WATER AND SANITATION PROGRAM: **WORKING PAPER**

Global Scaling Up Handwashing

Practical Guidance for Measuring Handwashing Behavior: 2013 Update

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The Water and Sanitation Program is a multi-donor partnership administered by the World Bank to support poor people in obtaining affordable, safe, and sustainable access to water and sanitation services.

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The first edition of "Practical Guidance for Measuring Handwashing Behavior" was published by the Water and Sanitation Program in 2010. There has been substantial research relevant to handwashing behavior measurement since the previous publication. Based on the substantial continued interest in measuring handwashing behavior among researchers and practitioners alike, we present here the first update to this document. We have updated the format to address the validity of each measure as compared with other handwashing measures and health outcomes, potential for bias or data collection errors, use in evaluating handwashing programs, as well as the bottom line for researchers and practitioners.

Christina Crabtree Ide, Kelly Kamm, Jelena Vujcic, and Anne Weaver contributed extensively to the review of the recent handwashing literature. Gratitude goes to Benjamin Arnold, Bertha Briceño, Claire Chase, Craig Kullmann, and Amy Pickering for thoughtful reviews of this document. The following individuals, in alphabetical order, contributed to the thinking presented in the first edition of this guidance document: Adam Biran, Anna Bowen, Val Curtis, Jacqueline Devine, Stewart Granger, Orlando Hernandez, Steve Luby, Jack Molyneaux, Eddy Perez, and Wolf-Peter Schmidt. Sincere thanks go to them for their constant interest in this topic and their intellectual generosity.

Global Scaling Up Handwashing is a project by the Water and Sanitation Program (WSP) focused on applying innovative behavior change approaches to improve handwashing with soap behavior among women of reproductive age (ages 15–49) and primary school-age children (ages 5–9). It was implemented by local and national governments with technical support from WSP in four countries: Peru, Senegal, Tanzania, and Vietnam. For more information, please visit www.wsp.org/scalinguphandwashing.

This Working Paper is one in a series of knowledge products designed to showcase project findings, assessments, and lessons learned in the Global Scaling Up Handwashing project. This paper is conceived as a work in progress to encourage the exchange of ideas about development issues. For more information, please email Pavani Ram at wsp@worldbank.org or visit www.wsp.org.

SANITATION FOR ALL

Executive Summary

In low- and middle-income settings, accurate measures of handwashing behavior are critical to understanding households' health environment. But it can be challenging to measure handwashing. This document discusses a set of handwashing indicators and recommendations prepared to support the Water and Sanitation Program's Global Scaling Up Handwashing project carried out in four countries. Descriptions of these measures, and the recommendations for their use (Table 1, page 20), should be of interest to a broad audience.

The following handwashing measures are assessed based on their validity, reliability, and efficiency:

Self-reports via questionnaire are the easiest way to measure handwashing. Several studies have shown a relationship between self-reported handwashing behavior and disease risk. But, individuals often report better handwashing behavior than they display during observation. This exaggeration of true behavior may result from a perceived high social desirability of handwashing. Questionnaires remain an important source of information about handwashing knowledge and other determinants of handwashing behavior.

Rapid observations include several easily collected valid and reliable indicators. These include observations on the availability of soap and water, the presence of these tools at dedicated handwashing stations, and inspections of hand cleanliness. While these indicators do not directly indicate handwashing behavior, they are currently used as surrogate markers because they are reliable and efficient. But evidence of how well they predict actual handwashing behavior and disease risk is still forthcoming.

Microbiological measures of hand contamination are objective measures of hand contamination, and consequently would seem desirable. However, this is currently a costly way to assess hand cleanliness. Large sample sizes may be needed to overcome the variability noted in results of hand microbiology testing. If the cost of such measurement can be decreased and reliability improved, hand microbiology may eventually be useful for measuring household environmental contamination.

Structured observations have been used frequently in the handwashing literature. These observations require trained observers to watch and record household handwashing and related behaviors, and yield details about handwashing at critical times, such as after defecation. Handwashing behavior, as recorded during structured observation, has been associated with disease risk. However, individuals are reactive to the presence of an outside observer. While the reactivity generated by structured observation warrants caution, structured observations remain a cornerstone of handwashing measurement because of the rich details yielded by them.

Sensors have been used in several studies to provide an objective record of the number and timing of soap-use events. A variety of sensors have been tested in research studies including accelerometers embedded in bars of soap, infrared sensors at entries to restrooms coupled with monitoring of liquid soap use, and radiofrequency-controlled transmitters worn by subjects with readers at handwashing locations. The use of sensor technology is promising in select settings, despite facing several challenges: These methods are relatively expensive, because of specialized hardware and personnel costs for analysis of sensor-elicited data. In addition, some of the sensor methods do not generate respondent-specific information and some do not inform about rates of handwashing with soap at critical times, such as after defecation. In spite of these caveats, sensor-based handwashing measurement yields objectivity and reliability and, thus, further evaluation is clearly warranted.

Based on these assessments, the following recommendations are made for various types of studies carried out in low- and middle-income countries, including *well-funded* projects, projects with *minimal funding,* and *mixed-purpose, large population-based surveys.*

For ***well-funded*** projects, the most rigorous methods should be used. Structured observations and rapid observations

should be used to obtain objective measures of handwashing. It is assumed that well-funded studies have the resources to involve experienced researchers with research and statistical expertise. ***Self-reported*** measures may be used to learn about knowledge and other determinants of handwashing. ***Hand contamination and sensor-based measures*** should be considered, as much is still to be learned of them. These well-funded studies should also continue to measure health outcomes to better document the relationship between handwashing promotion and health outcomes, as well as between measured handwashing behaviors and health outcomes.

Studies with ***minimal funding*** should consider carrying out ***structured observations*** in a small sample of households, primarily to assess change in behaviors targeted by the handwashing intervention. Rapid observations are the most efficient source of household-level handwashing information. ***Rapid observations*** are markers for actual behavior. Self-reports may be used to measure knowledge and other possible determinants of handwashing behavior. Minimally funded studies that need affordable yet reliable methods to monitor handwashing behavior may warrant an investment in sample size estimates by a statistician or epidemiologist. These investments can frequently pay for themselves, as sample needs are frequently much lower than expected.

For ***mixed-purpose, large population surveys,*** such as the Demographic and Health Survey (DHS) or the Multiple Indicator Cluster Survey (MICS), where handwashing is only one of many behaviors of interest, ***rapid observations*** are recommended as the most efficient method of measuring handwashing behavior.

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I. Introduction

Advocates of promoting handwashing with soap agree that this behavior has important health benefits across the globe, especially in low- and middle-income countries, including for the prevention of diarrhea and acute respiratory infections, such as influenza.[1] Efforts, both large-scale and focused, are underway worldwide to promote handwashing with soap at the community level (www.globalhandwashing.org). Although there is broad agreement about the health benefits of promoting handwashing with soap, there is not similar agreement about the best ways to measure the behavior that these promotion programs set out to change. Most intervention studies report health outcomes data but they do not provide information about effects of the program on handwashing behavior.[2] Vindigni and colleagues noted that, as of their writing, only 27 unique studies carried out in low- and middle-income countries had evaluated behavior change resulting from handwashing promotion.[3] Among these 27 studies, proxy measures and self-reported behavior were commonly used, with only rare use of structured observations to directly measure handwashing behavior. There is a pressing need to appreciate the limitations and challenges to these and other methods of measuring handwashing behavior, as well as to develop a pragmatic route forward for the evaluation of handwashing promotion programs, which are increasingly being implemented in dozens of countries worldwide.

The reality is this: there is no universally applicable method for measuring handwashing behavior that is valid, relevant, affordable, and logistically feasible for the various settings in which such behavior might need to be measured. The aim of this document is to describe techniques and to propose strategies for measuring handwashing behavior in low- and middle-income country contexts.

Measures of handwashing behavior may be scrutinized with respect to the following criteria:

- Validity: "an expression of the degree to which a measurement measures what it purports to measure"[4]

  The validity of a measure of handwashing may be evaluated based on how it compares to other measures of handwashing. An individual who demonstrates good handwashing practice, as indicated by one measure, may be expected to demonstrate good handwashing practice, as indicated by other measures. For example, self-reported handwashing may be compared to directly observed handwashing behavior, as measured by structured observation, or compared to the presence of handwashing materials at designated locations.

  Since improved health is the ultimate goal of handwashing, the validity of a handwashing measure may also be assessed by comparing to health outcomes. For example, the disease experience of those who report washing hands may be compared to the disease experience of those who do not report washing hands. Evaluating a handwashing measure against a health outcome, such as diarrhea, provides information on whether the handwashing measure is relevant to population health.

- Efficiency: "the effects or end results achieved in relation to the effort expended in terms of money, resources, and time"[5]

All measurement of handwashing is challenged by the complexities of this human behavior. An individual may wash hands with soap in the context of some critical times for pathogen acquisition or transmission, such as after

[1] Curtis 2003; Curtis and Cairncross 2003; Luby et al. 2004; Luby et al. 2005; Rabie and Curtis 2006; Aiello et al. 2008; Talaat et al. 2011.
[2] Cairncross et al. 2010.
[3] Vindigni et al. 2011.
[4] Last 2001.
[5] Ibid.

defecation, but not at others, such as before feeding a child. Thus, summarizing an individual's overall handwashing behavior requires taking into account variations in behavior at different critical times. Moreover, an individual may be inconsistent in her behavior, for example washing hands with soap after some defecation events but not all; such variation in reliability also risks the possibility of misclassifying an individual as "handwasher" or "non-handwasher." Furthermore, both reported and observed markers of handwashing behavior have been found to be significantly associated with socioeconomic status, making adjusting for this important explanatory factor extremely important.[6]

Described below are the positive and negative attributes of various commonly applied and novel methods of measuring handwashing behavior. Self-reported, proxy, and directly observed measures are described. For each type of measure, we present information as available on the validity of the measure (as compared to other handwashing measures, as well as to health outcomes, where data are available), the efficiency of the measure, the potential for bias or data collection errors, the use of the measure in the evaluation of handwashing programs, other useful information for the researcher or practitioner, and the bottom line of the utility of the measure. We conclude with recommendations for the measurement of handwashing behavior in a variety of contexts, including research and large nationally-representative surveys.

[6] Luby and Halder 2008.

II. Methods of Measuring Handwashing Behavior

Self-report

The easiest way to measure handwashing behavior is to use a questionnaire to ask the respondent directly about her behavior. The respondent may be questioned about how she washes hands (e.g., with or without soap), how recently she washed, how often she washes (e.g., on the day before interview), and when she washes. Information about handwashing at critical times may be posed in several ways:

- an open-ended fashion: e.g., when do you wash your hands with soap
- in a closed-ended fashion: e.g., do you wash your hands with soap before feeding your child, *or*
- in a scaled fashion: e.g., how frequently do you wash your hands with soap before feeding your child? always, almost always, sometimes, or never?

Validity

Comparison with other handwashing measures:

In a pair of studies by Pickering and colleagues, self-reported handwashing behavior was not associated with hand contamination levels in one study[7] but was found to be associated in the other study.[8] Report of recent handwashing (<1 hour before specimen collection) was associated with lower levels of hand contamination, and individuals reporting always washing hands with soap after defecation had lower levels of *E. coli* and fecal streptococci than individuals reporting sometimes or never washing hands with soap after defecation.

In our analysis of the endline data from the Impact Evaluation of the Global Scaling Up Handwashing project, in which we accounted for the frequency of reported soap use, we found moderate or greater agreement between self-reported handwashing after fecal contact and observation of soap anywhere in the home in both Peru and Vietnam. In Vietnam, we found that persons reporting handwashing with soap after fecal contact were more likely to be observed washing hands with soap after fecal contact (RRadj=2.93, 95% CI=1.53 – 5.64); we did not find similar relationships in Peru and Senegal (Ram, WSP paper in preparation).

Comparison with health outcomes:

Several studies have found that groups with high self-reported handwashing behavior have lower disease risk than groups with relatively lower self-reported handwashing behavior. Two observational studies have reported associations between self-reported handwashing behavior and child mortality. Rhee and colleagues showed that mothers' reports that the birth attendant washed her hands with soap and water before assisting with the delivery, and reports that she herself sometimes or always washed hands before handling the neonate, were associated with significantly reduced risk of neonatal mortality: maternal handwashing (RR 0.40, 95% CI 0.28 – 0.58) and birth attendant handwashing (RR 0.81, 95% CI 0.68 – 0.98).[9] Unfortunately, the multivariate analysis yielding these risk ratios did not adequately account for socioeconomic status covariates, which are often shown to be strongly correlated with handwashing behaviors.[10] Unicomb and colleagues have described a case-control analysis in which caregivers of children who died from diarrhea reported less frequent handwashing (18 times per day) than caregivers of well children (21 times per day) (ORadj 0.90, 95% CI 0.89 – 0.95, in a multivariate model adjusting for wealth and education).[11] In another case-control analysis, Silk and colleagues noted that caregivers of well children were more likely to report frequent handwashing (more than 12 times in the previous day) than caregivers of children with pneumonia.[12] Most recently, Luby and colleagues published a study of nearly 500 households, in which maternal self-report of handwashing with soap before feeding a child was associated with decreased diarrhea in the child.[13]

[7] Pickering, Davis et al. 2010.
[8] Pickering, Boehm et al. 2010.
[9] Rhee et al. 2008.
[10] Luby and Halder 2008; Schmidt et al. 2009; Ram, Halder et al. 2010.
[11] Unicomb et al. 2010.
[12] Silk et al. 2010.
[13] Luby et al., *Using Child Health Outcomes,* 2011.

Efficiency

Collecting handwashing behavior information by self-report is efficient, since the data can be gathered quickly using questionnaires, among a large number of households, at relatively low cost. Because of this efficiency, self-report is frequently included in assessments of handwashing behavior. However, as outlined below, substantial concerns about bias suggest that sole reliance on self-report typically yield overly optimistic estimates of handwashing behavior.

Potential for bias or data collection errors

Awareness of the social desirability of handwashing may result in an individual's overestimation of self-reported handwashing behavior. This overestimation has been demonstrated repeatedly, when self-reported behavior has been compared to observed behavior.[14] In Bangladesh, whereas 77 percent of respondents *reported* washing hands with soap or ash after defecation, only 32 percent were *observed* to do so.[15] Stanton and colleagues, and Biran and colleagues have each shown that there is poor agreement between reported behavior and observed behavior; however, these studies did not account for the high frequency of reported soap use, which can lead to an artificially low estimations of agreement.[16] In our own recent analysis of endline data from the Impact Evaluation of the Global Scaling Up Handwashing project, we found that handwashing with soap after defecation was reported by 65 percent of caregivers in Peru, 45 percent of caregivers in Senegal, and 45 percent of caregivers in Vietnam (Ram, WSP paper in preparation). In contrast, soap was used for handwashing at only 34 percent, 25 percent, and 24 percent of fecal contact events in Peru, Senegal, and Vietnam, respectively.

Use in evaluation of handwashing programs

Self-reported handwashing behavior is commonly recorded in handwashing promotion program evaluations. For example, Biran and colleagues showed minimal change, and relatively rare reporting of soap use, before and after a handwashing promotion and soap provision intervention in India.[17] Huda and colleagues describe that a pilot intervention was tested using self-reported handwashing as the principal behavioral outcome.[18] Since self-reported handwashing was shown to increase in response to the intervention, an at-scale water, sanitation, and handwashing intervention was subsequently implemented in Bangladesh. However, a robust evaluation of the at-scale intervention using observational methods, and not self-report, demonstrated no behavior change attributable to the intervention. In Thailand, a handwashing and face mask intervention to prevent household transmission of influenza found that respondents in the intervention arm reported handwashing more frequently than in the control arm.[19]

Other useful information

The large discrepancies in reported compared to observed behavior indicate that self-report is a limited measure of an individual's true handwashing behavior. Questionnaires may also be used to elicit information relevant to behavioral determinants that may facilitate or impede handwashing; such determinants may include attitudes and beliefs, and logistical factors such as access to adequate quantities of water. One set of determinants that is commonly measured is knowledge related to handwashing behavior. Knowledge is the understanding of how, when, and why to wash hands. In contrast, behavior is the execution, i.e., the washing of hands with soap after one defecates. Questions regarding whether and when hands *should* be washed with soap may provide information about the respondent's knowledge of appropriate handwashing behavior. However, knowledge does not equate to behavior, in that an individual may *know* well when to wash hands but the individual does not often practice handwashing at those times because of various barriers. Describing changes in knowledge of appropriate handwashing behavior, e.g., naming of critical times, may be useful as part of monitoring a handwashing promotion campaign that proposes to increase knowledge of handwashing in the target population.

[14] Stanton et al. 1987; Manun'Ebo et al. 1997; Biran et al. 2008; Danquah 2010.
[15] "Handwashing Behavior in Rural Bangladesh." 2008. *Health and Science Bulletin* Vol. 6, No. 3.
[16] Byrt et al. 1993; Sim and Wright 2005.
[17] Biran et al. 2009.
[18] Huda et al. 2012.
[19] Simmerman et al. 2011.

Other possible determinants of handwashing behavior that can be measured by questionnaires relate to the opportunity to access handwashing tools (e.g., as in the FOAM framework—Focus on Opportunity, Ability, and Motivation—access to soap and water near a latrine), ability (e.g., capacity to ensure access to steady supply of soap), and motivation (e.g., beliefs about the importance of soap).[20] Appropriate measurement of these and other possible determinants can be maximized by reliance on a clearly considered framework for handwashing behavior change.[21] Since this document focuses on measurement of handwashing behavior, a review of frameworks to promote handwashing behavior change is beyond its scope.

The bottom line

Although there is some data to suggest that self-reported handwashing, in general or at specific critical times, is associated with improved health, there is overwhelming evidence indicating that individuals overestimate their own handwashing behavior. Therefore, we do not recommend the use of self-reported handwashing behavior. Questionnaires may be used, instead, to capture knowledge of critical times to wash hands, and to capture psychosocial constructs, such as self-efficacy and social norms, which may influence handwashing behavior.

Proxy Measures: Measurement of Microbiological Hand Contamination

Measurement of microbiological contamination of hands is another proxy measure of handwashing behavior. The underlying assumption is that hands that are washed with soap will be less contaminated with fecal organisms than hands that are not washed with soap. The details of measuring hand contamination, e.g., by fingertip rinses or hand imprints on semi-solid media, among others, are beyond the scope of this paper but are covered in numerous peer-reviewed publications.[22] Broadly, hand contamination data is reported as the number of colony-forming units (a microbiological term used to denote the density of organisms) of the organism of interest per hand, or per volume of media in which hands were rinsed; organisms typically sought are fecal coliforms, *E. coli* (a subset of fecal coliforms), and fecal streptococci. Numerous studies have tested contamination of hands to compare the microbiological efficacy of different hand cleansing regimens.[23] A number of studies have found that hand contamination is reduced after handwashing with soap, or after cleansing with waterless sanitizers.[24]

Validity

Comparison with other handwashing measures:

In our work in Bangladesh, we have found that hand contamination was neither associated with soap use observed during structured observation, nor correlated with the number of times soap was used per day, as measured by accelerometers embedded in soap.[25] Presence of soap in the household was not associated with levels of hand contamination in two studies carried out in Tanzania.[26] However, visible dirt on the palm, finger pads, or under nails was significantly and inversely associated with fecal streptococci and *E. coli*.[27]

Comparison with health outcomes:

Evidence from Pakistan[28] and Tanzania[29] supports a positive association between hand contamination and health outcomes, meaning that children of mothers whose hands are more contaminated have been found to have higher rates of diarrhea than children of mothers whose hands are less contaminated. Pickering and colleagues found in Tanzania that mean levels of fecal streptococci were positively associated with the prevalence of respiratory symptoms,[30] but found an inverse relationship between the levels of *E. coli* on hands and respiratory symptoms, a surprising finding that merits further exploration.[31]

[20] Coombes and Devine 2010.
[21] Hernandez et al. 2012.
[22] Pinfold 1990; Hoque et al. 1995; Luby, Agboatwalla et al. 2001; Luby, Agboatwalla et al. 2007; Judah et al. 2009; Pickering, Boehm et al. 2010; Pickering, Davis et al. 2010; Burton et al. 2011.
[23] CDC 2002; Grayson et al. 2009; Luby, Kadir et al. 2010; Pickering, Boehm et al. 2010; Burton et al. 2011; Pickering, Davis et al. 2011.
[24] Pinfold 1990; Hoque et al. 1995; Luby, Agboatwalla et al. 2001; CDC 2002; Pickering, Boehm et al. 2010.
[25] Ram, Luby et al. 2010.
[26] Pickering, Boehm et al. 2010; Pickering, Davis et al. 2010.
[27] Pickering, Davis et al. 2010.
[28] Luby, Agboatwalla et al. 2007.
[29] Pickering, Davis et al. 2010.
[30] Pickering, Boehm et al. 2010; Pickering, Davis et al. 2010.
[31] Pickering, Davis et al. 2010.

Efficiency

Currently, measuring hand contamination is relatively expensive; in Bangladesh, laboratory-based microbiological testing for fecal coliforms and *E. coli* costs approximately US$10 per individual, well beyond the means of most program monitoring and evaluation budgets. In other sites, the cost of hand rinse sampling is US$2–3, which may be more approachable for modest budgets. A field-friendly method of measuring fecal coliforms and *E. coli* on hands is being sought and may prove to be an inexpensive and feasible method of testing for hand contamination.[32]

Potential for bias or data collection errors

Hand contamination provides greater objectivity than self-report. But, there are limitations to the data resulting from microbiological testing of hands. First, handwashing does not necessarily eliminate all organisms from hands.[33] Also, the level of hand contamination on an individual's hands can vary greatly within the course of several hours; in Bangladesh, we found about three orders of magnitude differences between counts of fecal coliforms estimated at random and at critical times. In addition, there was rapid recontamination of hands in this environment, with fecal coliforms on hands of 100 percent, and *E. coli* on 80 percent of 25 participating women two hours after a thorough handwashing with soap.[34] Thus, in a heavily fecally contaminated environment, a single hand contamination measure likely only reflects very recent handwashing behavior and not typical behavior of the individual. Time elapsed since hands were last washed with soap has been associated with the level of hand contamination.[35] Other factors affect hand contamination, and thus, the detection of organisms on hands, including the presence of a wristwatch, jewelry, length of fingernails, and recent application of hand lotion.[36] Duration since last fecal contact, and overall fecal contamination of the environment likely also impact the level of contamination detected on a subject's hands. Also, in some cultures, an individual's two hands may have different levels of contamination, since left hands may have more fecal contact than right hands.[37]

Use in evaluation of handwashing programs

A few studies have used hand contamination to evaluate handwashing programs. In Thailand, Pinfold found that respondents in an intervention group had significantly lower finger contamination after the intervention, compared to the control group.[38] In contrast, Luby and colleagues found no difference in hand contamination among mothers in an intervention group exposed to handwashing promotion and soap provision, and mothers in a comparison group that received no promotion or soap provision.[39]

Other useful information

Contamination of mothers' and children's hands with fecal indicator bacteria was correlated with contamination of household stored water.[40] Hand contamination levels were associated with several household activities, including leaving the household compound, bathing, preparing food, and eating, as measured by structured observation in a study of 22 respondents.[41]

In a high-income country, evaluating the sheer presence or absence of organisms on hands, rather than the numbers of organisms, may be useful to predict prior handwashing behavior. In household environments lacking access to improved sanitation, far greater fecal contamination may be expected. Thus, the presence or absence approach for evaluating microbial hand contamination is unlikely to demonstrate sufficient heterogeneity in order to discriminate between "better" and "worse" handwashers; i.e., we anticipate that the vast majority of persons residing in households in low-income contexts would be found to have detectable organisms of fecal contact, irrespective of handwashing or other hygiene behaviors.

Organism-based testing (e.g., for *E. coli* or Rotavirus) may be feasible in study settings as molecular methods become less expensive.[42]

[32] Wang et al. 2011.
[33] Pickering, Boehm et al. 2010.
[34] Ram, Jahid et al. 2011.
[35] Pickering, Julian et al. 2011.
[36] Fagernes and Lingaas 2011.
[37] Hoque et al. 1995.
[38] Pinfold and Horan 1996.
[39] Luby, Agboatwalla et al. 2007.
[40] Pickering, Davis et al. 2010.
[41] Pickering, Julian et al. 2011.
[42] Ibid.

The bottom line

Given the relative expense of quantification of microbial hand contamination currently and challenges to its validity as a measurement of overall handwashing behavior, it is not recommended that hand contamination tests be built into routine evaluations of handwashing promotion programs at this time. Further study to refine microbiology as a measure of overall handwashing behavior may enhance the utility of this approach in the future.

Proxy Measures: Rapid Observation of Handwashing Materials

Observations of the household can be efficient means to gather clues about the household's handwashing behavior since they can be rapidly collected, in a large number of households, and at relatively low cost. Here, handwashing materials refer to soap and water. Rapid observations provide useful information on whether or not soap is present in the home, whether and where the household has a designated place for handwashing, whether the tools required (i.e., soap and water, or mud/ash and water) are simultaneously in place to practice the behavior for the individual that chooses to do so, and whether soap is readily available for handwashing (e.g., within one minute).

Validity

Comparison with other handwashing measures:

Analyses by Halder, Luby, and colleagues have demonstrated that observation of water at the handwashing place used after defecation was associated with observed hand cleanliness,[43] and with observed handwashing with soap during structured observation.[44] Soap availability at the handwashing place used after defecation was also associated with observed hand cleanliness.[45] Similarly, in endline surveys from the Impact Evaluation of the Global Scaling Up Handwashing project, we found that presence of soap and water, at the places used to wash hands after defecation or before food preparation, was associated with observed handwashing with soap in Peru and Vietnam; in Senegal, we found similar associations in crude analyses but, after adjusting for wealth, the associations were not significant (Ram, WSP paper in preparation).

In multiple countries, there is moderate or greater agreement amongst the following variables: presence of soap anywhere in the home, presence of soap and water at the handwashing place used after defecation, and presence of soap and water at the handwashing place used before food preparation, suggesting internal consistency between these various observed measures (Ram, WSP paper in preparation).

For the indicator of availability of handwashing materials within one minute of request, the time frame of one minute is arbitrary and does not reflect the diversity of living set-ups found around the world; i.e., soap may be at the cooking place, which is located at some distance from both the latrine and the main living area of the household. We have found conflicting associations between rapid retrieval of soap and observed handwashing behavior: in Peru, there was no association; in Senegal, caregivers of young children were more likely to wash hands if they lived in households where soap was retrieved within one minute, compared to caregivers in households where soap was retrieved more slowly. In contrast, and inexplicably, in Vietnam, caregivers in households where soap was retrieved within one minute were significantly less likely to be observed washing hands than caregivers in households where soap was retrieved slowly. These conflicting findings indicate that rapid retrieval of soap is not currently a reasonable marker of handwashing behavior.

Comparison with health outcomes:

There is some evidence for the health benefit associated with the presence of handwashing materials at designated handwashing locations. Luby and colleagues have demonstrated in studies from Bangladesh that the presence of water at a handwashing place was associated with a small but statistically significant decrease in respiratory illness episodes.[46]

[43] Halder et al. 2010.
[44] Luby, Halder et al. 2009.
[45] Halder et al. 2010.
[46] Luby and Halder 2008; Luby et al., *Using Child Health Outcomes,* 2011.

Efficiency

Rapid observations are being widely used to capture handwashing behavior, including in the Multi-indicator Cluster Surveys (MICS) supported by UNICEF. The MICS 4 questionnaires include the following indicators: designated place for handwashing where soap and water are present, and availability of soap anywhere in the dwelling. The Rapid CATCH indicators used by the US Agency for International Development (USAID) child survival grantees include the measurement of the presence of soap at the location where hands are usually washed (http://www.childsurvival.com/kpc2000/kpc2008.cfm).

Potential for bias or data collection errors

In Bangladesh, Gadgil and colleagues made serial visits—in all 1,716 visits—to 220 households to assess the presence (and weight) of soap and other household toiletries.[47] Although a majority of households were found to have soap at any one visit, only about 50 percent of households had soap available at every visit.

The presence of soap and water at a designated handwashing place cannot confirm the frequency or consistency of handwashing with soap for the individual or the household as a whole, whether hands are washed during critical times such as after defecation. While the presence of soap is necessary for the behavior (handwashing with soap) to be carried out, it is not sufficient, in that a host of logistical and psychosocial determinants likely induce or prevent the handwashing behavior from being carried out.[48] Additionally, rapid observations of the household do not provide information on the handwashing behavior of an individual of interest, such as the mother of a young child. Instead, they may only provide information about the household as a whole, since, in most households, soap is a communal resource and not an individual one. Still, since handwashing behavior tends to be socially mediated, household-level measurement may be very useful for describing handwashing behavior of a population.

Use in evaluation of handwashing programs

Several intervention studies have demonstrated immediate increases in the maintenance of handwashing facilities,[49] including studies in Bangladeshi households,[50] Kenyan schools,[51] and community health clubs.[52]

Other useful information

Hand cleansing agents include soap, ash, or mud, depending on the cultural context and the focus of the handwashing promotion program (e.g., soap specifically or any cleansing agent). Choice of specific indicators should be made based on the behavioral recommendations included in the handwashing promotion.

The bottom line

Given the associations between presence of soap and water at designated handwashing locations and observed handwashing behavior in multiple countries, and the inverse association between presence of water and respiratory illness in two studies in Bangladesh, as well as the efficiency of collecting these data, rapid observation of handwashing materials—anywhere in the home and especially at designated handwashing locations—is an important approach to measuring handwashing behavior.

Proxy Measures: Hand Cleansing Product Consumption

Product consumption has been used as an approach to measure hand hygiene in healthcare settings in high-income countries for many years.[53] Studies have measured the volume of soap or hand sanitizer in a fixed container at two time points in order to estimate the volume of cleansing agent consumed in the duration between measurements.

Although common in healthcare settings in high-income settings, there is little information about estimation of soap consumption as a measure of handwashing behavior in low- and middle-income countries. One approach to

[47] Gadgil et al. 2010.
[48] Danquah 2010.
[49] Vindigni et al. 2011.
[50] Luby, Agboatwalla et al. 2009.
[51] Freeman et al. 2011.
[52] Whaley and Webster 2011.
[53] McGuckin et al. 2009.

measuring soap consumption is to estimate the amount of money spent by households on soap. Alternatively, Gadgil and colleagues investigated the utility of serial soap weight measurement as a method to estimate household soap consumption, which was defined as the difference between soap weights in two serial visits. Soap weight differences were stable across the approximately eight visits made to each household, suggesting that one estimate of soap weight difference, i.e., calculated from weights measured at two serial visits two to three days apart, is sufficient to estimate soap consumption. Wealth was associated with the presence of soap in the home but was not associated with soap weight differences.

Validity

Comparison with other handwashing measures:

In the study by Gadgil and colleagues, consumption of bar soap was correlated with consumption of laundry detergent, the total number of handwashing stations in the home, and the number of handwashing events by the main caregiver as observed during structured observation.[54] To our knowledge, this is the only study to date reporting findings on the use of serial soap weights for estimation of soap consumption at the household level in a low- or middle-income country.

Comparison with health outcomes:

At the time of this writing, we are not aware of studies that have assessed the relationship between soap consumption and health outcomes in low- or middle-income country contexts.

Efficiency

The minimum of two visits required to estimate change in soap weight or volume reduces the efficiency of data collection and, thus, this approach may not be feasible for many large-scale studies, such as DHS or MICS.

Amount spent recently on soap purchase can be easily queried in a questionnaire.

Potential for bias or data collection errors

Human error in the collection of consumption data, e.g., due to poor training on use of scales to weigh soap or lack of standardization in volume measurement, represents an important source of bias in these data.

Use in evaluation of handwashing programs

Luby and colleagues found no difference between handwashing intervention and control households with respect to soap purchase, despite seeing differences between comparison groups with respect to presence of soap and water at a handwashing place, and rubbing of hands several times during a handwashing demonstration.[55]

Other useful information

In Gadgil's study of soap consumption in Bangladesh, the median bar soap weight consumption was estimated at 1.2 grams/day per household resident; laundry soap consumption was estimated at 2.3 grams/day per household resident.[56] Given the lack of data on soap consumption from households in low-income settings, Gadgil's data may serve as a useful reference.

The bottom line

There is insufficient evidence for or against the use of soap expenditure to make a recommendation on this measure at this time. A number of studies measuring soap consumption, through volume or weight checks, are currently in the analysis phase. Whether soap consumption should be used more broadly to measure handwashing behavior will be borne out by these additional analyses. Measuring consumption by evaluating soap weight or volume requires two visits to the home or facility, thereby increasing the costs and logistical challenges of the data collection.

Proxy Measures: Observation of Behavior During Handwashing Demonstration

One approach to using rapid observations to obtain clues to individual behavior is to ask the individual of interest to demonstrate usual handwashing practice, in general, or

[54] Gadgil et al. 2010.
[55] Luby, Agboatwalla et al. 2009.
[56] Gadgil et al. 2010.

as typical after defecation. Details to note include washing of one or both hands, use of soap or other hand cleansing agent, duration of lathering or hand rubbing, and method of drying (or not drying).

Validity

Comparison with other handwashing measures:

In the 2008 study by Biran and colleagues, there was a fair degree of agreement between observation of soap use during handwashing demonstration and observation of both hands being washed with soap after all fecal contact events witnessed during structured observation.[57]

As with a number of measures of handwashing behavior, awareness of social desirability may prompt improved handwashing practice during the demonstration compared to usual behavior. Halder and colleagues found that, while 51 percent of caregivers used soap when asked to demonstrate how they typically wash their hands after defecation, only 33 percent of caregivers were observed to wash hands during structured observation.[58]

Comparison with health outcomes:

Use of soap during demonstration of usual handwashing after defecation was significantly associated with less diarrhea than non-use of soap in one study.[59] Air drying of hands during the handwashing demonstration was also independently associated with reduced respiratory illness in this same study.

Efficiency

Observation of behavior during handwashing demonstrations is typically quite efficient since it can be incorporated into an interview with the target respondent. A few minutes may be required for the respondent to gather any necessary materials to perform the handwashing.

Potential for bias or data collection errors

In a randomized controlled trial investigating responsiveness to simple versus more complex handwashing instructions, Sagerman and colleagues found that the duration of hand rubbing increased from baseline to post-intervention even among study participants that were not instructed to increase the duration of hand rubbing, suggesting reactivity to the observation.[60] A similar finding was noted among schoolchildren in a study of waterless hand cleansing in Nairobi, Kenya.[61]

Use in evaluation of handwashing programs

In a study evaluating residual effects of a handwashing promotion intervention 18 months after intervention, Luby and colleagues showed that subjects in intervention households were more likely to rub palms several times during a handwashing demonstration, compared to subjects in control households.[62] Freeman and colleagues reported that Kenyan students, exposed to a water treatment and hygiene promotion intervention, completed the several steps of handwashing during a handwashing demonstration, compared to students in control schools.[63]

The bottom line

To date, relatively few studies have examined the validity of handwashing demonstrations for the measurement of usual handwashing behavior. There is some evidence that these data are compromised by social desirability bias but further exploration is required to understand the utility of this measurement approach.

Proxy Measures: Visual Inspection of Hand Cleanliness

A number of studies have used visual inspection of respondent hands to characterize their degree of cleanliness. Typically, a three-point scale has been used, denoting "clean," "no visible dirt but unclean appearance," and "visible dirt."

In some settings, subjects have expressed concern about whether hand inspections are appropriate and acceptable. The evaluator should decide whether hand inspections are appropriate in the setting of the study or evaluation. The

[57] Biran et al. 2008.
[58] Halder et al. 2010.
[59] Luby et al., *The Effect of Handwashing*, 2011.
[60] Sagerman et al. 2011.
[61] Pickering, Davis et al. 2011.
[62] Luby, Agboatwalla et al. 2009.
[63] Freeman et al. 2011.

use of photos, pictorials, or direct observation of hands representing each level of cleanliness may be helpful to improve on standardization of data collection. The trainer should seek to ensure high inter-rater reliability; i.e., different enumerators code the same level of cleanliness for a pair of hands.

Validity

Comparison with other handwashing measures:
Pickering and colleagues have found that visible dirt on palms, fingerpads, or under nails is associated with increased microbiological contamination of hands.[64]

A high hand cleanliness score was significantly associated with observed handwashing with soap after fecal contact in both Peru and Vietnam, after adjustment for wealth, indicating that hand cleanliness inspection is a reasonable proxy measure for handwashing behavior in some contexts; we did not find such an association in Senegal (Ram, WSP paper in preparation).

Comparison with health outcomes:
Luby and colleagues have found that observation of visibly clean finger pads on a child's hands was associated with reduced diarrhea prevalence; there was no association between mother's hand cleanliness and child's diarrhea risk.[65]

Efficiency

Visual inspections of hand cleanliness are efficiently performed, easily included in interviews with the target respondent. Standardization of fieldworkers' coding of cleanliness is critical, and should be done using photographs of local individuals' hands. Data for the measure may be collected surreptitiously, or by actively informing the respondent of the examination. If the latter approach is chosen, it is possible that the participant will refuse the inspection.

Potential for bias or data collection errors

In the Impact Evaluation of the Global Scaling Up Handwashing project, at baseline, clean hands were identified in 42 percent of 3,718 caregivers in Peru, 71 percent of 1,992 Senegal caregivers, and 63 percent of 3,068 Vietnam caregivers (Ram, baseline report). In all three countries, households of caregivers with clean hands were more likely to have had soap and water present at a place designated for handwashing before food preparation and eating. Also, in Senegal and Vietnam, households of caregivers with clean hands were significantly more likely to have had soap and water observed at the place for handwashing after defecation. Caregivers with clean hands were progressively and significantly more likely to be in the wealthiest four quintiles than in the poorest quintile in all three countries.

Halder and colleagues found that household wealth and water availability at handwashing locations were significantly associated with the cleanliness of mother's and child's hands.[66] The strong associations between wealth and hand cleanliness, seen in Halder's work and ours in the Global Scaling Up Impact Evaluation, may be attributable to unmeasured determinants of handwashing behavior or to interviewer bias, should be considered in analysis of these data generated from observational studies.

Other useful information

In some settings, subjects have expressed concern about whether hand inspections are appropriate and acceptable. The evaluator should decide whether hand inspections are appropriate in the setting of the study or evaluation. The use of photos, pictorials, or direct observation of hands representing each level of cleanliness may be helpful to improve on standardization of data collection. The trainer should seek to ensure high inter-rater reliability; i.e., different enumerators code the same level of cleanliness for a pair of hands.

The bottom line

Visual inspections of hand cleanliness are efficiently performed. This measure is relatively novel and needs to further exploration in order to determine whether it is valid globally.

Direct Measures: Structured Observations

Structured observations consist of the placement of an observer for several hours, typically between three and seven hours, in a household.[67] The observer records opportunities

[64] Pickering, Davis et al. 2010.
[65] Luby et al., *Using Child Health Outcomes,* 2011.
[66] Halder et al. 2010.
[67] Bentley et al. 1994; Curtis et al. 2001; Biran et al. 2008.

for handwashing, such as feeding a child or visiting the toilet, and the target respondent's handwashing practices. A sample tool used in the healthcare setting is provided by McAteer and colleagues;[68] sample tools used in school and community settings are available from the author of this paper. The benefits of structured observation are the ability to record objective data on handwashing practices and the richness of information gathered.[69] During structured observation, the observer has the opportunity to record information about numerous individuals of interest, including mothers, young children, non-caregiver males, etc. Additionally, the observer can record detailed information on particular critical times, whether hands are washed, whether both hands are washed, the type of cleansing agent used, and the way in which hands are dried. This richness of details allows for assessment of consistency in handwashing practices. Respondents may be assigned to categories representing degrees of appropriate handwashing practice, based on observation of behavior during multiple opportunities for handwashing.[70]

Validity

Comparison with other handwashing measures:

Structured observation data has frequently been used as the standard of comparison for other handwashing measures in a number of studies, as noted in other parts of this document.[71]

Comparison with health outcomes:

A recent robust analysis of structured observation data supports the utility of structured observation for detection of handwashing measures that are meaningful for disease risk. Luby and colleagues examined diarrhea prevalence among children of caregivers in 347 households observed during five-hour structured observations.[72] This study indicated that observation of handwashing with soap after defecation was significantly associated with lower likelihood of diarrhea. "Compared with children living in households where persons prepared food without washing their hands, children living in households where the food preparer washed at least one hand with water only (odds ratio [OR] = 0.78; 95% confidence interval [CI] = 0.57 − 1.05), washed both hands with water only (OR = 0.67; 95% CI = 0.51 − 0.89), or washed at least one hand with soap (OR = 0.30; 95% CI = 0.19 − 0.47) had less diarrhea."[73] To our knowledge, this is the first evidence from household settings that handwashing at two specific critical times is associated with disease risk. There was no association between observed handwashing behavior at other critical times (before feeding a child, before eating, after cleaning the anus of a child who had defecated) and diarrhea risk. This study highlights the importance of capturing detailed information around handwashing behavior and underscores the utility of structured observation for such crucial data collection.

Efficiency

Several groups have successfully completed structured observations on the scale of hundreds of households without substantial difficulty. They provide a wealth of detail regarding handwashing behavior at critical times of interest, including defecation, feeding, eating, and cooking. Because of the rich contextual detail, structured observation data can be used to explore thoroughly the determinants of handwashing behavior. Aunger and colleagues used structured observation data to elucidate psychosocial determinants of handwashing behavior, and found the following to be observed with improved handwashing behavior: habitual handwashing at critical times, lack of concern about the costliness of soap, and an expressed need for cleanliness of oneself or one's household.[74]

The use of structured observation for measurement of handwashing behavior can incur substantial costs in terms of personnel time. Highly trained staff experienced in behavioral observation methods are preferable for performing observations, or at least training observers.[75]

[68] McAteer et al. 2008.
[69] Bentley et al. 1994.
[70] Biran et al. 2008.
[71] Curtis et al. 2001; Biran et al. 2008; Biran et al. 2009; Luby, Halder et al. 2009; Halder et al. 2010.
[72] Luby et al., *The Effect of Handwashing,* 2011.
[73] Ibid.
[74] Aunger et al. 2010.
[75] Bentley et al. 1994.

In a 2007 study in Bangladesh commissioned by the Water and Sanitation Program, where five-hour structured observations were compared to 90-minute structured observations, shorter observation periods resulted in a greater-than-proportional loss in observed numbers of fecal contact events, suggesting that it is counter-productive to shorten the observation periods in an attempt to reduce data collection costs. Extended durations of observation come at a cost since each observer can only conduct one observation per household per day. It would be practically difficult to carry out two five-hour, or even four-hour, observations in a single day without risking substantial interviewer fatigue and compromise in the quality of observed data. Moreover, handwashing, bathing, and toileting behavior may differ according to the time of day, possibly rendering morning observations incomparable to afternoon observations. Thus, depending on the required sample size to demonstrate project outcomes of interest, structured observations would require substantial numbers of trained individuals, or a prolonged data collection period, either of which might be expensive for the program being monitored.

Potential for bias or data collection errors

The same awareness of social desirability that likely results in overestimation of self-reported handwashing behavior may also result in reactivity to the presence of the observer during a structured observation.[76] That is, an individual may practice better handwashing behaviors while an observer is present than when she is unobserved. Using acceleration sensors in soap bars, we have shown that households increased the number of times soap was used by 35 percent during structured observation, compared to days when no human observer was present.[77] Nearly one-quarter of households, characterized by markers of improved socioeconomic status, increased soap use by more than double during structured observation. Reactive households were also much more likely to have soap available at a designated handwashing location near the toilet, suggesting that they may, indeed, prioritize hand hygiene more than non-reactive households.

Despite the potential for reactivity, structured observations typically demonstrate *very* poor handwashing behavior among study populations. Curtis and colleagues have shown that the percent of toilet use events followed by handwashing with soap ranged from 3 percent to 42 percent, with a mean of 17 percent for the 11 low- and middle-income countries under study.[78] Handwashing with soap was performed on an average of 5 percent of occasions of feeding an index child. Similarly, in the three Global Scaling Up Handwashing project countries, we find that fewer than 10 percent of food preparation events and child feeding events are preceded by handwashing with soap. Despite the unarguable presence of reactivity to structured observation, structured observations tend to confirm the tremendous need to improve handwashing behaviors in low- and middle-income countries.

Use in evaluation of handwashing programs

Structured observations have been used for the evaluation of handwashing promotion programs. The risk with reactivity to structured observation is that the evaluator would overestimate the change in handwashing behavior in response to an intervention. Biran and colleagues evaluated a hygiene education campaign in rural India and found no improvement in observed handwashing after defecation, cleaning a child who had defecated, or other fecal contact, despite about one-third of respondents having heard of the intervention.[79] Huda and colleagues found similarly that a large-scale program to promote water, sanitation, and hygiene behaviors did not result in improved handwashing behaviors, as evidenced by structured observations.[80]

Other useful information

It is essential that the researcher/evaluator intensively train observers to record in a standardized fashion. Such training should, for example, emphasize details such as the time frame within which handwashing would be considered associated with a particular critical time (e.g., the number of minutes after defecation that handwashing occurs) as well as observational techniques, such as the need to utilize neutral body language and avoid judgment or prompting of socially

[76] Cousens et al. 1996.
[77] Ram, Halder et al. 2010.
[78] Curtis et al. 2009.
[79] Biran et al. 2009.
[80] Huda et al. 2011.

desirable behaviors). Ideally, the time frame for observation would be based on local knowledge of the timing of behaviors of interest. If handwashing after defecation is the behavior of interest, then timing the observation to ensure that the observer is present in the home when most people defecate (early in the morning in many cultures) would be very important. This is not always feasible due to safety or logistical concerns, thus necessitating structured observation at other times of day. Over the span of several hours, an observer can only complete observation in one household.

A key factor in minimizing reactivity to structured observation is the information given to the target respondent in advance of the observation. During the informed consent process, and in other verbal and non-verbal communications by the study worker and observer, it is critical not to emphasize that the observation is principally about measuring handwashing behavior. Without violating the respondent's right to understand the nature of the study, the evaluator may indicate that the observation is aimed at understanding "general household practices." The observer's training and skills with respect to objective data collection may also impact reactivity on the part of the individuals being observed.

The bottom line

Information obtained from structured observation can guide handwashing promotion recommendations but also inform an evaluator about whether a handwashing program is affecting behaviors of interest, and that are relevant to child health goals. Structured observations have been used to evaluate the behavioral impact of hand hygiene promotion programs and indicate that, while there may be reactivity to structured observation, that reactivity may not be enhanced solely by exposure to handwashing promotion.

Direct Measures: Video Observation

Video observation has been used in several studies published or carried out since 2008, in quantitative studies in schools and health facilities and qualitative studies in households. A large amount of data can be captured by video for two reasons: capturing of events is not restricted as structured observation might be, since in the latter, there are time limitations of having a human observer present (e.g., five hours or seven hours before an observer fatigues). While, theoretically, a human observer may miss events if many are occurring simultaneously, video can be viewed repeatedly in order to capture the details of most or all events recorded. Still, videos for quantitative evaluation have typically been recorded by placing cameras in fixed locations; as key targets of observation (e.g., primary caregivers) move about from place to place during their daily activity, video cameras in fixed locations would likely miss a number of events that could be captured by the human observer who would be able to move about to gain appropriate views of the target's handwashing behavior.

Validity

Comparison with other handwashing measures:

To our knowledge, there are no published comparisons of video-based handwashing measurement to other approaches to measuring the behavior in low- and middle-income country settings. In a school-based study in Kenya, Pickering and colleagues have found the rate of hand cleansing with waterless sanitizer to be roughly similar among schoolchildren provided access to alcohol-based hand sanitizer (hands cleansed with sanitizer during 82 percent of events detected by structured observation, 79 percent of events detected by video camera).[81] On preliminary data analysis, video surveillance captured approximately 30 percent fewer events than structured observation, perhaps since the camera was focused on a fixed location (sanitizer dispenser), rather than being responsive to movement of individuals.

Comparison with health outcomes:

To our knowledge, there is no data from community settings in low- and middle-income countries on the relationship between video-recorded handwashing behavior and health outcomes.

Efficiency

Video may best be used to document handwashing behavior in particularly densely populated areas, e.g., outside shared latrines in a community, in school or healthcare settings, since a large number of events could be captured in such contexts. Researchers should be aware of the intensity

[81] Pickering, Davis et al. 2011.

of person-time required to analyze video observation data. As in the Armellino study, we found that a large number of events are captured in video in schools because of the large number of persons under observation (Pickering, unpublished observations). Thus, even by reviewing video at 8× or 16× speed, many person-months were spent analyzing data from just a few weeks of observation.

Potential for bias or data collection errors

We suspect, based on our work using video cameras in schools in Kenya, that there is reactivity to the presence of video cameras—e.g., children looking at the cameras and showing amusing behavior (Pickering, unpublished observations).

Use in evaluation of handwashing programs

Armellino and colleagues placed video cameras positioned to capture hand cleansing behavior at every sink and sanitizer dispenser in 11 patient rooms in an intensive care unit in New York State, USA.[82] In a 16-week period before any intervention, 60,542 events were captured and rates of hand cleansing were reported to be less than 10 percent. After feedback of video-recorded data was provided to the health workers, 73,080 events were observed and hand cleansing was estimated at 82 percent based on video observation. This study indicates that video observation of hand cleansing behavior during patient contact was responsive to an intervention that provided feedback about individuals' hand hygiene behavior.

Other useful information

Video cameras may be particularly useful to establish uptake of handwashing hardware and purposively mounted in fixed locations through an intervention program. In households, schools, or health facilities that have not received such hardware, or that have not received guidance on placement of such hardware, video recording may be less meaningful; the location of the hardware relative to the latrine or food preparation area may be distant, or inconvenient, making the link between the critical time and the associated handwashing behavior difficult to establish.

The ethical considerations are considerable with the use of video recording. Under traditional human subjects' research guidelines, a single human observer is bound to the privacy of individuals that she is observing. Video recordings that can be preserved indefinitely in digital media can pose privacy and confidentiality concerns to those under observation. A subject's identity can be disclosed by the video. Individuals may display private, or even illegal, behavior whether they are aware of the video cameras in place or not. Researchers are reminded to solicit scientific and ethical reviews from accredited agencies carrying out human subjects research oversight before attempting to use observation methods. It is ethically appropriate, and relevant to the program's best interests, to maintain the confidentiality of video data, as with all other identifiable data. Procedures regarding the handling of video displaying potentially private or illegal behavior should be defined *a priori.*

The bottom line

Video recording remains a relatively novel approach to measuring handwashing behavior. It may be most useful for evaluating behavior in semi-private or public settings, such as in schools and healthcare facilities, where there is minimal expectation of privacy. The evaluator seeking to use video observation needs to plan not only for capturing the video data, but also the extensive time required to analyze such data.

Direct Measures: Sensors

This section describes sensor-based methods of recording handwashing behavior. One such method is a Unilever-developed technology embedding accelerometers in ordinary-appearing Lifebuoy® soap. The accelerometer tracks movement of the soap in three dimensions.[83] Based on the movement patterns of the soap, the number of times soap is used in a given time period can be counted. The soap can be left in a household for several days, allowing for observation of soap use behavior over a much longer period of time than would be feasible by structured observation. The accelerometer's ability to detect consistency in soap use behavior has been demonstrated in Bangladesh, where the

[82] Armellino et al. 2012.
[83] Ram, Halder et al. 2010.

number of times soap was used in a household was remarkably consistent across each of eight days. The accelerometer allows detection of soap movement, with a time stamp, but by itself, it does not allow for describing handwashing at specific critical times. Biran reports attaching motion sensors to water vessels reserved for cleansing oneself after defecation, thereby allowing for detection of defecation events and subsequent handwashing.[84] This novel approach found that, despite an increase in the number of soap uses overall, there was no increase in the number of soap uses following a defecation event among intervention households, compared to control households.

As an alternative sensor-based approach, colleagues at the London School of Hygiene and Tropical Medicine have used wireless infrared sensors at the entryways of restrooms, and at soap dispensers inside restrooms, to measure soap use among British commuters.[85] The sensors at the entryways of restrooms allowed for detection of entry into the restroom, such that the denominator was the number of people entering the restroom in a given hour. The measurement of handwashing behavior was based on the numerator defined as the number of soap dispenses in a given hour, with uses in the first five minutes of the hour excluded. This novel approach enabled the investigators to investigate the immediate effects on soap use behavior of automated text messages appearing at the entryway of the restrooms that reinforced a number of psychosocial motivators of handwashing. The cost and sophisticated analyses required would place this technology, as with soap with motion sensors, squarely in the research arena for the foreseeable future.

Another technology-based approach is the use of radio-frequency-controlled transmitters and readers that can demonstrate proximity between an individual wearing a transmitter and a hand cleansing device bearing a reader; such an approach can yield individual-level data on the use of handwashing devices.[86] We are not aware of the use of such devices in low- and middle-income settings and anticipate that cost and analysis considerations put them beyond the reach of most researchers and handwashing program evaluators.

Even more distant is the potential for computer-aided tracking of humans and objects, which may be useful as a detection methodology or even a technology to aid in reminding individuals to wash hands if they have not done so at critical times.[87] We see little potential in the near future for such interesting technologies in the low- and middle-income country settings of concern here.

Validity

Comparison with other handwashing measures:

There is minimal information on the comparison of the sensor-based methods to other handwashing measures in low- and middle-income settings. An early study of the accelerometer-embedded soaps demonstrated a significant correlation between soap consumption and number of soap uses, as indicated by the accelerometers.[88]

Comparison with health outcomes:

We are not aware of health outcomes data from resource-limited settings for sensor-based measures of handwashing behavior.

Efficiency

Currently, the largest drawback to any of the sensor-based approaches described to date is the limitation of capacity to deploy, extract, and analyze data to highly qualified research staff, often to those involved in developing the sensor methodology. Transfer of technical capacity, or development of more field-friendly sensor approaches, are imperative if any of the sensor-based methods are to become more widely adopted for monitoring handwashing behavior. However, such transfer clearly comes at the risk of lack of assurance of the various steps contributing to data quality. The cost of individual sensors is expected to be high; for example, the accelerometers for embedding into soap are projected at approximately US$120, which may be prohibitive if a program actually had to purchase large numbers of the sensors.

[84] Biran et al. 2009.
[85] Judah et al. 2009.
[86] Munro and Munro 2009.
[87] Hoey et al. 2010.
[88] Ram, Halder et al. 2010.

Potential for bias or data collection errors

It is possible that, overall, households increase the number of times they use soap when the sensor is in place, compared to when the sensor is not in place. We did not find evidence that the households used the accelerometer-embedded soap more frequently on the first day of its presence in the home and then reduced use as they became accustomed to it.[89]

Use in evaluation of handwashing programs

Biran and colleagues have used the accelerometer-embedded soap to evaluate a handwashing promotion program in rural India and found an increase in the number of soap uses overall.[90]

Other useful information

Sensor-based data may provide individual-level information, as with radiofrequency tags, which would be worn by individuals of interest, or group-level information, as with the accelerometer, which is embedded in a bar of soap that may be used by the entire family.

In many countries, households often use multipurpose bar soaps, liquid soaps, or powdered detergent for washing hands. Therefore, embedding accelerometers multipurpose bar soaps, which may also be used for washing laundry or dishes, is potentially problematic in terms of identifying handwashing-specific events. The movement signatures for handwashing may be difficult to distinguish from those of washing clothes, washing dishes, or playing with the soap. Replacing powder or liquid with a bar may allow introduce substantial bias, in that the observed household is given a novel and "special" way of washing hands that it has not previously used.

The bottom line

These various sensor technologies are in the early stages of development and, to our knowledge, none are readily deployable for routine research or evaluation purposes in low- or middle-income countries. Further validation, and a substantial lowering of costs and expertise required for use and analysis, are required before sensor-based technologies can be readily adopted for handwashing measurement in resource-limited settings.

Use of Composite Measures

Several studies have attempted to combine information from different methods of measuring handwashing behavior.[91] These composite measures have included information obtained from demonstration of handwashing, as well as information from self-report. Strina and colleagues used a composite measure that included handwashing information, as well as observations of other hygiene behaviors, such as household drinking water storage and treatment, washing of vegetables, eating potentially dirty food, and so on.[92] In our review of the literature, no composite measure of handwashing has been validated in different geographic or cultural contexts.

Validity

Comparison with other handwashing measures:

Stevenson and colleagues have performed a series of studies in Australia to evaluate an index of responses to 23 questions (HI23) measuring self-reported hygiene behaviors.[93] The questions address several domains of hygiene, including hand hygiene, food hygiene, and home hygiene. Stevenson shows that the scale is associated with a disgust scale, as well as observed handwashing behavior in response to disgust-eliciting stimuli. We are not aware of replications of these studies, or adaptation of Stevenson's hygiene index to low- and middle-income country settings, where hygiene-related attitudes and perceptions of social desirability may differ vastly from the Australian setting of Stevenson's work.

Gadgil and colleagues tested a 14-point scale for handwashing habit in a study of soap consumption and use in urban Bangladesh, based on the Verplanken self-reported habit index (evaluated by Verplanken for various habits other than handwashing).[94] They found no association between handwashing habit and consistent presence of soap in the home.

[89] Ram, Halder et al. 2010.
[90] Biran et al. 2009.
[91] Hoque et al. 1995; Yalcin et al. 2004; Sandora et al. 2005.
[92] Strina et al. 2003.
[93] Stevenson et al. 2009.
[94] Verplanken and Orbell 2003; Gadgil et al. 2011.

Comparison with health outcomes:
Webb and colleagues constructed individual and combined hygiene indices using observed information on drinking water, food, personal hygiene, and household domestic hygiene. Scores for the overall hygiene index and the personal hygiene index (which included wearing of shoes, and observations of cleanliness of mother and child hands) were inversely associated with child diarrhea morbidity.[95]

Potential for bias or data collection errors

Stevenson's hygiene index score was correlated with scores indicating the social desirability of hygiene, but awareness of social desirability explained only 2.5 percent of the variance in the hygiene index score, indicating relatively small degree of bias.[96]

Other useful information

The interpretation of an index is often difficult and comparison of index scores across studies or evaluations may be challenging or impossible. For example, an index constructed using principal component analysis, a data reduction method, would be meaningless outside of the study sample within which it is developed.

The bottom line

At present, there is insufficient evidence to support the use of a single composite measure in research or evaluation of handwashing promotion. This is an area that merits exploration in secondary analyses of large datasets containing numerous measures of reported and observed measures of handwashing behavior.

[95] Webb et al. 2006.
[96] Stevenson et al. 2009.

III. Conclusion

This document attempts to give a balanced view of each of the routinely used and novel methods of measuring handwashing behavior. Positive and negative attributes of each method have been described (see Table 1). The attempt to be balanced may lead to skepticism about the utility of measuring handwashing behavior at all. Since there are few perfect measurements available for outcomes of human behavior or health, researchers and public health practitioners must frequently accept the limitations of the measures available to them, but not get paralyzed by those limitations. Examples of imperfect measures that still provide useful and necessary information are self-reported breastfeeding or self-reported use of oral rehydration therapy for diarrhea treatment, as well as caregiver reported symptoms of childhood diarrhea and other illnesses. These measures are undertaken in every Demographic and Health Survey (DHS) and every Multiple Indicator Cluster Survey (MICS) undertaken in resource-poor countries. While these self-reported measures may exaggerate individuals' true practices and health conditions, they do provide insights into trends in these behaviors over time and important predictors of child morbidity and mortality. To that end, described below are potential approaches to measuring handwashing behavior for a variety of program types and settings. Reference to health outcomes as proxy measures of handwashing behavior has been intentionally minimized, since, almost universally, measurement of health outcomes such as diarrhea incidence or prevalence is very costly. As indicated below, additional data on the relationship between other measures of handwashing behavior and health outcomes is clearly needed.

TABLE 1: SUMMARY OF STRATEGIES TO MEASURE HANDWASHING BEHAVIOR

Measurement Strategy	Requirements for Use	Advantages	Disadvantages	Appropriate Setting for Use
Self-report	• Questionnaire • Training	• Is efficient • Shown to be associated with health outcomes • Can be incorporated into multipurpose surveys	• Shown repeatedly to overestimate handwashing behavior	• Questionnaires may be useful for tracking knowledge, monitoring the reach of a handwashing promotion program, or identifying barriers to handwashing
Microbiological Hand Contamination	• Supplies for hand rinse/hand imprint collection • Microbiology laboratory or equipment for field-level quantitation of hand contamination • Training and quality control • At least one staff member with microbiology experience	• Is objective • Reflects individual hand contamination	• Is not reliable • Is expensive • Serves as a proxy measure of handwashing behavior • Requires some structured observation for measurement at critical times (e.g., after defecation)	• Well-funded handwashing promotion program evaluations or research studies may be able to improve the utility of microbiological hand contamination as a marker of handwashing behavior • Not recommended for small or minimally funded handwashing promotion programs • Not recommended for nationally or regionally representative multipurpose surveys (e.g., DHS, MICS)
Rapid Observations of Handwashing Materials	• Checklist • Training	• Is efficient • Is objective • Can be incorporated into multipurpose surveys • Shown to have internal validity with structured observation	• Serves as a proxy measure • Cannot confirm the frequency or consistency of handwashing • Does not reflect individual-level behavior	• Well-funded handwashing promotion program evaluations or research studies • Evaluations of small or minimally funded handwashing promotion programs • Nationally or regionally representative multipurpose surveys (e.g., DHS, MICS)
Hand Cleansing Product Consumption	• Scale to weigh soap, or containers to measure volume • A minimum of two visits to households (to measure change in soap weight or volume between visits) • Checklist • Training	• Is objective	• Requires two visits to the home, thereby reducing efficiency of data collection	• Well-funded handwashing promotion program evaluations or research studies
Observation of Behavior During Handwashing Demonstration	• Checklist • Training	• Is efficient • Does not rely on respondent self-report • Can be incorporated into multipurpose surveys • Shown to have internal validity with structured observation • Associated with diarrhea and respiratory illness	• May be subject to reactivity	• Well-funded handwashing promotion program evaluations or research studies • Evaluations of small or minimally funded handwashing promotion programs

TABLE 1: SUMMARY OF STRATEGIES TO MEASURE HANDWASHING BEHAVIOR (*Continued*)

Measurement Strategy	Requirements for Use	Advantages	Disadvantages	Appropriate Setting for Use
Visual Inspection of Hand Cleanliness	• Checklist • Training	• Is efficient • Does not rely on respondent self-report • Can be incorporated into multipurpose surveys • Shown to have internal validity with structured observation • Associated with microbiological contamination and diarrhea prevalence	• May not be comparable across studies and geographic regions • May be subjective (based on interviewer training and biases)	• Well-funded handwashing promotion program evaluations or research studies • Evaluations of small or minimally funded handwashing promotion programs
Structured Observations	• Structured format to capture details regarding critical times of interest and handwashing behaviors • Several hours of observation, preferably at the same time of day in all households, and at times that capture critical times of interest and that are locally acceptable • Training and quality control • Preferable to have staff with experience in behavioral observation	• Is objective • Reflects individual behavior • Captures rich detail on handwashing behavior	• Shown to result in reactivity, because of the presence of the human observer • Is costly in terms of person-time • Requires highly trained staff	• Well-funded handwashing promotion program evaluations or research studies • Sample size calculations, and consultation with persons with epidemiological and statistical expertise, may indicate feasibility of this approach for evaluation of even small handwashing promotion programs
Video Observations Video recording frequency of handwashing with soap at critical times, e.g., after defecation	• Video cameras and memory cards (e.g., SD cards) • Monitors to view video recording • Use of structured format to capture details regarding critical times of interest and handwashing behaviors • Staff time for observation	• Is objective • Is efficient • Captures rich detail on handwashing behavior • Video can be viewed repeatedly in order to capture details missed on earlier viewings	• Can result in reactivity, because of the presence of the video camera • Can be costly both in terms of technology and in terms of person-time for analysis • May be limited to information within line of “sight” of camera	• Well-funded handwashing promotion program evaluations or research studies • Sample size calculations, and consultation with persons with epidemiological and statistical expertise, may indicate feasibility of this approach for evaluation of even small handwashing promotion programs • May be particularly useful for facility-based observation where large numbers of events might occur (e.g., schools, healthcare facilities)

TABLE 1: SUMMARY OF STRATEGIES TO MEASURE HANDWASHING BEHAVIOR (*Continued*)

Measurement Strategy	Requirements for Use	Advantages	Disadvantages	Appropriate Setting for Use
Sensor-based Methods	• Equipment, such as soaps with accelerometers • Training in the preparation, initialization, deployment, data download, and data analysis	• Is objective • Does not require the presence of a human observer	• Depending on the technology, sensor data may not reflect individual-level behavior • May or may not provide information on handwashing at critical times • Currently available technologies require highly trained staff • Are costly in terms of equipment needs • May not be useful in settings in which bar soap is used for multiple purposes, or in which liquid or powder soap is commonly used	• Well-funded handwashing promotion program evaluations or research studies • Sample size calculations, and consultation with persons with epidemiological and statistical expertise, may indicate feasibility of this approach for evaluation of even small handwashing promotion programs

IV. Recommendations for Various Scenarios

Here, we provide recommendations for the measurement of handwashing behavior in low- and middle-income country contexts. The recommendations below are made on the basis of ease of data collection and potential cost to the program or study. The focus here is on the measurement of handwashing behavior, although we comment on the utility of collecting data regarding knowledge, attitudes, and health outcomes in some of these contexts.

Well-funded Handwashing Promotion Programs or Research Studies

Well-funded programs or studies have the resources to involve experienced researchers with research and statistical expertise. Ideally, such studies should strive to use the most rigorous methods to measure handwashing behavior. Specifically, structured observations are recommended. Structured observation data can elucidate handwashing behavior for specific household members, e.g., primary caregivers of young children, and/or during particular critical times, e.g., after defecation.

Rapid observations, which are proxies, should also be included among measures of handwashing behavior used in well-funded programs. These observations provide useful information on the facilitating environment found in the home for good handwashing behavior.

For measurement of changes in knowledge or attitudes, or exposure to handwashing promotion programs or specific messages, questionnaires may prove useful. As noted above, the use of questionnaires for measurement of handwashing behavior is not recommended, since self-reported handwashing behavior overestimates observed behavior.

At present, random or critical-time measurement of hand contamination is also not recommended as a measure of handwashing behavior, given the substantial variability detected in several studies described above. But, as detailed below, well-funded programs or research studies may serve as opportunities for improving upon this measure. Future studies should address the utility of indicator organisms other than *E. coli,* whether variability in hand contamination is evident in other laboratories, and the relationship between hand contamination and health outcomes. Well-funded studies may also be ideal for testing of new technologies, such as sensors, for the measurement of handwashing behavior.

Several questions of import may be answered in the context of well-funded public health program evaluations and research studies:

- There is a fundamental gap in the literature on the relationship between the various measures of handwashing behavior and health outcomes. For most measures, there is a paucity of information on whether changes in a given handwashing measure are correlated with changes in risk of health outcomes of interest, such as diarrhea and respiratory infections. We strongly recommend that well-funded research studies and programs include measurement of both behavioral outcomes and health outcomes in the same study populations, and preferably in a longitudinal fashion, in order to examine these relationships in detail.
- Well-funded programs and research studies may be opportunities to validate novel methods, such as video observation, sensor-based methods, and hand cleansing product consumption.
- The utility of handwashing indices may be further examined, particularly in relationship to health outcomes, and as a means of identifying important explanatory factors associated with handwashing behavior.
- At present, there is still a paucity of published effectiveness data regarding the impact of public health programs on behavioral and health outcomes. It is strongly recommended that effectiveness data (positive, negative, and neutral) be published in peer-reviewed literature in order to inform the public health community, policy makers, and funding agencies.

Handwashing Promotion Programs with Minimal Funding

Ideally, these programs, as better-funded programs, would obtain objective measurement of handwashing behavior

with structured observations. Cost is the primary limiting factor. Program evaluation staff are strongly encouraged to consult statistical and/or epidemiologic expertise in order to determine required sample sizes for measurement of handwashing behavior using structured observations, or sensor-based methods. Indeed, these more robust but more costly methods may be carried out in a subset of participants. Universal recommendations regarding sample sizes cannot be made here, given the diversity in program types, evaluation designs, and program goals and targets.

Rapid observations, which are proxies, are certainly recommended as efficient measures of handwashing behavior in meagerly-funded public health programs. Also, such programs may consider other approaches, perhaps in a subset of sample populations; these include structured observation, video observation, inspections of hand cleanliness, and hand cleansing product consumption.

Questionnaires remain useful for measurement of knowledge, attitudes, and program exposure.

Nationally Representative Surveys, e.g., DHS or MICS Surveys

The Demographic and Health Surveys are described as "nationally-representative household surveys that provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition." The multi-indicator cluster surveys (MICS) are conducted by UNICEF and may be described similarly. DHS and MICS surveys are conducted every three to five years in most low- and middle-income countries. Handwashing is only one of a myriad number of topics covered in these surveys and, thus, measurement of handwashing behavior is necessarily restricted to the most efficiently administered questions. It is not feasible to do more intensive measurements, such as structured observations, in the context of these large nationally representative surveys. Therefore, the use of rapid observations of handwashing materials is recommended and has been adopted.

References

Aiello, A.E., R.M. Coulborn, V. Perez, E.L. Larson. 2008. "Effect of Hand Hygiene on Infectious Disease Risk in the Community Setting: A Meta-Analysis." *American Journal of Public Health* 98:1372–1381.

Armellino, D., E. Hussain, M.E. Schilling, et al. 2012. "Using High-Technology to Enforce Low-Technology Safety Measures: The Use of Third-Party Remote Video Auditing and Real-Time Feedback in Healthcare." *Clinical Infectious Diseases* 54:1–7.

Aunger, R., W.P. Schmidt, A. Ranpura, et al. 2010. "Three Kinds of Psychological Determinants for Hand-Washing Behaviour in Kenya." *Social Science & Medicine* 70:383–91.

Bentley, M., M. Boot, J. Gittelsohn, R. Stallings. 1994. *The Use of Structured Observations in the Study of Health Behaviour.* The Hague, The Netherlands: IRC International Water and Sanitation Centre.

Biran, A., T. Rabie, W. Schmidt, S. Juvekar, S. Hirve, V. Curtis. 2008. "Comparing the Performance of Indicators of Hand-Washing Practices in Rural Indian Households." *Tropical Medicine & International Health* 13:278–85.

Biran, A., W.P. Schmidt, R. Wright, et al. 2009. "The Effect of a Soap Promotion and Hygiene Education Campaign on Handwashing Behaviour in Rural India: A Cluster Randomised Trial." *Tropical Medicine & International Health* 14:1303–14.

Burton, M., E. Cobb, P. Donachie, G. Judah, V. Curtis, W.P. Schmidt. 2011. "The Effect of Handwashing with Water or Soap on Bacterial Contamination of Hands." *International Journal of Environmental Research and Public Health* 8:97–104.

Byrt, T., J. Bishop, J.B. Carlin. 1993. "Bias, Prevalence and Kappa." *Journal of Clinical Epidemiology* 46:423–9.

Cairncross, S., C. Hunt, S. Boisson, et al. 2010. "Water, Sanitation and Hygiene for the Prevention of Diarrhoea." *International Journal of Epidemiology* 39(Suppl 1):i193–205.

Centers for Disease Control (CDC). 2002. "Guideline for Hand Hygiene in Health-Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force." *Morbidity and Mortality Weekly Report* 51(RR-16):1–56.

Coombes, Yolande and Jacqueline Devine. 2010. "Introducing FOAM: A Framework to Analyze Handwashing Behaviors to Design Effective Handwashing Programs." Working Paper, World Bank/Water and Sanitation Program.

Cousens, S., B. Kanki, S. Toure, I. Diallo, V. Curtis. 1996. "Reactivity and Repeatability of Hygiene Behaviour: Structured Observations from Burkina Faso." *Social Science & Medicine* 43:1299–308.

Curtis,Valerie A., L.O. Danquah, R.V. Aunger. 2009. "Planned, Motivated and Habitual Hygiene Behaviour: An Eleven Country Review." *Health Education Research.* Published online 13 March 2009. doi:10.1093/her/cyp002

Curtis, Valerie. 2003. "Talking Dirty: How to Save a Million Lives." *International Journal of Environmental Health Research and Public Health* 13(Suppl 1):S73–9.

Curtis, Valerie., B. Kanki, S. Cousens, et al. 2001. "Evidence of Behavior Change Following a Hygiene Promotion Programme in Burkina Faso." *Bulletin of the World Health Organization* 79:518–27.

Curtis, Valerie and S. Cairncross. 2003. "Effect of Washing Hands with Soap on Diarrhoea Risk in the Community: A Systematic Review." *Lancet Infectious Diseases* 3:275–81.

Danquah, L. 2010. "Measuring Hand Washing Behaviour: Methodological and Validity Issues." Presented at South Asia Hygiene Practitioners' Workshop. Dhaka, Bangladesh.

Fagernes, M. and E. Lingaas. 2011. "Factors Interfering with the Microflora on Hands: A Regression Analysis of Samples from 465 Healthcare Workers." *Journal of Advanced Nursing* 67:297–307.

Freeman, M.C., L.E. Greene, R. Dreibelbis, et al. 2011. "Assessing the Impact of a School-Based Water Treatment, Hygiene and Sanitation Programme on Pupil Absence in Nyanza Province, Kenya: A Cluster-Randomized Trial." *Tropical Medicine & International Health* 17:380–391.

Gadgil, M.A., M.A.Y. Sharker, P.K. Ram, L. Unicomb, S.P. Luby. 2010. "Pilot Study of Serial Soap Weights as New Method of Measuring Handwashing in Dhaka, Bangladesh." Presented at the annual meeting for the American Society of Tropical Medicine and Hygiene. Atlanta, Georgia, November 3–7.

Gadgil, M.A., M.A.Y. Sharker, L. Unicomb, S.P. Luby, P.K. Ram. 2011. "Consistent Soap Availability Correlates with Use of Inexpensive Soap Products and Improved Handwashing in Low-Income Households in Dhaka, Bangladesh." Presented at the annual meeting for the American Society of Tropical Medicine and Hygiene, Philadelphia, Pennsylvania, December 4–8.

Grayson, M.L., S. Melvani, J. Druce, et al. 2009. "Efficacy of Soap and Water and Alcohol-Based Hand-Rub Preparations against Live H1N1 Influenza Virus on the Hands of Human Volunteers." *Clinical Infectious Diseases* 48:285–91.

Halder, A.K., C. Tronchet, S. Akhter, A. Bhuiya, R. Johnston, S.P. Luby. 2010. "Observed Hand Cleanliness and Other Measures of Handwashing Behavior in Rural Bangladesh." *BMC Public Health* 10:545.

Hernandez, O., J. Devine, J. Karver, C. Chase, Y. Coombes. 2012. "Measuring the Behavioral Determinants of Handwashing with Soap." Working Paper, World Bank/Water and Sanitation Program.

Hoey, J., P. Poupart, A. von Bertoldi, T. Craig, C. Boutilier, A. Mihailidis. 2010. "Automated Handwashing Assistance for Persons with Dementia Using Video and a Partially Observable Markov Decision Process." Computer Vision and Image Understanding 114:503–19.

Hoque, B.A., D. Mahalanabis, M.J. Alam, M.S. Islam. 1995. "Post-Defecation Handwashing in Bangladesh: Practice and Efficiency Perspectives." *Public Health* 109:15–24.

Huda, T.M., L. Unicomb, R.B. Johnston, A.K. Halder, M.A. Yushuf Sharker, S.P. Luby. 2012. "Interim Evaluation of a Large Scale Sanitation, Hygiene and Water Improvement Programme on Childhood Diarrhea and Respiratory Disease in Rural Bangladesh." *Social Science & Medicine* 75:604–611. doi: 10.1016/j.socscimed.2011.10.042.

International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). 2008."Handwashing Behavior in Rural Bangladesh." *Health and Science Bulletin* Vol. 6, No. 3.

Judah, G., R. Aunger, W.P. Schmidt, S. Michie, S. Granger, V. Curtis. 2009. "Experimental Pretesting of Hand-Washing Interventions in a Natural Setting." *American Journal of Public Health* 99(Suppl 2): S405–11.

Last, J.M., editor. 2001. *A Dictionary of Epidemiology.* 4th ed. New York: Oxford University Press.

Luby, S.P. and A.K. Halder. 2008. "Associations among Handwashing Indicators, Wealth, and Symptoms of Childhood Respiratory Illness in Urban Bangladesh." *Tropical Medicine & International Health* 13:835–44.

Luby, S.P., A.K. Halder, C. Tronchet, S. Akhter, A. Bhuiya, R.B. Johnston. 2009. "Household Characteristics Associated with Handwashing with Soap in Rural Bangladesh." *American Journal of Tropical Medicine and Hygiene* 81:882–7.

Luby, S.P., A.K. Halder, T. Huda, L. Unicomb, R.B. Johnston. 2011. "The Effect of Handwashing at Recommended Times with Water Alone and with Soap on Child Diarrhea in Rural Bangladesh: An Observational Study." *PLOS Medicine* 8(6): e1001052. doi:10.1371/journal.pmed.1001052.

Luby, S.P., A.K. Halder, T.M. Huda, L. Unicomb, R.B. Johnston. 2011. "Using Child Health Outcomes to Identify Effective Measures of Handwashing." *American Journal of Tropical Medicine and Hygiene* 85:882–92.

Luby, S.P., M. Agboatwalla, A. Bowen, E. Kenah, Y. Sharker, R.M. Hoekstra. 2009. "Difficulties in Maintaining Improved Handwashing Behavior, Karachi, Pakistan." *American Journal of Tropical Medicine and Hygiene* 81:140–5.

Luby, S.P., M. Agboatwalla, A. Raza, et al. 2001. "Microbiologic Effectiveness of Hand Washing with Soap in an Urban Squatter Settlement, Karachi, Pakistan." *Epidemiology and Infection* 127:237–44.

Luby, S.P., M. Agboatwalla, W. Billhimer, R.M. Hoekstra. 2007. "Field Trial of a Low Cost Method to Evaluate Hand Cleanliness." *Tropical Medicine & International Health* 12:765–71.

Luby, S.P., M.A. Kadir, M.A. Yushuf Sharker, F. Yeasmin, L. Unicomb, M. Sirajul Islam. 2010. "A Community-Randomised Controlled Trial Promoting Waterless Hand Sanitizer and Handwashing with Soap, Dhaka, Bangladesh." *Tropical Medicine & International Health* 15:1508–16.

Luby, Stephen P., M. Agboatwalla, D.R. Feikin, et al. 2005. "Effect of Handwashing on Child Health: A Randomised Controlled Trial." *Lancet* 366:225–33.

Luby, Stephen, M. Agboatwalla, J. Painter, A. Altaf, W. Billhimer, R. Hoekstra. 2004. "Effect of Intensive Handwashing Promotion on Childhood Diarrhea in High-Risk Communities in Pakistan: A Randomized Controlled Trial." *JAMA* 291:2547–54.

Manun'Ebo, M., S. Cousens, P. Haggerty, M. Kalengaie, A. Ashworth, B. Kirkwood. 1997. "Measuring Hygiene Practices: A Comparison of Questionnaires with Direct Observations in Rural Zaire." *Tropical Medicine & International Health* 2:1015–21.

McAteer, J., S. Stone, C. Fuller, et al. 2008. "Development of an Observational Measure of Healthcare Worker Hand-Hygiene Behaviour: The Hand-Hygiene Observation Tool (HHOT)." *Journal of Hospital Infection* 68:222–9.

McGuckin, M., R. Waterman, J. Govednik. 2009. "Hand Hygiene Compliance Rates in the United States—A One-Year Multicenter Collaboration Using Product/Volume Usage Measurement and Feedback." *American Journal of Medical Quality* 24:205–13.

Munro, A.D., R.G. Munro, inventors. 2009. "RF Controlled Devices to Increase Compliance with Handwashing Protocols." Patent Number 20090237254, United States of America.

Pickering, A.J., A.B. Boehm, M. Mwanjali, J. Davis. 2010. "Efficacy of Waterless Hand Hygiene Compared with Handwashing with Soap: A Field Study in Dar es Salaam, Tanzania." *American Journal of Tropical Medicine and Hygiene* 82:270–8.

Pickering, A.J., J. Davis, A. Blum, et al. 2011. "Access to Waterless Hand Sanitizer Improves Hand Cleaning Behavior and Health at Primary Schools in Kibera, Kenya." Presented at the annual meeting for the American Society of Tropical Medicine and Hygiene. Philadelphia, Pennsylvania, December 4–8.

Pickering, A.J., J. Davis, A.B. Boehm. 2011. "Efficacy of Alcohol-Based Hand Sanitizer on Hands Soiled with Dirt and Cooking Oil." *Journal of Water and Health* 9:429–33.

Pickering, A.J., J. Davis, S.P. Walters, et al. 2010. "Hands, Water, and Health: Fecal Contamination in Tanzanian Communities with Improved, Non-Networked Water Supplies." *Environmental Science & Technology* 44:3267–72.

Pickering, A.J., T.R. Julian, S. Mamuya, A.B. Boehm, J. Davis. 2011. "Bacterial Hand Contamination among Tanzanian Mothers Varies Temporally and Following Household Activities." *Tropical Medicine & International Health* 16:233–9.

Pinfold, J.V. 1990. "Faecal Contamination of Water and Fingertip-Rinses as a Method for Evaluating the Effect of Low-Cost Water Supply and Sanitation Activities on Faeco-Oral Disease Transmission. I. A Case Study in Rural North-East Thailand." *Epidemiology and Infection* 105:363–75.

Pinfold, J.V., N.J. Horan. 1996. "Measuring the Effect of a Hygiene Behaviour Intervention by Indicators of Behaviour and Diarrhoeal Disease." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 90:366–71.

Rabie, Tamer and Valerie Curtis. 2006. "Handwashing and Risk of Respiratory Infections: A Quantitative Systematic Review." *Tropical Medicine & International Health* 11:258–67.

Ram, P., S. Luby, A. Halder, M. Islam, S. Granger. 2010. "Improving Measures of Handwashing Behavior." Working Paper, World Bank/Water and Sanitation Program.

Ram, P.K., A.K. Halder, S.P. Granger, et al. 2010. "Is Structured Observation a Valid Technique to Measure Handwashing Behavior? Use of Acceleration Sensors Embedded in Soap to Assess Reactivity to Structured Observation." *American Journal of Tropical Medicine and Hygiene* 83:1070–6.

Ram, P.K., I. Jahid, A.K. Halder, et al. 2011. "Variability in Hand Contamination Based on Serial Measurements: Implications for Assessment of Hand-Cleansing Behavior and Disease Risk." *American Journal of Tropical Medicine and Hygiene* 84:510–6.

Rhee, V., L.C. Mullany, S.K. Khatry, et al. 2008. "Maternal and Birth Attendant Hand Washing and Neonatal Mortality in Southern Nepal." *Archives of Pediatric & Adolescent Medicine* 162:603–8.

Sagerman, D., F.A. Nizame, M. Nuruzzaman, J. Yu, S.P. Luby, P.K. Ram. 2010. "Impact of Complexity of Handwashing Instructions on Adherence in a Low Income Setting, Dhaka, Bangladesh." Presented at the annual meeting for the American Society of Tropical Medicine and Hygiene. Philadelphia, Pennsylvania, December 4–8.

Sandora, T.J., E.M. Taveras, M.C. Shih, et al. 2005. "A Randomized, Controlled Trial of a Multifaceted Intervention Including Alcohol-Based Hand Sanitizer and Hand-Hygiene Education to Reduce Illness Transmission in the Home." *Pediatrics* 116:587–94.

Schmidt, W.P., R. Aunger, Y. Coombes, et al. 2009. "Determinants of Handwashing Practices in Kenya: The Role of Media Exposure, Poverty and Infrastructure." *Tropical Medicine & International Health* 14:1534–41.

Silk, B.J., S. Doshi, D. Dutt, et al. 2010. "Hand Hygiene and Radiographically-Confirmed Pneumonia among Young Children Living in Urban Dhaka, Bangladesh: Preliminary Results from a Case-Control Study." Poster presented at the annual meeting for the American Society of Tropical Medicine and Hygiene. Atlanta, Georgia, November 3–7.

Sim, J., C.C. Wright. 2005. "The Kappa Statistic in Reliability Studies: Use, Interpretation, and Sample Size Requirements." *Physical Therapy* 85:257–68.

Simmerman, J.M., P. Suntarattiwong, J. Levy, et al. 2011. "Findings from a Household Randomized Controlled Trial of Hand Washing and Face Masks to Reduce Influenza Transmission in Bangkok, Thailand." *Influenza and Other Respiratory Viruses* 5:256–67.

Stanton, B.F., J.D. Clemens, K.M. Aziz, M. Rahman. 1987. "Twenty-Four-Hour Recall, Knowledge-Attitude-Practice Questionnaires, and Direct Observations of Sanitary Practices: A Comparative Study." *Bulletin of the World Health Organization* 65:217–22.

Stevenson, R.J., T.I. Case, D. Hodgson, R. Porzig-Drummond, J. Barouei, M.J. Oaten. 2009. "A Scale for Measuring Hygiene Behavior: Development, Reliability and Validity." *American Journal of Infection Control* 37:557–64.

Strina, A., S. Cairncross, M.L. Barreto, C. Larrea, M.S. Prado. 2003. "Childhood Diarrhea and Observed Hygiene Behavior in Salvador, Brazil." *American Journal of Epidemiology* 157:1032–8.

Talaat, M., S. Afifi, E. Dueger, et al. 2011. "Effects of Hand Hygiene Campaigns on Incidence of Laboratory-Confirmed Influenza and Absenteeism in Schoolchildren, Cairo, Egypt." *Emerging Infectious Diseases* 17:619–25.

Unicomb, L.E., T.M.N. Huda, R.B. Johnston, et al. 2010. "The Relationship between Diarrheal Death and Measures of Water, Sanitation, and Hygiene among Children < 5 Years of Age in Bangladesh." Poster presented at the annual meeting for the American Society of Tropical Medicine and Hygiene, Atlanta, Georgia, November 3–7.

Verplanken, B. and S. Orbell. 2003. "Reflections on Past Behavior: A Self-Report Index of Habit Strength." *Journal of Applied Social Psychology* 33:1313–30.

Vindigni, S.M., P.L. Riley, M. Jhung. 2011. "Systematic Review: Handwashing Behaviour in Low- to Middle-Income Countries: Outcome Measures and Behaviour Maintenance." *Tropical Medicine & International Health* 16:466–77.

Wang, A., L. McMahan, M. Sobsey, C. Stauber, S. Rutstein. 2011. "Evaluation of Household Microbial Water Quality Testing in a Peruvian Demographic and Health Pilot Study Using the Portable Compartment Bag Test (CB) for *E. coli.*" Presented at the annual meeting for the American Society of Tropical Medicine and Hygiene. Philadelphia, Pennsylvania, December 4–8.

Webb, A.L., A.D. Stein, U. Ramakrishnan, V.S. Hertzberg, M. Urizar, R. Martorell. 2006. "A Simple Index to Measure Hygiene Behaviours." *International Journal of Epidemiology* 35:1469–77.

Whaley, L. and J. Webster. 2011. "The Effectiveness and Sustainability of Two Demand-Driven Sanitation and Hygiene Approaches in Zimbabwe." *Journal of Water, Sanitation, and Hygiene for Development* 1:20–36.

Yalcin, S.S., S. Yalcin, S. Altin. 2004. "Hand Washing and Adolescents: A Study from Seven Schools in Konya, Turkey." *International Journal of Adolescent Medicine and Health* 16:371–6.

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