
St Louis et al, 1990[10]	Guinea, urban	Case-control	Reported handwashing with soap	Adult	8	Cholera	Before meal 4·76 (1·05–25) After defecation 2·86 (0·77–11·1)	Yes Yes
Wilson et al, 1991[11]	Indonesia, rural	Intervention trial	Soap and handwashing before food contact and after defecation	Children under 11 years	1,4,5	Diarrhoea	4·71 (1·84–12·09)	Yes
Yeager et al, 1991[12]	Peru, urban	Household survey	Reported handwashing with soap after changing diapers	Children under 3 years	7,8	Diarrhoea	1·12 (0·98–1·26)	Yes
Knight et al, 1992[13]	Malaysia, rural	Case-control	Reported handwashing	Children 4–49 months	7,8	Diarrhoea	Before preparing food 1·10 (0·57–2·13) Before eating 1·23 (0·62–2·45) After defecation 0·90 (0·33–2·42) Water in latrine for handwashing 2·8 (1·02–7·72)	No No No No
Khin et al, 1994[14]	Burma, unspecified	Case-control	Observed not using soap before child feeding	Children 1–59 months	7	Severe persistent diarrhoea	Mother 's hands 1·26 (0·87–1·72) Child's hands 2·90 (2·19–3·87)	Yes Yes
Shahid et al, 1996[15]	Bangladesh, rural	Intervention trial	Soap and pitcher distributed: advised to wash hands with soap before eating or handling food, after toilet	All ages	1,2,5,6	Diarrhoea Shigellosis	2·63 (2·33–3·03) 2·5 (1·45–4·35)	Yes Yes
Birmingham et al, 1997[16]	Burundi, rural	Household survey	Reported not having soap at home, not washing hands before food, not washing hands after toilet	All ages	8	Dysentery	Soap at home 1·7 (0·9–3·4) Before eating 0·7 (0·1–2·8) Before preparing food 1·8 (1·0–3·4) After defecation 0·5 (0·3–1·1)	Yes No No No
Velema et al, 1997[17]	Indonesia, urban	Case-control	Reported never using soap when washing hands	Adults	7,8	Typhoid	29·8 (2·19–407)	Yes
Peterson et al, 1998[18]	Malawi, refugee camp	Cohort	Absence of soap at home	All ages	1,3,5,6	Diarrhoea	1·36 (1·02–1·85)	Yes
Barros et al, 1999[19]	Brazil, urban child care centres	Cohort	Observed child handwashing	Children 3–35 months	9	Diarrhoea	Before meals 1·73 (1·15–2·20) After defecation 1·63 (1·02–2·60) Frequent soap for changing nappies 1·49 (1·04–2·13)	No No Yes

Table 1 continued

Study	Location, setting	Type of study	Exposure/intervention	Age group	Methodological shortcomings*	Outcome	Relative risk (95% CI)	Soap use specified
Hoque et al, 1999[20]	Bangladesh, rural	Case-control	Reported use of soap, ash, or soil for handwashing after defecation by mother	Children 1–59 months	8	Diarrhoea mortality	0·97 (0·57–1·62)	Yes (or ash or mud)
Roberts et al, 2000[21]	Australia, urban child-care centres	Intervention trial	Lessons, demonstrations, and supervised practice of handwashing by carers	Children 0–3 years	2, 5	Diarrhoea	2·00 (1·47–2·78)	Yes
Hussein Gasem et al, 2001[22]	Indonesia, urban and rural	Case-control	Reported never or sometimes washing hands before preparing food	Adults	8	Severe typhoid	3·97 (1·22–12·93)	No

*Methodological shortcomings, for trials: 1=intervention not randomised; 2=baseline incidences not given; 3=no concurrent control group; 4=unsatisfactory case definition; 5=no placebo intervention; 6=compliance not assessed. Methodological shortcomings, for observational studies: 7=no or inadequate control for confounding; 8=unreliable measure of handwashing; 9=high loss to follow-up.

calculate them) of the risk of not washing hands. Intervention trials not solely concerned with handwashing were excluded.

The following were tabulated: location, date, and type of study; handwashing occasion and actor; use of soap; disease outcome measure; age group; and the risk measure for intestinal disease without versus with handwashing and its 95% CI, quoted or calculated from the data. Where odds ratios were presented, they were treated as if they were relative risks.[5] Where both crude and adjusted odds ratios were presented, adjusted values were used. The methodological shortcomings of each study were listed.

Meta-analysis

Risk estimates from the studies were pooled in meta-analyses with STATA software (STATA Corporation, College Station, TX, USA). Many studies offered multiple measures of handwashing practices and/or multiple measures of outcome. The risk values for studies with several measures of handwashing practice were combined by averaging, if they concerned the same sample group. If they concerned different groups, they were treated as if they were separate studies. Similarly, studies with two different outcome measures were entered into the meta-analysis as if they were separate studies. Forest plots and random-effects pooled estimates of risk were generated.

Studies were combined as follows: all studies combined; all intervention trials; studies of good methodological quality only (trials with baselines and concurrent control groups, observational studies with adequate control for confounding); studies specifically mentioning the use of soap for handwashing; severe outcomes (hospitalised cases of enteric infection, cholera, shigellosis, typhoid and death); and studies with shigellosis as the outcome.

Publication bias was explored via a funnel plot of all studies. Estimates of the effect of handwashing on mortality were extrapolated from published figures.

Results

38 papers with relevant content were retrieved, of which 17 studies with observational and intervention designs were retained. Seven studies reported the impact of an intervention to promote handwashing. The remaining ten studies were observational, recording existing handwashing practices and relating them to disease rates. Six of the observational studies had a case-control design, two were household surveys, and two were cohort studies (table 1). Relative risks are the excess risk of diarrhoeal disease associated with not washing hands, and are those quoted in the studies (as RRs or ORs) or calculated from the data provided.

Ten studies were set in Asia, three in Africa, two in Latin America, one in the USA, and one in Australia. Nine were done in urban settings, five in rural settings, one in both urban and rural settings, one in a refugee camp, and one did not specify the location. Three studies were set in childcare facilities, whereas the others reported domestic handwashing practice. Many different types of, and occasions for, handwashing were recorded including washing by child carers, by children, and by adult study respondents. Handwash occasions reported included: after defecation or after the toilet, after cleaning up a child or handling nappies, before eating, and before preparing or handling food. One study used the presence of soap in the home as an indicator of handwashing. Two studies did not specify whether soap was used for handwashing or not. Outcome measures concerned children and adults, and included diarrhoea, dysentery, typhoid, cholera, and shigellosis. Three studies reported multiple outcomes.

All studies had methodological flaws.[23–25] Only two of the seven intervention studies were effectively randomised. The other intervention trials compared only two communities or two pairs of communities, with one subject to intervention and one as control. None of the intervention trials provided adequate data on compliance with handwashing. Only two observational studies used actual observations of handwashing to provide the data on exposure. The others relied on oral reports of handwashing, which are known to poorly reflect reality.[26–28] The relative risks of disease associated with not washing hands ranged from 29·8 to 0·50, with a median value of 1·67.

In addition, one small case-control study of infectious mortality risk with retrospective data on reported handwashing was located.[29] It showed a reduction in overall mortality associated with reported handwashing with soap, but not in diarrhoea mortality.

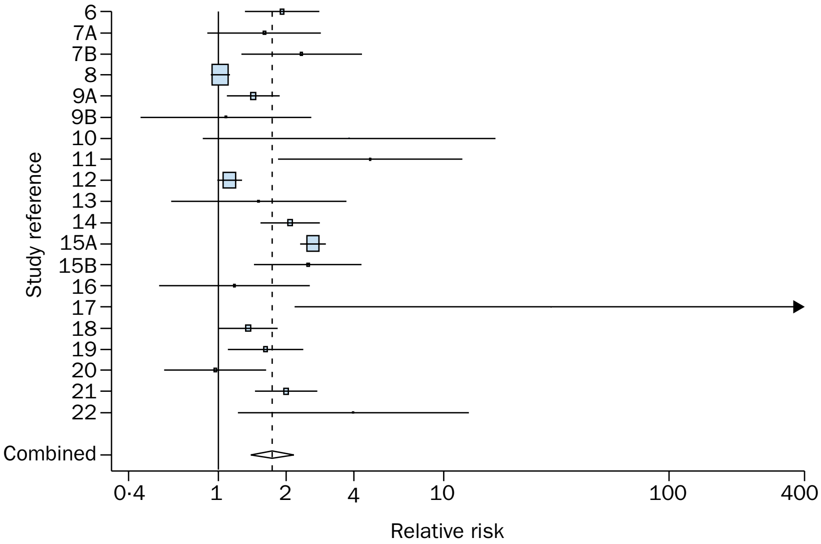

Figure 2. Forest plot of all studies. Combined random effects relative risk 1·74 (1·39–2·18). Numbers on the y axis are references for the studies in table 1; letters refer to different measures from the same study. The squares and horizontal lines correspond to the relative risk and 95% CI for each study. The area of the square represents the size of each trial. The diamond represents the combined relative risk and 95% CI by the random effects model.

Meta-analysis

Figure 2 shows a forest plot of the risk estimates for all studies, irrespective of design, with their 95% CIs. The summary risk estimate was 1·74 (95% CI 1·39–2·18), giving an equivalent reduction in risk of 43% (28–54%). Figure 3 shows the pooled results of the intervention trials only. The pooled summary estimate was 1·88, equivalent to a 47% reduction in diarrhoea risk associated with handwashing (24–63%).

Table 2 gives the pooled risk estimates for the different combinations of studies. The percentage reduction in diarrhoeal risk was 42% (31–51%) when only the high-quality studies were combined. Similar results (44% reduction) were found when soap use was specifically mentioned. The robustness of the summary risk estimate was tested by dropping one study at a time from the meta-analysis for all of the studies. This yielded summary estimates of risk reduction ranging from 38% to 45%.

When the results of studies with severe outcomes were combined, handwashing was found to be associated with a 48% reduction in severe enteric infections (35–66%) and a 59% reduction in shigellosis (two studies only, 95% CI 38–73%).

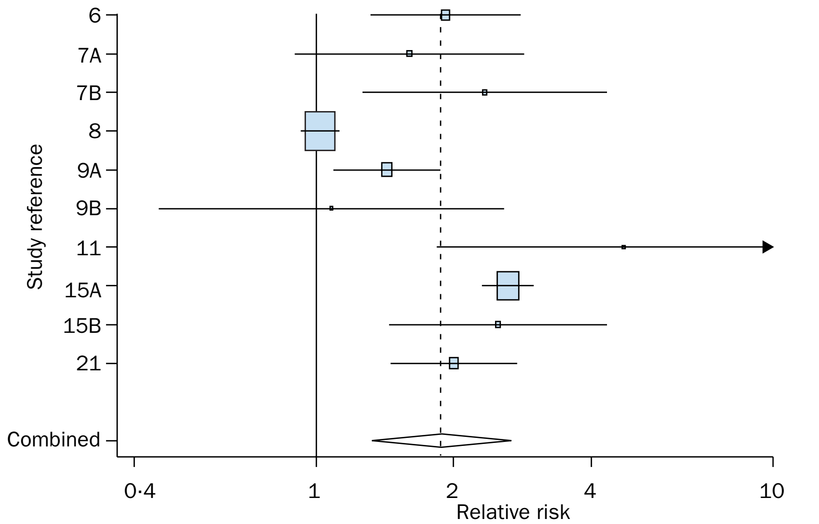

Figure 3. Forest plot of the intervention studies. Combined random effects relative risk 1·88 (1·31–2·68). Numbers on the y axis are references for the studies in table 1; letters refer to different measures from the same study. The squares and horizontal lines correspond to the relative risk and 95% CI for each study. The area of the square represents the size of each trial. The diamond represents the combined relative risk and 95% CI by the random effects model.

Discussion

Principal findings

We found only 17 studies suitable for review offering 20 data points. Most were of poor quality and the range of results was considerable. Taken as a whole, however, the literature points to an important role for handwashing in preventing diarrhoeal disease. We found that interventions to promote washing hands with soap were associated with a decrease in risk of diarrhoeal disease of 47% (95% CI 24–63%). Handwashing was also associated with a 48–59% reduced risk of more severe outcomes.

Estimating potential reductions in mortality

Good epidemiological evidence for the impact of handwashing on diarrhoea mortality is hard to obtain, since randomised trials with mortality as an outcome would be unethical, and retrospective studies unreliable through reporting bias. Esrey et al[31] have suggested that reducing the rate of pathogen ingestion causes the incidence of severe infections to begin to fall before that of mild ones. Morris and colleagues[32] found that a 5% decrease in the proportion of days on which a child suffered from diarrhoea was associated with a 17% relative decrease in the risk of mortality. Victora et al[33] showed that the environmental risk factors for diarrhoea are also risk factors for diarrhoea deaths. These reports suggest that interventions to reduce diarrhoeal illness may reduce diarrhoeal deaths to the same or to an even greater extent. Most diarrhoea deaths are associated with persistent diarrhoea and dysentery.[34,35] Studies of the health impact of water supplies and sanitation[36–40] also suggest

Table 2. Pooled estimates of the impact of handwashing on enteric infections and the equivalent reduction in diarrhoeal disease using different combinations of studies

Combinations of studies	Number of data points	Pooled estimate (95% CI)*	Equivalent reduction in diarrhoeal disease risk (%)
1 All studies	20	1·74 (1·39–2·18)	43
2 Intervention studies only	10	1·88 (1·31–2·68)	47
3 Studies of high methodological quality	6	1·72 (1·45–2·04)	42
4 Handwashing with soap only	19	1·78 (1·41–2·26)	44
5 Severe outcomes only	9	1·91 (1·35–2·70)	48
6 Shigellosis only	2	2·43 (1·61–3·66)	59

*Tests for heterogeneity gave significant results for all combinations of studies, save for combinations 3 and 6. Random effects models were therefore used for pooled estimates.[30] For combinations 3 and 6 both fixed and random effect models gave the same pooled estimate.

that shigella, cause of bacillary dysentery and of much persistent diarrhoea, has a much lower infective dose and may thus be more susceptible than other pathogens to control by hygiene improvements.

The one study of handwashing and diarrhoea mortality that was located[20] showed no association, but relied on self report of handwashing by the mother within a month of the death of her child from diarrhoea, and had wide confidence intervals. Recall bias of handwashing after a diarrhoea death may explain why handwashing appeared to reduce overall mortality, but not for diarrhoea.

The most recent detailed published estimate of the total annual death rate from diarrhoeal diseases is 2·2 million[1]. Victora et al[41] suggested 1·5 million child deaths. Kotloff and colleagues' claim[35] that shigella is responsible for 1·1 million deaths a year with a range of 0·77–11·6 million, is thought by some to be an overestimate. Table 3 gives estimates of the number of lives that could be saved by the universal adoption of handwashing with soap. The average of estimates 1, 2, and 3 is about 1·07 million.

Strengths and weaknesses of the review

Whilst this paper adds to our knowledge of the role of handwashing in the prevention of the diarrhoeal diseases, it also highlights the weakness of the published evidence. Intervention trials provide the best evidence for the impact of handwashing[42] because confounding cannot be ruled out in observational studies. However, none of the intervention studies in this review used the ideal randomised controlled trial methodology, and all had methodological flaws. Only two of the seven intervention studies were effectively randomised, only one actually measured the impact of the intervention on handwashing practices, and none used placebo control groups. Reported risk reductions in intervention groups might thus be explained by the Hawthorn effect.[42] Few studies provided enough detail about the content of the intervention, the type of message and the number of contacts with targets, to gauge how much impact should have been expected. The lack of data on the impact of the interventions on handwashing practices makes sensitivity analyses, to model the potential effects of different types and intensity of intervention, impossible.

Nevertheless, similar levels of risk reduction were found when studies of high methodological quality were combined, and when those with different designs, including observational studies were combined. Although more, and better studies are needed, it is unlikely that this consistent pattern of impact can entirely be explained by the methodological shortcomings of the studies.

A funnel plot showed weak evidence of publication bias (Begg's test, p=0·11).[43] Omission of unpublished studies may have biased the pooled estimates upwards, although we failed to locate any such studies.

It is biologically plausible that handwashing prevents the transmission of diarrhoeal pathogens. Hands can carry pathogens from faeces to surfaces, to foods, and to future hosts, and handwashing with soap is effective in removing pathogens[44–47] Handwashing after stool contact is relatively rare: in nine studies reporting rates of handwashing with soap after stool contact in developing countries[8,12,19,48–52] the median rate of handwashing with soap after cleaning up a child was 13% (range 0–20%) and for the carer after defecation was 14% (range 1–20%). Children are an important reservoir of diarrhoeal pathogens and the carer who cleans the child is often the main preparer of food for the household.

The reduction in the risks of mortality associated with handwashing were extrapolated from morbidity risks with a number of assumptions. If any of these are violated (total diarrhoeal death estimates revised, lives saved not proportional to reduction in disease risk) the estimate of lives potentially saved through handwashing would need to

Table 3. Estimates of diarrhoea deaths preventable by handwashing

	Assumptions	Calculation	Total deaths prevented (millions)
1	Deaths prevented by handwashing proportional to reduction in risk of severe infection	2·2x0·48	1·056
2	0·77 million shigellosis deaths. Handwashing prevents 59% of shigellosis deaths and 47% of other deaths	0·77x0·59+ 1·43x0·47	1·126
3	Deaths prevented proportional to diarrhoea reduction in intervention studies	2·2x0·47	1·034
4	Low estimate: deaths prevented proportional to lowest estimate of risk reduction	2·2x0·24	0·528
5	High estimate: deaths prevented proportional to highest estimate of severe disease risk reduction	2·2x0·63	1·386

be revised. Apportioning deaths to different causes is an uncertain art, since deaths in poverty are often the consequence of multiple factors and multiple infections. While there may be other, underlying causes such as malnutrition, diarrhoea is often an immediate cause of death, and its prevention could avert mortality. Successive estimates of global diarrhoeal deaths have fallen from 4·6 million in 1980 through 3·3 million,[53] 2·9 million,[54] to 2·2 million in 2000.[55]

On the other hand, we have not taken into account growing evidence from developed countries that handwashing can substantially reduce the risk of respiratory tract infection (four studies, median risk reduction 45%).[56–59] If handwashing can produce reductions in respiratory morbidity and mortality in developing countries, then the impact of handwashing on mortality might be much greater than suggested here.

Meaning and implications of the study

Handwashing has been regarded as a key infection-control practice since Semmelweis.[60] While there is much discussion about how to improve handwashing habits in health-care settings,[61–63] the importance of handwashing in homes, particularly in developing countries, receives scant attention.

Interest in the diarrhoeal diseases peaked in the 1980s with efforts to promote oral rehydration and improved water supply. Today, they are ranked third as cause of death and second as cause of healthy life years lost due to premature mortality and disability.[54,64] However, whereas major new initiatives to combat malaria, HIV, and tuberculosis have been announced, interest in research and intervention in the diarrhoeal diseases has waned.

Modern methods of promoting handwashing can be effective and cost-effective on a large scale.[51,65] Work we are currently undertaking suggests that soap is widely available, even in poor households in developing countries, although it is mostly used for bathing and washing clothes.

Search strategy and selection criteria

These are described in detail in the Methods section.

Future research

Although our evidence suggests that the promotion of handwashing with soap in homes in developing countries should become a public health intervention of choice, much work remains to be done. Rigorous intervention trials are needed to explore the impact of handwashing on diarrhoea and other infections, in a variety of settings. Efforts to modify human behaviour are complex and can only expect to be successful if they are built on understanding what motivates, facilitates, and hinders adequate handwashing behaviour.[66,67] The effectiveness of new and existing approaches to handwashing promotion need to be measured and their cost-effectiveness documented. Basic work is still needed to clarify when hands should be washed, how often, by whom, and in what manner. Simple indicators of handwashing compliance need to be developed and validated.

Implications

Although more, and more rigorous, intervention trials of the health impact of handwashing are badly needed, current evidence shows a clear and consistent pattern. If handwashing with soap could save over a million lives, if rates of handwashing are currently very low, and if carefully designed handwashing promotion programmes can be effective and cost-effective, then handwashing promotion may become an intervention of choice.

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Conflicts of interest

We have received a grant from Unilever Research Ltd.

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