Contextual and Psychosocial Determinants of Effective Handwashing Technique: Recommendations for Interventions from a Case Study in Harare, Zimbabwe

Max N. D. Friedrich,^{1*} Marc E. Binkert,¹ and Hans-Joachim Mosler¹

¹Department of Environmental Social Sciences, Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland

Abstract. Handwashing has been shown to considerably reduce diarrhea morbidity and mortality. To decontaminate hands effectively, the use of running water, soap, and various scrubbing steps are recommended. This study aims to identify the behavioral determinants of effective handwashing. Everyday handwashing technique of 434 primary caregivers in high-density suburbs of Harare, Zimbabwe, was observed and measured as an 8-point sum score of effective handwashing technique. Multiple linear and logistic regression analyses were performed to predict observed handwashing technique from potential contextual and psychosocial determinants. Knowledge of how to wash hands effectively, availability of a handwashing station with functioning water tap, self-reported frequency of handwashing, perceived vulnerability, and action planning were the main determinants of effective handwashing technique. The models were able to explain 39% and 36% of the variance in overall handwashing technique and thoroughness of handscrubbing. Memory aids and guided practice are proposed to consolidate action knowledge, and personalized risk messages should increase the perceived vulnerability of contracting diarrhea. Planning where, when, and how to maintain a designated place for handwashing with sufficient soap and water is proposed to increase action planning. Since frequent self-reported handwashing was associated with performing more effective handwashing technique, behavior change interventions should target both handwashing frequency and technique concurrently.

INTRODUCTION

Hand hygiene is key to reducing the global burden of diarrhea and respiratory diseases.^{1–5} By acquiring pathogens from surfaces in the environment and transferring them to the mouth or nose, hands constitute a key route for the transmission of infectious diseases.⁶ Handwashing with soap has been shown to decontaminate hands^{7–9} and reduce the risk of ingesting pathogens and acquiring diarrhea.

Performing the handwashing technique correctly is crucial for handwashing to effectively decontaminate hands in health care,^{10,11} the food industry,¹² and household settings.¹³ For domestic handwashing, the Centers for Disease Control and Prevention (CDC) recommends tap and clean water use, soap use, specific scrubbing steps, and drying hands with a clean towel or air-drying. These recommendations have been corroborated by microbiological analyses of handwashing effectiveness in the population of this case study in Harare, Zimbabwe.¹⁴ To our knowledge, there are, however, no studies which investigated the relationship between handwashing technique and health outcomes. Those studies reporting health benefits of handwashing found these benefits in the absence of particular attention to handwashing technique.

How individuals can be motivated to actually perform effective handwashing technique remains unclear as few studies have investigated the psychosocial and contextual determinants that drive individuals to perform effective handwashing technique. An intervention that included information on how to wash hands effectively and how effective handwashing prevents disease, prompts, and advice on how to cope with barriers was found to improve handwashing technique in health-care settings.¹⁵ In two studies of domestic handwashing, the perceived health benefits of effective handwashing¹⁶ and attitudinal factors such as the value of

personal appearance¹⁷ have been found to be related to more effective handwashing. Contextual factors such as higher education level, higher frequency of handwashing after defecation and before eating, and for children, the amount of time spent with parents have been found to be associated with performing effective handwashing technique.^{16,18,19} Although these studies provide valuable insights on potential behavioral determinants of effective handwashing, none of them were based on a theoretical framework. To our knowledge, no study yet has systematically investigated the behavioral determinants of effective handwashing. As a consequence, evidence on which behavioral factors steer handwashing technique is fragmentary. The roles of many potential determinants, such as self-efficacy or self-regulation, which have been postulated in theory, remain unknown. Furthermore, the steps that constitute effective handwashing technique, specifically moistening and rinsing hands with running water, applying soap, scrubbing hands with certain steps, and drying hands using a clean towel or air-drying, can be seen as discrete behaviors that are each steered by distinct behavioral determinants. As a consequence, analyses are required to individually identify the behavioral determinants of each handwashing step.

To identify the determinants of water and sanitation behaviors in developing countries, the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) model has been applied in various contexts.^{20–23} It comprises a broad array of potential behavioral determinants derived from major theories of social and health psychology and provides a guideline for selecting behavior change interventions based on behavioral determinants identified in the target populations. The RANAS model has been successfully applied to predict and change the frequency of handwashing at key handwashing situations in several countries.^{24–27}

Taken together, washing hands with an effective technique is recommended by various institutions. However, what drives individuals to do so or prevents them from actually applying effective handwashing techniques remains largely unknown. The first goal of this study is to identify the contextual and

*Address correspondence to Max N. D. Friedrich, Department of Environmental Social Sciences, Swiss Federal Institute of Aquatic Science and Technology (Eawag), Überlandstrasse 133, Dübendorf 8600, Switzerland. E-mail: max.friedrich@eawag.ch

psychosocial determinants of performing effective handwashing technique through a case study in high-density suburbs of Harare, Zimbabwe. The second goal is to select behavior change techniques that target the determinants identified and that thus are suitable for improving handwashing technique in the target population.

METHODS

Study design. A cross-sectional survey was performed in high-density suburbs of Harare in June and July 2014. The study was approved by the Medical Research Council of Zimbabwe, the Research Council of Zimbabwe, and the Ethical Review Board of the University of Zurich.

Sampling. Participants were recruited from high-density suburbs of Harare, Zimbabwe, through random route sampling, by selecting every fifth household starting from randomly selected junctions in the study area. Informed, written consent was obtained from all participants 1 day prior to data collection. To be included in the sampling frame, households needed to have at least one child attending the local primary school. The primary caregiver in each household was the target participant. With 56 respondents refusing participation in the survey, the refusal rate was 12%. Nonresponding, ineligible, and refusing households were replaced by the fifth next household on the sampling route. In total, 450 primary caregivers were sampled. Eliminating cases with missing values yielded a final sample size of 434 cases. Estimation of the detectable effect sizes using G*power specified that small to medium effects ($f^2 = 0.07$) were detected with a Type 1 error probability of $\alpha = 0.05$ and a statistical power of 0.95.

Data collection. Data were collected through structured observations of handwashing technique, structured quantitative interviews, and spot-check observations using OpenDataKit software (Department of Computer Science and Engineering, University of Washington, Seattle, WA) on tablet computers.²⁸ Prior to data collection, enumerators were enrolled in 1 week of theoretical and practical training, which was followed by 1 week's training in data collection in the field.

For measuring handwashing technique, it was randomly decided whether participants were asked to demonstrate handwashing before eating or after defecation using the random function of OpenDataKit software. The respondent was requested to wash hands in the usual way and reminded that all data were handled confidentially, and that his/her community would benefit most from the survey if the usual handwashing procedure was demonstrated. Enumerators observed the handwashing technique and subsequently recorded the procedure they had observed. The steps recorded included all handwashing steps recommended by CDC for domestic handwashing¹³: how hands were moistened and rinsed, whether soap was used, whether specific scrubbing steps were performed, and how hands were dried after washing (Table 1).

The subsequent structured quantitative interview surveyed potential determinants of performing effective handwashing technique. It was conducted in the local language, Shona, and lasted approximately 1 hour. The questionnaire had been developed in English, translated to Shona, and retranslated to English to minimize the risk of translation mistakes. The interview was divided into two parts. The first part surveyed general constructs that did not require respondents

TABLE 1

Handwashing step	n	%
Scrubbing steps		
Scrubbed the palm*	425	98
Scrubbed back*	374	86
Scrubbed between fingers*	243	56
Scrubbed under nails*	108	25
Scrubbed finger tips	111	26
Soap use		
Used soap*	235	54
Did not use soap	199	46
Moistening/rinsing		
Used running water*	213	49
Poured water on hands	83	19
Dipped hands into water	138	32
Drying		
Air-dried*	319	74
Used clean towel*	26	6
Used dirty towel	31	7
Rubbed hands on clothes	58	13

N = 434. Handwashing steps marked with a * are recommended by the Centers for Disease Control and Prevention. While performing the marked scrubbing steps is recommended, either air-drying or using a clean towel is required.

to have a uniform definition of effective handwashing technique. These comprised general knowledge of diarrhea and its transmission, diarrhea incidence in the household, the perceived severity of diarrhea, the perceived frequency of handwashing with soap at key times, action knowledge, action planning, and additional items on the determinants of handwashing frequency. The first part of the interview was followed by a handwashing instruction in which the enumerator demonstrated to the respondent how to wash hands "in a new way." This new way included all steps considered to constitute effective handwashing (see definition below). This was necessary to ensure that all respondents had the same understanding of effective handwashing technique and to survey their beliefs about effective handwashing technique in a standard way across participants. Perceived vulnerability, attitudes, norms, self-efficacy, action control, and commitment were surveyed in the second part of the interview, followed by the expenditure of time for water collection and sociodemographic characteristics. At the end of each household visit, spot-check observations on the types and condition of handwashing facilities and general hygiene indicators (reported elsewhere) were conducted.

Approximately half of the participants were subject to 3 hours of structured observation of handwashing frequency and microbiological hand sampling before and after the handwashing demonstration.

Measures. General handwashing technique was operationalized through a sum score similar to previous research by Gould²⁹ and Chudleigh and others.³⁰ The number of components of effective handwashing technique that were performed by the respondents was summed on an 8-point index. Based on the recommendations from the CDC,¹³ running water use, soap use, scrubbing palms, scrubbing the back of the hand, scrubbing between fingers, scrubbing under finger nails, and air-drying or drying with a clean towel were counted as elements of effective handwashing technique. In addition, scrubbing the finger tips was included. The duration of handwashing or handscrubbing was not considered, because growing evidence suggests that it is less relevant for handwashing effectiveness.^{31–33} Thoroughness of

handscrubbing was operationalized through a similar sum score which included the number of scrubbing steps performed. Scrubbing palms, scrubbing the back of the hand, scrubbing between fingers, scrubbing under finger nails, and scrubbing the finger tips were counted. Soap use was measured dichotomously and included use of liquid and bar soap. Running water use was also measured dichotomously and represented use of taps with a piped water connection which were installed at kitchen or outside sinks. Tippy taps or containers with valves were not used by participants.

Psychosocial factors of handwashing were selected and measured according to the RANAS model.²³ Factors were measured through single or multiple items. Health and action knowledge were surveyed through open questions with multiple, prespecified answer categories from which the enumerator selected the answers given by the respondent. The ratio of correct answers given by the respondent to the total number of possible answers was aggregated to indices forming the constructs for health and action knowledge. Action planning was surveyed through dichotomous items asking the respondents whether he/she had concrete plans regarding specific aspects of handwashing, such as where to keep soap or which device to use. Perceived handwashing frequency was computed as the mean of multiple items in which the participants rated the frequency of handwashing on a scale from 0 to 10 for various key handwashing situations (before eating, before cooking, before breastfeeding, before feeding a child, after defecation, after cleaning up a child's bottom, after other contact with stool). All remaining factors were surveyed using unipolar items ranging from 1 to 5. Diarrhea was explained to respondents using the United Nations Children's Fund and World Health Organization³⁴ definition as the condition of having at least three loose or liquid bowel movements per day. Diarrhea incidence in primary caregivers and children of the household during the 2 weeks prior to data collection was recorded. The daily time spent on water collection was measured through two open items that surveyed the time spent to collect water once and the number of times per day that water was collected, which were then multiplied. The household's total water storage capacity, the presence of separate handwashing facilities for food- and stool-related handwashing, and the presence of a functioning water tap was measured through spot checks. Item wordings, descriptive statistics, and inter-correlations of constructs are available from the authors on request.

Analysis. All statistical analyses were performed using IBM SPSS Statistics 22 (Armonk, NY). Only independent variables that correlated significantly with the respective measure of handwashing technique were included in the multivariate models. Since some of the variables were nonnormally distributed, Spearman correlations were applied. Five multivariate models were computed to predict overall handwashing technique, the thoroughness of handscrubbing, soap use, running water use, and air-drying. To predict the overall handwashing technique and the thoroughness of handscrubbing, multiple linear regression models with two steps were fitted to the data. Structural factors were entered in the first step. In the second step, psychosocial and additional factors were included, whereas structural factors which had been insignificant in the first model were removed. To identify the determinants of soap use, running water use, and air-

drying, binary logistic regression was performed. The same hierarchical procedure as in the linear regression was used.

RESULTS

Complications. Since the model predicting air-drying of hands did not fit the data well ($R^2 = 0.11$ (Nagelkerke), Model $X^2(9) = 34.85$, $P < 0.001$), it is not reported in the following sections. It is available from the authors on request.

Participants. Of the 434 participants, 421 (97%) were female and 13 (3%) were male. On average, the participants had attended 10 years of formal education (standard deviation [SD] = 2.5) and were 38 years old (SD = 11.9). The average household size of participants amounted to 5.6 household members (SD = 1.9), and the average household income was 315 USD (SD = 290).

Descriptive analysis of handwashing technique. Participants' handwashing technique is presented in Table 1. The absolute and relative number of participants who performed each handwashing step is displayed. On average, participants performed 4.7 (SD = 7.1) of the eight steps of effective handwashing. On average, participants performed 2.9 (SD = 1.1) of five scrubbing steps.

Determinants of handwashing technique. Table 2 presents the results of the hierarchical multiple linear regressions of structural and psychosocial determinants of handwashing on general handwashing technique, the number of handscrubbing steps performed, and the hierarchical multiple binary logistic regressions explaining soap use and running water use.

Determinants of the overall handwashing technique. Model 1 included structural factors and accounted for 13% of the variance in handwashing technique. However, the inclusion of psychosocial factors and the perceived frequency of handwashing with soap increased the model fit to 39%. Standardized regression coefficients revealed that knowing the handwashing steps that constitute effective technique (action knowledge) and having a functioning tap as handwashing facility were the most relevant predictors of handwashing technique. Counterintuitively, the participants' perception that they showed a good example to children when washing hands in the recommended way (example) was negatively associated with effective handwashing technique. The perceived frequency of handwashing with soap, planning where to wash hands and store soap (action planning), and the perceived risk of contracting diarrhea (perceived vulnerability) were further significant determinants.

Determinants of thorough handscrubbing. Although merely 2% of the variance in the number of performed scrubbing steps was explained by structural factors, adding psychosocial factors, handwashing frequency, and performance of other handwashing steps increased the explained variance to 37%. Knowing the steps of effective handwashing was the strongest predictor in the model. Further, participants who used soap, air-dried their hands, and had a functioning tap also scrubbed their hands more thoroughly. Having basic knowledge about diarrhea and its prevention (health knowledge) and feeling capable of complying with the recommended handwashing technique (self-efficacy) was also associated with performing more handscrubbing steps. The participants' perception that they showed a good example to children when washing

TABLE 2
Hierarchical multiple linear regression explaining handwashing technique and number of scrubbing steps performed and hierarchical multiple binary logistic regression explaining soap use and use of running water

Predictor	Overall technique			Thoroughness of scrubbing			Soap use			Running water use		
	B	95% CI	Beta	B	95% CI	Beta	B	Odds ratio	95% CI	B	Odds ratio	95% CI
Model 1												
Constant	3.72***	3.34, 4.1		2.57***	2.32, 2.82		-0.91***	0.40		-2.42***	0.09	
Water collection time * frequency	0.00	0, 0	-0.04	0.00	0, 0	-0.03				-0.01*	0.99	0.99, 1
Separate handwashing facilities food/stool	0.24	-0.14, 0.62	0.06	0.17	-0.1, 0.44	0.06	0.43(+)	1.54	0.94, 2.52			
Functioning tap	1.15***	0.84, 1.47	0.33	0.34**	0.11, 0.56	0.15	0.56**	1.74	1.16, 2.61	3.17***	23.75	13.53, 41.7
Situation: stool related	0.29(+)	-0.01, 0.59	0.09				0.77***	2.15	1.46, 3.19	0.87**	2.38	1.44, 3.94
R ² (adjusted)/R ² (Nagelkerke)	0.13			0.02			0.09			0.51		
F/X ²	17.16***			4.54**			29.09***			206.90***		
Model 2												
Constant	0.70	-0.97, 2.38		0.35	-0.8, 1.5		-4.09*	0.02		-3.74***	0.02	
Water collection time * frequency										-0.01*	0.99	0.99, 1
Functioning tap	1.02***	0.76, 1.28	0.30	0.25*	0.03, 0.48	0.11	0.03	1.03	0.56, 1.87	3.12***	22.72	12.76, 40.47
Situation: stool related							1.06***	2.87	1.77, 4.66	0.84**	2.31	1.37, 3.89
Perceived vulnerability	0.26*	0.01, 0.5	0.08	0.12	-0.05, 0.29	0.06	0.45*	1.57	1, 2.46			
Perceived severity							-0.37*	0.69	0.52, 0.92			
Health knowledge	0.10	-0.12, 0.32	0.04	0.19*	0.03, 0.34	0.11						
Investment							-0.29**	0.75	0.62, 0.91			
Return							0.15	1.16	0.78, 1.72			
Example	-0.48***	-0.69, -0.27	-0.18	-0.17*	-0.31, -0.02	-0.09	-0.88***	0.42	0.27, 0.63			
Descriptive norm house	0.08	-0.04, 0.2	0.05	0.00	-0.08, 0.08	0.00	0.25(+)	1.28	0.98, 1.67	0.17	1.19	0.94, 1.5
Descriptive norm community							-0.11	0.90	0.57, 1.43			
Action knowledge time	-0.06	-0.23, 0.22	0.00	0.03	-0.13, 0.18	0.01						
Action knowledge steps	0.74***	0.57, 0.91	0.37	0.55***	0.43, 0.66	0.41	0.28(+)	1.33	0.99, 1.79			
Self-efficacy	0.07	-0.1, 0.24	0.04	0.10(+)	-0.01, 0.22	0.08	0.02	1.02	0.74, 1.41			
Action planning	0.22**	0.08, 0.37	0.12	0.03	-0.07, 0.13	0.03	0.44**	1.55	1.17, 2.06	0.19	1.21	0.9, 1.64
Action control	0.05	-0.24, 0.33	0.02	-0.02	-0.21, 0.18	-0.01	0.34	1.40	0.81, 2.43			
Used running water				-0.02	-0.24, 0.21	-0.01	0.69*	2.00	1.1, 3.62			
Used soap				0.48***	0.28, 0.68	0.21				0.41	1.50	0.84, 2.69
Air-dried				0.39***	0.19, 0.59	0.15						
Handwashing frequency	0.24**	0.09, 0.4	0.13	-0.06	-0.17, 0.05	-0.05	0.86***	2.37	1.75, 3.2	0.00	1.00	0.73, 1.35
R ² (adjusted)/R ² (Nagelkerke)	0.39			0.37			0.42			0.52		
F/X ²	26.34***			18.85***			161.69***			216.90***		

CI = confidence interval. N = 434; (+) P < 0.1, *P < 0.05, **P < 0.01, ***P < 0.001.

hands in the recommended way was negatively associated with thorough handscrubbing.

Determinants of soap use. Although the model including structural factors correctly estimated soap use for 60% of participants, the model additionally including psychosocial factors correctly estimated 76%. The data show that soap was related to the handwashing situation: Soap was more frequently used when stool-related handwashing was demonstrated. Further, washing hands with running water and higher perceived frequency of handwashing with soap in daily life was related to soap use. Unstandardized parameter estimates of the psychosocial factors, which were all coded from 1 to 5, can be directly compared: The perception that participants showed a good example to children when washing hands in the recommended way was negatively related to soap use and the strongest psychosocial determinants in the model. Further, participants who felt less vulnerable to diarrhea when washing hands with the effective technique used soap more frequently. Participants who had a concrete plan where to wash hands and keep soap for handwashing and participants who perceived diarrhea to be less severe used soap more frequently. Further determinants of soap use included the perception that performing effective handwashing technique was effortful, knowledge of the steps of effective handwashing, and perceiving other household members washing hands with soap.

Determinants of running water use. The model including structural factors correctly estimated running water use for 74% of the participants, and including psychosocial factors did not improve the model fit further. The availability of running water at the handwashing facility was the most prominent determinant of actually using running water for handwashing. In addition, participants used running water more frequently for stool-related than food-related handwashing. Interestingly, the preliminary correlational analyses revealed that sociodemographic characteristics of the households, such as the number of household members and household income, and of the participants, such as age and education, were not found to be related to any of the above measures of handwashing technique.

DISCUSSION

The goal of this study was to identify the contextual and psychosocial determinants of performing effective handwashing technique and, based on the results, develop data-driven and population-tailored behavior change interventions. In a cross-sectional survey, we observed the handwashing technique of 434 primary caregivers of primary school children in Harare and surveyed psychosocial and structural determinants through quantitative structured interviews and spot checks. Knowledge of how to wash hands effectively, availability of a handwashing station with functioning water tap, self-reported frequency of handwashing, perceived vulnerability, and action planning were the main determinants of performing effective handwashing technique. Creative memory aids, guided practice, personalized risk messages, and daily routine planning are proposed to change the identified determinants and trigger behavior change toward more effective handwashing technique.

Interpretation of results and practical implications. Performing effective handwashing technique was found to be related

to frequent handwashing. This suggests that promoting frequent handwashing at key handwashing situations is also a promising strategy to increase handwashing effectiveness.

Performance of the different components of handwashing technique was interdependent. Participants who used soap and air-dried hands also scrubbed hands more thoroughly. Using running water from a tap and using soap were strongly associated with each other. This means that promoting a single element of effective handwashing technique might also prompt participants to improve on other components.

Having a place for handwashing with a functioning tap was the strongest structural determinant of effective overall handwashing technique. This stems from the fact that participants who had a functioning tap at the time of visit actually used it for handwashing. This is not trivial: Despite having a functioning water tap, people could still prefer to moist hands by dipping them into a bowl with water, which is a traditional way of handwashing in Zimbabwe.³⁵ Further, those who had a tap scrubbed hands more thoroughly. As a consequence, promoting and supporting tap acquisition is a promising strategy for improving handwashing technique.

Lower perceived vulnerability to diarrhea when washing hands with effective technique was related to better overall handwashing technique. According to the RANAS model, perceived vulnerability is targeted by personalized risk messages. A modified version of the handwashing experiment reported by Scott and others³⁶ is proposed; this visualized the remaining hand contamination after ineffective and effective handwashing and highlighted the resulting risks of contracting diarrhea.

The perception of the respondents that they showed a good example to children when washing hands as recommended was negatively related to the overall handwashing technique. This surprising result stems primarily from the negative association with soap use. Possible explanations are that participants believed that it was a waste of soap if children used it or that encouraging children to use soap might prompt them to play with it. Actually using soap made this belief more salient and resulted in the negative association detected in the bivariate correlations and regression models. This hypothesis is supported by findings from the qualitative prestudy of this survey, in which participants reported being worried that children might waste soap. Since this explanation suggests reverse causality, interventions targeting this factor are not proposed.

Action knowledge was the strongest predictor of overall handwashing technique and thoroughness of handscrubbing. Knowing how to perform the behavior is a precondition for its execution.²³ To increase action knowledge, the RANAS model suggests knowledge transfer. This could be achieved, first, through guided practice during the handwashing experiment and, second, through a memory aid in the form of a handwashing song which enumerates all the steps of the effective technique.

Action planning was a significant predictor of overall handwashing technique, which stems from the association between action planning and soap use. According to the RANAS model, action planning is increased by daily routine planning. Planning where, when, and how to maintain a designated place for handwashing would empower participants to maintain an enabling environment in which to perform effective handwashing technique. Plans should also account for possible disruptions of the daily life, for

example through power or water cuts. This may also be a promising intervention strategy to partly substitute the availability of a functioning water tap.

Limitations and future directions. This article proposes interventions to increase compliance with existing handwashing recommendations. Compliance with complex recommendations might be inconvenient or even not practicable in some contexts.^{6,37} This calls for additional studies in low-income settings of developing countries to establish which of the presently recommended handwashing steps are both practicable during the daily life of participants and relevant for removing pathogens. This should inform the content of future handwashing recommendations.

Handwashing technique that is frequently repeated in the same contexts during the daily routine may be strongly habit driven. It may thus not be predominantly determined by the behavioral factors postulated in the RANAS model but be triggered by cues such as location and preceding actions. Implementation intentions and installation of prompts are proposed to counter the possibly strong habit of washing hands with the usual, mostly insufficient technique and complement the data-driven interventions.^{38,39}

Being directly observed while washing hands may have prompted participants to wash their hands in an ideal way. However, despite being observed, participants washed hands with a suboptimal technique. To reduce the observation bias, participants were explicitly reminded that they would help their community most if they supported the study by washing hands in the usual way, and that all data were handled confidentially. Further, the primary aim of this study was not to objectively survey compliance with handwashing guidelines in the study communities but to uncover correlational associations between handwashing technique and structural and psychosocial factors. Even if the observed handwashing technique had been subject to biases, it would not per se have affected the relation to the determinants of handwashing. Assessing handwashing technique through structured observations would probably yield a less biased measure of handwashing technique. Comparing the values obtained from demonstrations to the values obtained from structured observations would provide valuable insights on whether handwashing demonstrations are valid proxy measures for observed handwashing technique.

Most of the behavioral determinants of handwashing technique were surveyed on single-item scales which results in less reliability of the constructs. However, those items which were measured on multiple-item scales showed acceptable internal reliability. Further, this study was purely cross-sectional and, consequently, no causality can be inferred. This calls for field experiments to manipulate these behavioral determinants with the proposed interventions and test whether changes in the determinants would actually result in behavior change and habit formation. Long-term evaluations are recommended to assess the sustainability of the interventions.

CONCLUSIONS

This study is the first to apply a data- and theory-driven procedure to designing interventions that target a largely unheeded dimension of domestic hand hygiene: handwashing technique. This study suggests guided practice,

creative memory aids, such as a handwashing song, personalized risk messages, and daily routine planning to target the most important behavioral determinants and so improve handwashing technique in the target population. This study presents interventions to improve handwashing technique in low-income settings where environmental contamination is high and effective handwashing is most needed.

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Authors' addresses: Max N. D. Friedrich, Marc E. Binkert, and Hans-Joachim Mosler, Department of Environmental Social Sciences, Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland, E-mails: max.friedrich@eawag.ch, marc.binkert@uzh.ch, and hans-joachim.mosler@eawag.ch.

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