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Systematic Review

Hygiene and health: systematic review of handwashing practices worldwide and update of health effects

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Abstract

OBJECTIVE To estimate the global prevalence of handwashing with soap and derive a pooled estimate of the effect of hygiene on diarrhoeal diseases, based on a systematic search of the literature.

METHODS Studies with data on observed rates of handwashing with soap published between 1990 and August 2013 were identified from a systematic search of PubMed, Embase and ISI Web of Knowledge. A separate search was conducted for studies on the effect of hygiene on diarrhoeal disease that included randomised controlled trials, quasi-randomised trials with control group, observational studies using matching techniques and observational studies with a control group where the intervention was well defined. The search used Cochrane Library, Global Health, BIOSIS, PubMed, and Embase databases supplemented with reference lists from previously published systematic reviews to identify studies published between 1970 and August 2013. Results were combined using multilevel modelling for handwashing prevalence and meta-regression for risk estimates.

RESULTS From the 42 studies reporting handwashing prevalence we estimate that approximately 19% of the world population washes hands with soap after contact with excreta (i.e. use of a sanitation facility or contact with children's excreta). Meta-regression of risk estimates suggests that handwashing reduces the risk of diarrhoeal disease by 40% (risk ratio 0.60, 95% CI 0.53–0.68); however, when we included an adjustment for unblinded studies, the effect estimate was reduced to 23% (risk ratio 0.77, 95% CI 0.32–1.86).

CONCLUSIONS Our results show that handwashing after contact with excreta is poorly practiced globally, despite the likely positive health benefits.

keywords hygiene, diarrhoea, handwashing, risk estimates, meta-analysis

Introduction

Handwashing with soap at key times has been shown to reduce diarrhoeal disease and acute respiratory infection (Curtis & Cairncross 2003; Rabie & Curtis 2006; Aiello *et al.* 2008). Alongside adequate sanitation, handwashing with soap after stool contact is an important barrier to the faecal–oral spread of diarrhoea because it prevents pathogens from reaching the domestic environment and hence their subsequent ingestion. Handwashing with soap before contact with food and water also reduces the secondary transmission of pathogens from the environment to a new host (Curtis *et al.* 2000). Beyond diarrhoeal disease, handwashing is also thought to play a role in reducing the transmission of infections such as pneumonia, influenza, helminths, trachomae, neonatal infections, HIV-associated infections and environmental enteropathies (Aiello *et al.* 2008; Blencowe *et al.* 2011; Curtis *et al.* 2011; Ejere *et al.* 2012; Ejemot *et al.* 2012; ; Filteau 2009; ; Freeman *et al.* 2013; Greenland *et al.* 2013; Isaac *et al.* 2008; WHO 2009). Further, hand hygiene is essential for disease control in commercial and domestic food preparation as well as in health care, day care, educational and occupational settings (Roberts *et al.* 2000; Bowen *et al.* 2007; Ejemot *et al.* 2012). Previous studies have suggested that promoting hand hygiene may be one of the most cost-effective means of reducing the global burden of disease (Cairncross & Valdmanis 2006).

The purpose of this article was to obtain key inputs for the development of the first regional and global estimates of handwashing with soap following faecal exposure, in view of updating the estimates of the burden of disease for the impact of this behaviour on diarrhoeal disease. We systematically reviewed the prevalence of the relevant hand hygiene practices worldwide and updated the evidence linking hand hygiene practices to the prevention of diarrhoea. In both cases, we present adjusted estimates due to known biases. The methods are described in line with the 'Preferred Reporting Items for Systematic Reviews and Meta-Analysis' (PRISMA) guideline (Moher *et al.* 2009) and include a PRISMA checklist (Appendix S1). The results provide a basis for estimating the global burden of disease from inadequate hand hygiene practices (Prüss-Ustün *et al.* 2014).

Methods

We systematically reviewed the literature for observed handwashing prevalence and applied multilevel modelling to estimate handwashing practices worldwide, by region and by country. To estimate the effect of different hygiene interventions on diarrhoeal disease morbidity, we reviewed the literature and used meta-regression techniques. The protocol for this study was reviewed and agreed upon by an expert group convened by the World Health Organization (WHO) the searches began.

Exposure prevalence: selection criteria, search strategy and data extraction

Because self-report is known to dramatically overestimate rates of handwashing with soap (Biran *et al.* 2008), studies were sought that reported the observed prevalence of handwashing with soap after using a toilet or after contact with excreta (including children's excreta). We included contact with children's excreta both because evidence for the impact of the specific times for handwashing is limited (see Luby *et al.* 2011 for the only available study), and because handwashing after handling child faeces is a plausible proxy for handwashing in general. Similarly, though in most observational studies, it is not known whether the subject uses the latrine for defecation, handwashing after toilet use is a relevant proxy for handwashing after contact with excreta. Hospital- and school-based handwashing studies were excluded, as they are not representative of the general population.

A systematic search was conducted for studies published between 1990 and August 2013 using PubMed, Embase and ISI Web of Knowledge. No restrictions were placed on language or study type. The database search was supplemented with data identified in a previous review (Curtis *et al.* 2009) and with additional Google Scholar searches of author names identified during the systematic database search. In addition, experts were contacted for unpublished handwashing observations.

Studies were selected for inclusion using a two-step review process. Titles and abstracts of all studies identified in the search were screened for relevance. The full text of each of the relevant articles was then reviewed and studies were excluded if they did not provide data on the prevalence of observed handwashing with soap. Data were extracted from each study using a standard protocol. Data extracted included information on study setting (country), observation location (home or public setting), timeframe of survey, population subgroup, sample size, a description of how handwashing prevalence was measured and specific prevalence estimates for any of the handwashing occasions, such as after toilet use or after cleaning up after a child (Appendix S5).

Impact estimates: selection criteria, search strategy and data extraction

Studies were eligible for inclusion if they were published between 1970 and August 2013 and reported on the impact of a hygiene promotion program on diarrhoea. Eligible study designs included randomised controlled trials, quasi-randomised controlled trials, observational studies using matching techniques and observational studies with a control group, where the intervention was well defined. In addition to studies concerning individual, household and community hygiene interventions, institutional interventions (e.g. in day-care centres and schools) were also included on the assumption that associated behaviours may plausibly affect household protection (unlike the water and sanitation meta-regression by Wolf *et al.* 2014). Studies assessing the impact of handwashing with soap were excluded if they were on non-representative population groups (e.g. HIV-positive children) or if there was no control group. The primary outcome was diarrhoeal disease morbidity regardless of aetiology and case confirmation. The main definition for diarrhoea was the WHO standard of at least three loose stools passed in the previous 24 h (WHO 2005), but alternative case definitions were permitted.

Five databases were searched (Cochrane Library, PubMed, Global Health, Embase and BIOSIS) – using keyword and medical search headings. Reference lists of key articles (previously published systematic reviews and an unpublished literature review conducted by the WHO) were examined and subject experts and study authors were contacted to provide additional information where required. The search strategy was prepared in English, and only studies available in English or French were considered unless the relevant data had been extracted and made available in a previously published English or French language systematic review.

Titles and abstracts were screened by a single reviewer, and data extraction and quality assessment was carried out by two independent reviewers, using a structured and piloted form. Differences between reviewers over data extraction and quality assessment were reconciled with the intervention of a third abstractor, where required. The quality assessment criteria were adapted from the Newcastle-Ottawa scale (Wells *et al.* undated) for assessing the quality of studies for the health effects of interventions to reduce indoor air pollution (Pope *et al.* 2010). Specific quality criteria were adapted to study design (intervention, cohort, case–control, cross-sectional), to assess the risk of bias in sampling, exposure and outcome measurement, results, analysis and reporting.

Exposure prevalence: statistical analysis

We estimated the proportion of country populations washing hands with soap using data from the prevalence surveys. Multilevel modelling was used to obtain the proportion of the population washing hands with soap for the year 2012. A linear two-level model, with WHO regions (WHO 2013) as covariates and a random intercept by country, provided an estimate for countries using a methodology similar to (Wolf *et al.* 2013). Country means were estimated without weighting by sample size as surveys were not designed to be country-representative, and their variability was likely to be due to different settings (e.g. public restroom in motorway or university, or home) or population groups. For countries with only one survey, the survey value was used for country reporting but not for estimation of the regional mean. Regional estimates were calculated as the mean of prevalence from countries with surveys, without weighting by country population (this choice was made because country population is not likely to drive handwashing prevalence). The means for the two regions without surveys (Eastern Mediterranean low- and middle-income and Eastern Mediterranean high-income regions) were obtained from the mean of prevalence of low- and middle-income and high-income countries, respectively. The global mean was obtained by a regional population-weighted mean of regional prevalence. Uncertainty intervals were estimated by bootstrap sampling from the survey points.

Impact estimates: Statistical analysis

The summary effect estimates were calculated as risk ratios (RR) with 95% confidence intervals (CI). Studies with multiple intervention arms could provide more than one effect estimate, providing each arm had a separate control. Whenever possible we extracted effect estimates that were adjusted for clustering at household or community level.

Random-effects meta-analyses were conducted to examine the effect of hygiene promotion interventions on diarrhoeal morbidity. Meta-regression was used to assess the impact of different intervention types and further study characteristics that could potentially influence results (Thompson 1994). Additional pre-specified covariates were retained in the model if the *P*-value was smaller than 0.2 or if they changed effect estimates of other variables by at least 15% (Kirkwood & Sterne 2003; McNamee 2003).

We explored the following further study characteristics in meta-regression analysis:

- interventions focused on handwashing only *vs*. those covering a broad range of hygiene promotion messages;
- handwashing interventions with and without the provision of soap;
- high-income *vs*. low- and middle-income countries;
- improved water and/or improved sanitation at baseline;
- urban *vs*. rural area;
- length of follow-up (as continuous variable, or more or less than 12 months); and
- randomised *vs*. non-randomised.

As a sensitivity analysis, we excluded the studies with the lowest quality rating (12% of all hygiene studies). Additionally, we checked whether excluding the only study that used survey data changed the results (Fan & Mahal 2011).

Relating to the reasoning in Wolf *et al.* (2014) for non-blinding bias adjustment in household-level interventions with subjective assessed outcomes, we believe such an approach is also appropriate for hygiene intervention studies. It is not possible to blind educational interventions. Therefore, meta-regression was repeated with the result of each study separately adjusted by introducing bias through a prior distribution in a Bayesian framework (Welton *et al.* 2009). On the basis of the findings of Savović *et al.* (2012), who examined the distribution of bias due to lack of blinding in a large-scale meta-epidemiological study, different prior distributions on size and direction of this bias were explored (Welton *et al.* 2009). These distributions incorporate variability in bias across studies and across meta-analyses. The prior which best represents the findings of the meta-epidemiological study (Savović *et al.* 2012) is based on the mean bias and the sum of all variance components. This is the preferred approach for the current analysis, as it will adjust the biased studies and should appropriately down-weight them. More information on bias adjustment for non-blinding is provided in Supporting Information (Appendix S6).

The potential for an association between study size and effect size, which may be due to publication bias, was examined using funnel plots and statistical tests (Begg's and Egger's test). Analyses were performed with Stata 12 (Stata Statistical Software Release 12; StataCorp., College Station, TX, USA). Bayesian meta-regression and bias adjustments were performed using WinBUGS (Lunn *et al.* 2000).

Results

Prevalence of handwashing with soap

The initial search for handwashing with soap prevalence identified 2881 unique publications. Only 24 of these studies were found to provide prevalence data for handwashing with soap for at least one of the specified times of interest. Fifteen additional data sets were identified from the previous review conducted by Curtis *et al.* 2009 and two additional data sets were provided by contacted authors. Figure 1 provides the search flow diagram of the number of studies screened for eligibility and included in the calculations of pooled handwashing prevalence estimates for countries and regions. Study details for the 42 identified studies are presented in Appendix S2.

We estimate that 19% of people worldwide wash their hands with soap after contact with excreta. The regional mean prevalence of handwashing with soap ranges between 13% and 17% in low- and middle-income regions, and between 42% and 49% in high-income regions (Table 1). Country-level prevalence estimates can be found in Table 2. Country means in low- and middle-income regions vary between 5% and 25% of handwashing after contact with excreta, and between 48% and 72% in high-income countries. Israel and the Republic of Korea have lower handwashing prevalence than other high-income countries. They also are at the lower band of income within the high-income category (at time of surveys) and are geographically located outside the larger high-income regions. Given the availability of studies, we were not able to measure the changes in handwashing with soap prevalence over time.

Impact of handwashing promotion on diarrhoea

Figure 2 provides a flow diagram for the systematic search of publications linking handwashing with soap to diarrhoea outcomes. We identified 920 unique publications, of which 26 were retained for quantitative meta-analysis. Appendix S4 presents the citation, definitions and characteristics for each of the 26 studies included in the meta-analysis.

Of the 26 included studies, 14 employed interventions focused on handwashing messages while 12 delivered general hygiene education, which includes programs where handwashing with soap was only one component of a larger set of messages. Among the 14 handwashing-focused studies, 11 specifically mentioned and provided soap, but did not generally provide information on the actual use of soap. The summary effect size of all hygiene promotion interventions in a random-effects meta-analysis of all 26 observations was a 33% reduction in the risk of diarrhoea [risk ratio (RR) 0.67, 95% confidence interval (CI) 0.61–0.74]. We found a 40% reduction in the risk of diarrhoea from the promotion of handwashing with soap (RR 0.60, 95% CI 0.53–0.68) and a 24% reduction in the risk of diarrhoea for general hygiene education alone (RR 0.76, 95% CI 0.67–0.86). Promotion of handwashing (with provision of soap or where soap was used) was thus associated with greater reduction of diarrhoea than broader hygiene education ($P = 0.01$) (Table 3).

When testing for length of follow-up, there was weak evidence ($P = 0.17$) that the impact of the intervention on diarrhoea declined with time after initial implementation, with an approximately 10% increase in diarrhoea risk after one year, compared to the initial reported levels. This association was, however, strongly driven by a single study (Wilson *et al.* 1991), which showed a partic-

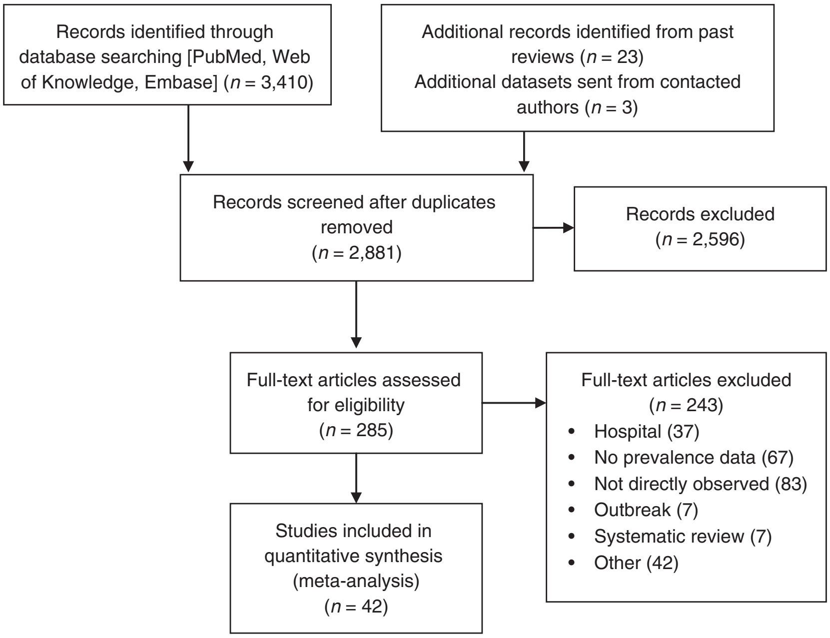

Figure 1 Flowchart describing study selection in handwashing prevalence.

Table 1 Mean prevalence of handwashing with soap by region

Region	Number of studies	Prevalence of handwashing with soap, (%) (95% CI)
Africa	13	14 (11, 18)
Americas HI	7	49 (33, 65)
Americas LMI	2	16 (7, 33)
Eastern Mediterranean HI*	–	44 (34, 57)
Eastern Mediterranean LMI*	–	15 (9, 24)
Europe HI	5	44 (29, 56)
Europe LMI	1	15 (6, 30)
South-East Asia	11	17 (7, 36)
Western Pacific HI	2	43 (25, 57)
Western Pacific LMI	2	13 (6, 25)
World	43	19 (8, 39)

LMI, low- and middle-income; HI, high-income; –, not available.
*No data available for Eastern Mediterranean (Emr); the mean for LMI countries was used for EmrLMI, and mean for HI countries for EmrHI, respectively.

ularly strong effect immediately post-intervention. Study duration was, therefore, not retained as covariate in the final analysis. No association was found between diarrhoea risk and the other tested covariates. The included covariates explained 32% of the between-study variance.

Omitting the studies with the poorest quality ratings, or the single study with a particularly high effect size immediately post-intervention, did not change the results of the model. A funnel plot of the hygiene promotion studies is shown in Appendix S3. Statistical tests for asymmetry were not statistically significant, although the plot does not exhibit the expected funnel shape, which is probably due to the variety of different study designs.

Interventions reporting the impact of handwashing with soap on diarrhoea mostly provide results for the association between maternal caregiver handwashing and diarrhoea among children under 5 years, with impacts on other age groups less frequently reported. Data on other age groups were extracted wherever possible and the results for all ages compared with children under five. No difference by age group was detected and so it has been assumed that the estimates derived here can be used for all ages.

Table 2 Mean prevalence of handwashing with soap by country

Region	Country	No. of Studies	Prevalence estimate, (%) (95% CI) without sample weighting
Afr	Burkina Faso	1	8 (4, 14)
	Ethiopia	1	22 (13, 34)
	Ghana	3	13 (6, 22)
	Kenya	5	15 (7, 29)
	Senegal	1	19 (12, 30)
	Uganda	1	15 (9, 24)
	Tanzania	1	5 (3, 10)
AmrHI	USA	7	49 (32, 65)
AmrLMI	Peru	2	16 (7, 32)
EurHI	Israel	1	12 (5, 26)
	Netherlands	1	50 (34, 66)
	United Kingdom	3	52 (34, 70)
EurLMI	Kyrgyzstan	1	16 (7, 32)
Sear	Bangladesh	7	18 (10, 27)
	India	3	15 (3, 27)
	Thailand	1	25 (15, 38)
WprHI	New Zealand	1	72 (44, 89)
	Republic of Korea	1	17 (9, 33)
WprLMI	China	2	13 (6, 24)

Afr, Africa; Amr, Americas; Emr, Eastern Mediterranean; Eur, Europe; Sear, Southeast Asia; Wpr, Western Pacific; LMI, low- and middle-income; HI, high-income.

Studies of hygiene cannot be blinded and generally rely on self-reported diarrhoea. We therefore introduced bias adjustments based on empirical evidence for all studies (Savović *et al.* 2012), in the same way as in the meta-regression on drinking water and sanitation (Wolf *et al.* 2014), with the results shown in Table 3. After adjusting for bias, while handwashing with soap leads to a marked reduction in the risk of diarrhoea, the result is no longer statistically significant.

Discussion

A systematic review of global handwashing showed that handwashing after possible contact with excreta is still far from universally practiced. The global mean prevalence of handwashing was estimated at 19%. Although this result is based on only 43 studies from 19 countries, the studies show remarkably little variability within regions of the same income level. The high-income countries with data on handwashing frequency show rates varying between 48% and 72%, and low-income countries show lower rates varying between 5% and 25%.

To our knowledge, this is the first systematic review of observed handwashing prevalence. We used data from studies that employed direct observation of handwashing behaviour rather than self-reported behaviour, as self reporting is known to overestimate real handwashing rates greatly (Biran *et al.* 2008). However, the presence of an observer has consistently been shown to lead to biased results due to increased handwashing behaviour (Ram *et al.* 2010; Pedersen *et al.*, 1986; Munger & Harris 1989). We would expect such bias to inflate our estimate, meaning that 19% is likely an overestimate of the global prevalence of handwashing. For this reason, it is even more pressing to determine handwashing promotional strategies that are effective and engender long-lasting behaviour change.

The risk ratio for the reduction in diarrhoeal disease risk from handwashing with soap (RR 0.60), before adjusting for potential bias due to lack of blinding, is largely consistent with previous estimates. It is found across types of study design and is robust to changes in inclusion criteria. Courtesy bias – the tendency of participants (who know they are in the intervention group, i.e. they are non-blinded) to provide answers to please the investigator – is a concern, as it may lead to over-reporting of handwashing behaviours and under-reporting of diarrhoea, thus an overestimation of the effect of the intervention. This effect has been discussed in the context of point-of-use water-treatment studies (Schmidt & Cairncross 2009) and may also apply to hygiene interventions (Luby *et al.* 2006). An additional challenge is that observations may lead to a Hawthorne effect (the effect,

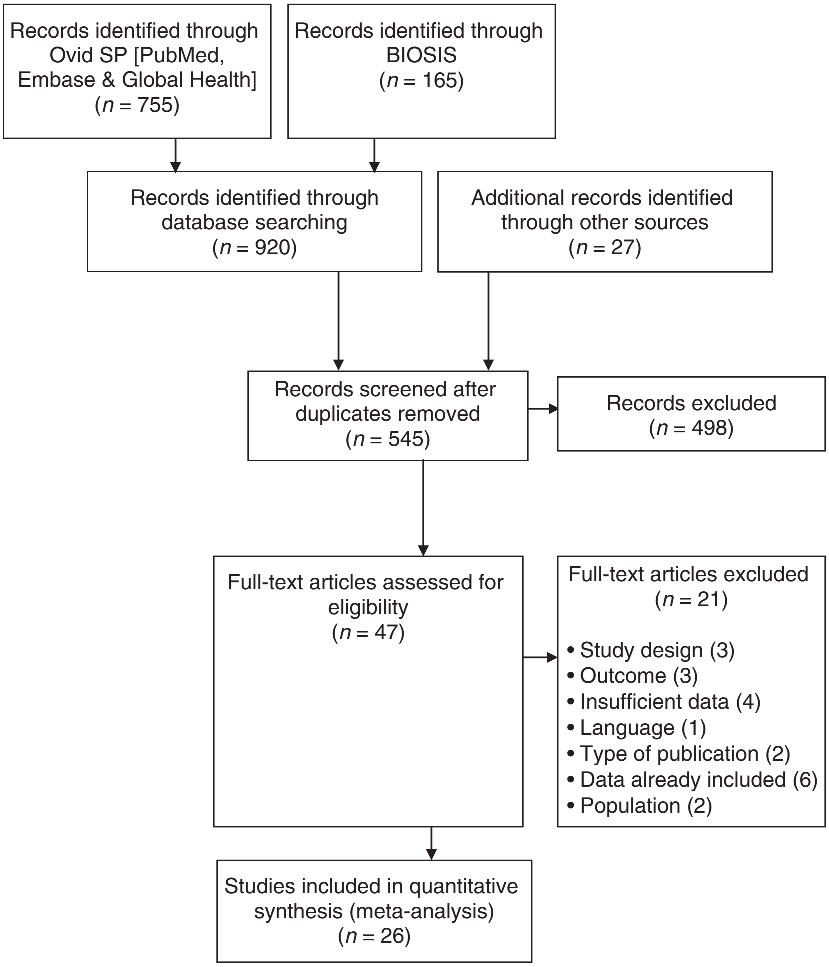

Figure 2 Flowchart describing the selection of studies on the effect of handwashing on diarrhoea.

Table 3 Meta-regression results for hygiene interventions, without and with bias adjusted for non-blinding

Bias adjustment for non-blinding	All hygiene education studies (n = 26)	Handwashing with soap only (n = 14)	General hygiene education only (n = 12)
No adjustment	0.67 (0.61, 0.74)	0.60 (0.53, 0.68)	0.76 (0.67, 0.86)
Adjustment	0.86 (0.36, 2.09)	0.77 (0.32, 1.86)	0.97 (0.40, 2.36)

usually positive, of being under investigation generally) which can result either in an overstatement or understatement of the effectiveness of the hygiene interventions (Ram *et al.* 2010).

In the absence of evidence as to the existence and magnitude of bias due to non-blinding, we chose to make a correction to our effect estimates based on the distribution of bias in a large-scale meta-epidemiological study of medical and pharmacological interventions (Savović *et al.* 2012). This is our best estimate of likely bias in the absence of further evidence (Wolf *et al.* 2014). The adjustment reduces the estimate of the effect of handwashing with soap on diarrhoea from an RR of 40% to an RR of 23%, an estimate that is not significant at the 5% level.

One short-term intervention study that reported observations of the amount of soap use, and employed an objective measure of illness (rectal swabs), showed strong reductions in the transmission of shigellosis following handwashing compared to a non-handwashing control group (Khan 1982). This comparatively high-quality study (in terms of both exposure and outcome assessment) does provide convincing evidence that hand hygiene has the potential to reduce risk of diarrhoea when there is sufficient motivation for people to comply. To improve our estimates of the health impact of handwashing with soap, future research should:

- employ objective outcome measures
- measure compliance with the intervention and
- explore the impact of courtesy bias, including how much it can be minimised by reducing perceived links between an intervention and the measurement of impact.

We used direct observation in this study because no gold standard measures of handwashing exist, and it is considered a more accurate measure than self-report. While additional studies that rely on observation may not be advisable given the known bias and cost, the need for more precise measures of handwashing behaviour remain. Newly emerging sensor technologies are likely to provide more accurate measures (Fleischman *et al.* 2011; Ford *et al.* 2014). While still costly and only realistic in high-income settings, data from studies in low-income setting may not be far off. Objective measures of illness are also improving that rely on immune response or provide pathogen specific phylogenics (Wu *et al.* 2010; Lammie *et al.* 2012), and do not rely on self-reported diarrhoea.

Even when we reduce the effect estimate for suspected courtesy bias, a concurrent publication suggests that handwashing with soap could reduce the burden of disease by some 296 872 (95% CI 0–882 159) lives a year based on 2012 data (Prüss-Ustün *et al.* 2014). As argued by Curtis and Cairncross in their review (2003), it is reasonable to assume that reductions of diarrhoeal morbidity would result in great reductions in mortality. This is a large number that does not take into account other possible health effects of handwashing. Two recent meta-analyses, for example, have investigated the link between hygiene and respiratory infections. A systematic review by Rabie and Curtis (2006) found a mean reduction in acute respiratory infections of 16% (95% CI 6–40%) from eight studies in community and institutional settings in high-income countries. In a review of 16 studies of various hand hygiene interventions (soap, sanitiser, education) from low-, middle- and high-income countries in both community and institutional settings, Aiello *et al.* (2008) found mean reduction in respiratory illness of 21% (95% CI 5–34%). In addition, as part of an observational study, handwashing has been reported to reduce neonatal mortality (Rhee *et al.* 2008). In a study that included, but was not limited to, handwashing promotion found reductions in worm infection in China (Bieri *et al.* 2013). Personal hygiene reduces the risk of severe trachoma infection (Emerson *et al.* 2000), mitigates the effects of Severe Acute Respiratory Syndrome (Fung & Cairncross 2006) and is recommended to address the risk of influenza pandemics (Cowling *et al.* 2009). However, the evidence on hand hygiene and diseases other than diarrhoeal infections in developing countries is too limited and the evidence from developed countries too heterogeneous to currently draw quantitative conclusions in view of population health impacts.

Further questions remain for research in handwashing. It is not yet clear which handwashing occasions are the most important. Although handwashing with soap after contact with faecal material (e.g. after defecation) provides an important barrier to faecal–oral transmission, it does not prevent secondary transmission (e.g. before preparing food and feeding children – Nizame *et al.* 2013). It is not clear how often hands should be washed, given the tendency for hands to become rapidly recontaminated in normal daily activity (Devamani 2001; Ram *et al.* 2011). It is currently not clear what are the optimal, and practical, hand-cleansing rates to prevent the transmission of respiratory and other pathogens. In addition, it is still not clear as to which hands matter most – is it the mother's, the child's, or those of people outside the family potentially vectoring novel pathogens?

With an overall average of 19% of the world population washing their hands with soap after using the toilet, much promotional work is still needed to increase the frequency of this practice, especially in the poorest countries with the highest disease burdens. The success of recent efforts to promote hand hygiene (Biran *et al.* 2014) is encouraging (Curtis *et al.* 2009), though it is clear that scaled approaches to improve handwashing with soap are needed.

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Supporting Information

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

Appendix S1. PRISMA guidelines checklist.

Appendix S2. Details of studies on hygiene and diarrhoea.

Appendix S3. Publication bias.

Appendix S4. Details of studies on hygiene and diarrhoea.

Appendix S5. Sample data extraction sheet.

Appendix S6. Blinding study participants in hygiene promotion interventions.

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