Changing handwashing behaviour in southern Ethiopia: A longitudinal study on infrastructural and commitment interventions

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ABSTRACT

Improved hand hygiene efficiently prevents the major killers of children under the age of five years in Ethiopia and globally, namely diarrhoeal and respiratory diseases. Effective handwashing interventions are thus in great demand. Evidence- and theory-based interventions, especially when matched to the target population’s needs, are expected to perform better than common practice. To test this hypothesis, we selected two interventions drawing on a baseline questionnaire-study that applied the RANAS (Risk, Attitudes, Norms, Abilities, Self-regulation) approach and focused on the primary caregivers of households in four rural, water-scarce kebeles (smallest administrative units of Ethiopia) in southern Ethiopia (N = 462). The two interventions were tested in combination with a standard education intervention in a quasi-experiment, as follows: kebele 1, education intervention, namely an F-diagram exercise, (n = 23); kebele 2, education intervention and public-commitment (n = 122); kebele 3, education intervention and tippy-tap-promotion (i.e. handwashing-station-promotion; n = 150); kebele 4, education intervention, public-commitment and tippy-tap-promotion (n = 113). In kebeles 3 and 4, nearly 100% of the households followed the promotion and invested material and time to construct for themselves a tippy-tap. Three months after intervention termination, the tippy-taps were in use with water and soap being present in up to 83% of the households (kebele 4). Pre-post data analysis on self-reported handwashing revealed that the population-tailored interventions, and especially the tippy-tap-promotion, performed better than the standard education intervention. Tendencies in observed behaviour and a recently developed implicit self-measure pointed to similar results. Changing people’s hand hygiene is known to be a challenging task, especially in a water-scarce environment. The present project suggests not only to apply theory and evidence to improve handwashing interventions’ effectiveness, but also emphasizes the relevance of tailoring interventions to the target population.

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1. Introduction

Improvements in hand hygiene efficiently prevent several major infectious illnesses, including diarrhoeal and respiratory diseases (Aiello et al., 2008; Cairncross et al., 2010). These are still the main causes of death in children younger than five years globally (Black et al., 2010). In Ethiopia, where the two diseases account for 38% of deaths in children below the age of five and for 25% of disability-adjusted life-years (World Health Organization Regional Office for Africa, 2010), handwashing rates are considerably low as in most developing countries (Federal Ministry of Health Ethiopia, 2011; Scott et al., 2007). Effective handwashing programs are thus in great demand (Federal Ministry of Health Ethiopia, 2011; Global Public-Private Partnership for Handwashing with Soap, 2013).

Evidence-based interventions, namely interventions for which accepted empirical evidence of effectiveness is available (Davidson et al., 2009), are the exception in handwashing programs in developing countries (Aboud and Singla, 2012); more frequently implemented are interventions based on ‘best practice’ whose scope is often confined to educational approaches transferring knowledge (e.g. Global WASH Cluster, 2011). This comes into conflict (1) with findings that health knowledge and risk awareness do not necessarily translate into handwashing (e.g. Auinger et al., 2010) and (2) with studies questioning the effectiveness of educative handwashing interventions (e.g. Biran et al., 2009; Scott et al., 2007). Moreover, knowledge and risk perception are only of secondary importance in several major theories on health
behaviour change (Conner and Norman, 2005). Correspondingly, there is evidence for the superiority of theory-based health behaviour interventions that aim to change behaviour by influencing the behavioural determinants defined within a specific theory over those lacking a theoretical underpinning (e.g. Taylor et al., 2011; Webb et al., 2010; but see also Prestwich et al., 2014). Furthermore, as each single theory identifies only a subset of potentially crucial behavioural determinants, it has been suggested that interventions, to be most effective, should consider a range of relevant theories (Abraham, 2012; Lippke and Ziegelmann, 2008; cf. Aboud and Singla, 2012). In line with this, a more recent approach to behaviour change in the water, sanitation and hygiene sector in developing countries subsumes the behavioural determinants specified in leading theories of behaviour change into a comprehensive framework, the RANAS (Risk, Attitudes, Norms, Ability, Self-regulation) approach (Mosler, 2012). The incorporated theories are the health belief model (Rosenstock, 1974), protection motivation theory (Rogers, 1975), social cognitive theory (Bandura, 1977), the theory of planned behaviour (Fishbein and Ajzen, 2010), and the health action process approach (Schwarzer, 2008). The RANAS model categorises the factors specified in these theories into five broader factor groups; risk factors, attitude factors, norm factors, ability factors, and self-regulation factors (see Table 1 for an overview of the factor groups and definitions of the factors). All these factors potentially determine whether a behaviour is adopted or not and might thus be targeted within interventions. The RANAS model's core asset is that for each factor it depicts specific behaviour change techniques (BCTs; smallest active components of a behaviour change intervention; Michie and Johnston, 2012) that are thought to change exactly this factor (see Table 1 for the intervention mapping; cf. Abraham and Michie, 2008; Michie and Johnston, 2012; Michie et al., 2013). With that, it constitutes a solid basis for a theory- and evidence-based intervention selection.

What is more, the RANAS approach takes into account that the key factors determining a behaviour may vary between populations so that different interventions may be indicated for different populations. Accordingly, Mosler (2012) suggests applying interventions that are not only theory- and evidence-based but also population-tailored, meaning interventions that are matched to the key behavioural factors in a specific population, i.e. factors with a high improvement potential (s.a. Aboud and Singla, 2012; Abraham, 2012; Bartholomew et al., 2006). Therefore, to select interventions based on the RANAS approach, in a first step the behavioural factors with the highest improvement potential for a specific behaviour in a specific population have to be identified based on a structured survey. A factor's improvement potential is high, when the factor is a key determinant of the specific behaviour in the specific population (to be assessed e.g. by means of regression analysis) and when the factor is also highly positively changeable (i.e. when the population's majority deviates from the ideal value that is expected to facilitate behaviour change; e.g. on average beneficiaries feel low in self-efficacy and think that they are not able to always wash hands with soap at key times). These factors, as they determine the behaviour in the specific population and as they have room to improve, are most likely to facilitate behaviour change and should thus be targeted in interventions. Accordingly, in a second step the BCTs that are mapped in the RANAS model to exactly these determinants should be selected for intervention development.

In brief, the RANAS approach's key assumption is that the most effective interventions are not only theory- and evidence-based but also tailored to the specific population (Mosler, 2012). To test this assumption, the present study investigated whether theory- and

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*Table 1*

Overview of the factors subsumed in the RANAS model and the linked behaviour change techniques (adapted from Mosler, 2012).

<table>
<thead>
<tr>
<th>Behaviour change techniques</th>
<th>Factor groups and factors' definitions</th>
</tr>
</thead>
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<tr>
<td>Information interventions</td>
<td>Risk factors</td>
</tr>
<tr>
<td>Presentation of facts/knowledge transfer</td>
<td>Perceived vulnerability: subjective perception of the individual risk of contracting a disease</td>
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<tr>
<td>Personal risk information</td>
<td>Perceived severity: subjective perception of the seriousness of a disease's individual consequences</td>
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<td>Showing scenarios</td>
<td>Factual knowledge: knowledge about a disease's causes and consequences and its prevention</td>
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<td>Fear arousal</td>
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<td>Persuasive interventions</td>
<td>Attitude factors</td>
</tr>
<tr>
<td>Persuasive arguments</td>
<td>Instrumental beliefs: a behaviour's advantages, e.g. health or status improvements, and disadvantages, e.g. time and monetary costs</td>
</tr>
<tr>
<td>Persuasive peripheral cues</td>
<td>Affective beliefs: feelings arising when thinking about or performing a behaviour</td>
</tr>
<tr>
<td>Affective persuasion</td>
<td></td>
</tr>
<tr>
<td>Normative interventions</td>
<td>Norm factors</td>
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<td>Highlighting norms</td>
<td>Descriptive norm: behaviours typically practiced by others</td>
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<td>Public commitment</td>
<td>Injunctive norm: behaviours typically approved or disapproved by others</td>
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<tr>
<td>Anticipated regret</td>
<td>Personal norm: personal standards about dos and don'ts</td>
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<tr>
<td>Infrastructural and ability interventions</td>
<td>Ability factors</td>
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<tr>
<td>Knowledge transfer (education)</td>
<td>Action knowledge: knowledge about how to perform a behaviour</td>
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<tr>
<td>Guided practice</td>
<td>Motivational self-efficacy: confidence in one's ability to initiate and execute a behaviour</td>
</tr>
<tr>
<td>Facilitating resources (financing)</td>
<td>Volitional self-efficacy: confidence in one's ability to maintain a behaviour in light of barriers and to recover from relapse</td>
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<td>Social help</td>
<td>Impediments: anticipated barriers and distractions to a behaviour</td>
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<td>Modeling/vicarious reinforcement</td>
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<tr>
<td>Coping with barriers</td>
<td>Self-regulation factors</td>
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<td>Coping with relapse</td>
<td>Action control: self-monitoring and efforts carried out to execute a behaviour according to standards set for oneself</td>
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<tr>
<td>Planning interventions and relapse prevention</td>
<td>Action planning: detailed planning of a behaviour's execution including the specification of 'when', 'where' and 'how'</td>
</tr>
<tr>
<td>Daily routine planning</td>
<td>Coping planning: establishing plans to overcome anticipated barriers and distractions to a behaviour</td>
</tr>
<tr>
<td>Outcome feedback</td>
<td>Remembering: ease of remembering a behaviour at a specific time/in a specific situation</td>
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<tr>
<td>Contingency management</td>
<td>Commitment strength: strength of commitment towards practicing a behaviour</td>
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<tr>
<td>Stimulus control</td>
<td></td>
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<tr>
<td>Forming implementation intentions</td>
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<tr>
<td>Prompts/Reminders</td>
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</table>
evidence-based population-tailored handwashing interventions are more effective in changing handwashing behaviour than a standard intervention. The population-tailored interventions were selected according to a baseline study applying the RANAS approach in four kebeles (smallest administrative units of Ethiopia, similar to wards) in the Borena Zone, Ethiopia, and tested in comparison to a standard education intervention within a quasi-experiment with pre-post design in the same four kebeles. With this, the study aimed to contribute to a foundation of theory and evidence in health programs in developing countries (Aboud and Singla, 2012).

To provide an overview of all the steps constituting the RANAS approach (Mosler, 2012), in the following the baseline study’s results (step 1) and the according intervention selection (step 2) are briefly summarized. With regard to the baseline results, the interested reader is referred to the Supplementary Material 1, which presents in more detail the study’s methods and results. The paper’s main part focuses on the above research question and presents the results of the quasi-experiment that tested the selected interventions’ effectiveness.

1.1. Tailoring interventions to a target population according to the RANAS approach: results from a baseline study and corresponding intervention selection

To select interventions in accordance to the RANAS approach (Mosler, 2012) a baseline study was conducted to determine the behavioural factors with the highest intervention potential with regard to handwashing in four kebeles in the Borena Zone, Ethiopia. As to the key determinants of handwashing, results from multiple regression analysis revealed severity, nurture, descriptive and injunctive norms, action control and impediments to be most influential (see Supplementary Material 1 – Table SM-3 for the regression results). In other words, people with higher severity beliefs, stronger feelings of nurture, stronger descriptive and injunctive norms, higher action control beliefs and less impediments were more likely to wash hands at key times. Further, of the factors being substantially correlated with behaviour, highest positive changeability (i.e. the population’s mean value deviated from the ideal value) was found for descriptive and injunctive norms and volitional self-efficacy (see Supplementary Material 1 – Table SM-3). Combining the results on handwashing determinants and mean values, the highest potential to intervene on was found for descriptive norm, followed by injunctive norm and impediments.

Related to the latter, a qualitative assessment of the handwashing situation in the study kebeles suggested that forgetting and a lack of any handwashing infrastructure hindered regular handwashing. In more detail, qualitative observational findings indicated that forgetting was rather underestimated as people were not aware that they forgot to wash hands. Regarding other health behaviours (e.g. water filtering), forgetting is often traceable and becomes evident rather quickly and easily. Instead, forgetting to wash hands at a certain moment may never become salient. What is more, even if forgetting is detected, it is of little help because handwashing must take place in predefined situations and cannot be compensated later. Further, the lack of any handwashing infrastructure brought about a presumably hindering handwashing technique employing mugs or jugs, which cannot be recommended. First, it is a rather inconvenient and time-consuming technique because (1) water is typically not readily available but has to be poured out of a jerry-can into a mug, (2) soap is often stored in a cupboard and not easily accessible either, and (3) only one hand at a time is free for handwashing (cf. tippytap.org, n.d.). Second, washing hands with a mug uses 500 mL of water, versus 40 mL using a handwashing-station (tippytap.org, n.d.).

To sum up, quantitative and qualitative results from the baseline study suggested targeting the descriptive and injunctive norms, impediments, forgetting and the current handwashing technique by interventions. According to the RANAS model, several BCTs would have been conceivable to tackle these factors (Mosler, 2012; see Table 1) but three seemed especially promising to target all the above factors: public commitment, facilitating resources and reminder. These BCTs were combined within two interventions; (1) a public-commitment intervention comprising public commitment and reminder, and (2) an infrastructure-promotion intervention comprising facilitating resources (i.e. construction of handwashing-stations) and reminder.

The public-commitment intervention seemed valuable because it was expected (1) that committing publicly would increase the injunctive norm (e.g. Kraemer and Mosler, 2012), (2) that seeing others commit would enhance the descriptive norm (Mosler, 2012) and (3) when the public commitment is delivered with a sign, that the sign would not only prolong the commitment process but also serve as a reminder so as to lower forgetting (Tobias, 2005). To our knowledge, public commitment has never been used to promote handwashing or hygiene; however, it has been successfully applied to promote other health behaviours (e.g. Kraemer and Mosler, 2012; Perlini and Ward, 2000) and pro-environmental behaviour (e.g. Lohkorst et al., 2013).

The infrastructure-promotion intervention seemed promising as having a handwashing infrastructure (i.e. a handwashing-station) was expected to lower impediments by saving water and making soap and water easy accessible and to mitigate forgetting by serving as a reminder (Devine and Koita, 2010; Luby et al., 2009b; Scott et al., 2007; tippytap.org, n.d.). Further, given that handwashing-stations are constructed outside the house, using the handwashing-stations should transform the traditionally privately-performed handwashing behaviour into a publically-performed one, which was assumed to enhance the descriptive norm (Curtis et al., 2009; Scott et al., 2007). Also, the energy, time, and costs publicly invested in its construction was expected to elevate others’ expectations, increasing the injunctive norm. The intervention selection is supported by previous research showing that a designated place and facility for handwashing (i.e. a handwashing-station) is correlated with higher levels of handwashing (Biran et al., 2005; Devine and Koita, 2010). Quantitative evaluations of handwashing-station interventions are rare; however, the intervention was successfully implemented to promote handwashing around school children (Zhang et al., 2013).

The two selected handwashing interventions were tested in comparison with an education-control. Intervention effects were expected to be smaller for education compared to education combined with public-commitment (educ + pub; H1), education combined with infrastructure-promotion (educ + infr; H2), and education combined with public-commitment and infrastructure-promotion (educ + pub + infr; H3). In addition, the study assumed that educ + pub + infr would yield more behaviour change than educ + pub (H4) and educ + infr (H5).

2. Method

These hypotheses were tested in a quasi-experiment with pre-post design and four arms (see Fig. 1). In all four arms, an education intervention was administered. The two interventions under study were applied in a full factorial design. In arm 1, the control group, only educ was implemented; arm 2 received educ + pub; arm 3 received educ + infr; and arm 4 received educ + pub + infr. Reporting of the quasi-experiment follows the Transparent
Fig. 1. Flow chart of the study design.
21. Research area

The project was conducted from February 2012 to March 2013 with support of a local non-governmental organisation (NGO) working in four woredas (departments) in the Borena Zone. The region is semi-arid, with 70% of the area being sparsely wooded grassland (for the information presented in the following, see Debsu, 2013). The inhabitants, the Boranans, are semi-nomadic pastoralists with men seasonally migrating with their cattle. Since the 1970s, governmental organizations and NGOs have been working in the Borena Zone to mitigate recurring droughts, which threaten the survival of livestock and cause food insecurity and famine. Because disaster-affected people are particularly vulnerable to communicable diseases (including diarrhoea; Stanke et al., 2013; Wisner and Adams, 2002) parts of the emergency help were hygiene interventions. In 2006 the first handwashing intervention was implemented in the region. The conditions for promoting regular handwashing are extremely difficult due to the aridity and because water supply coverage is low. Mostly, long distances must be walked for water collection, so that families can often fetch only around 25 L of water per day. Especially the women's work burden is high, encompassing water collection, cooking, child care, and collecting fodder and firewood.

2.2. Clusters and study population

While the local NGO worked in 28 kebeles across four woredas, the present study was limited to only four out of the twenty-eight kebeles due to the following. Security issues and logistical considerations restricted data collection to two out of the four woredas. Across these two woredas the local NGO was active in twelve kebeles but ongoing hygiene interventions by concurrent NGOs or limited accessibility led to the exclusion of eight kebeles. The inhabitants of the four remaining kebeles (two in each woreda) constituted the study population, which was the same as in the baseline study briefly presented in the Introduction and in more detail in the Supplementary Material 1. The four kebeles served as parallel intervention arms and were non-randomly assigned by the first author and NGO representatives to the control or one of the three intervention conditions (see Fig. 1). Within a kebele, each consisting of around 30 hamlets, only those hamlets were included which were reachable by car or a 20-min walk. Within a hamlet, households were randomly selected by the random-route-method (Hoffmeyer-Zlotnik, 2003). The eligibility criterion for participation, which was assessed by self-report, was being the primary caregiver of children younger than five years of age (usually the children's mother or else their grandmother or older sister). These were targeted (1) because they are responsible for childcare and cooking and thus have the highest impact on transmitting diarrhoea and (2) because they may act as models and therefore influence the family's hygiene behaviour.

Sample size estimation with G*Power 3.1 (Faul et al., 2009) yielded a total sample size of 400 households to detect a small to medium effect in Cohen's $F^2$ at the Type I error probability of 0.05 and a statistical power of 0.95. Allowing for an attrition rate of 20% in the follow-up survey, we aimed to collect data from 500 randomly selected primary caregivers. Due to difficulties in data collection (i.a. inaccessibility of hamlets; high absence of potential participants; a limited timeframe causing an enormous workload and hence major exhaustion), the baseline survey had to be terminated earlier than planned resulting in only 462 study households. Of these, 23 did not receive the allocated interventions (5%) and 31 were not available for follow-up (7%; see Fig. 1). Thus, in total, 408 primary caregivers were surveyed both at baseline and follow-up. Due to the untimely data collection termination at baseline, the control arm had a rather small sample size. Therefore, at follow-up, 106 additional participants were surveyed in the control arm.

According to expectations, all respondents were women. Most were married (baseline 86.8%; follow-up 89.9%) and the mothers of a child younger than five years in the household (baseline 85.1%; follow-up 85%). Their mean age was 34.27 years (SD = 13.89) at baseline and 34.37 years (SD = 13.66) at follow-up. The vast majority of the respondents had never attended school (baseline 97.6%; follow-up 96.9%) and were illiterate (baseline 97.2%; follow-up 98.4%). On average, study households comprised one child younger than five years (Mbaseline = 1.33, SDbaseline = 0.52; Mfollow-up = 1.36, SEfollow-up = 1.07). The mean income per person, per day was US $0.17 (SD = 0.51) at baseline and US $0.18 (SD = 0.05) at follow-up, which was far below the poverty line of US $1.25 (Ravallion et al., 2009). The vast majority of the respondents held traditional beliefs (baseline 96.7%; follow-up 94.7%).

2.3. Data collection procedure

Data were collected in two waves, namely at baseline (six months prior to interventions; these data were also used for the baseline study briefly presented in the Introduction and in the Supplementary Material 1) and follow-up (approximately three months after interventions) by one-hour-long structured face-to-face interviews in Afan Oromo. In addition, household observations were conducted, that is data collectors observed primary caregivers' handwashing behaviour at key times (Ram, 2013). The observations lasted for three hours per household and preceded the interviews. At baseline only part of the study households were observed (n = 151), and observations started only at dawn. At follow-up, all study households were observed, and observations took place at dawn or around noon during lunch preparation. One-hundred-thirty-nine households were observed both at baseline and follow-up. Data were collected by teams of 10 (baseline) and 14 (follow-up) local students and social workers of which two were female. The teams were trained in interviewing and observation techniques in a 4-day workshop and supervised during data collection by researchers and a local collaborator.

2.4. Measures

The interviews and observations were based on a structured questionnaire and a structured observation format, respectively, both developed for this study. The items covered socio-demographic characteristics and several outcome measures. Change in self-reported handwashing was the main outcome measure. However, to get a more detailed picture of the interventions' effects, additional outcome measures were applied, namely handwashing proxy-measures, observed handwashing and script-based covert handwashing recall, with the latter being measured only at follow-up. The questionnaire was prepared in English, translated into Afan Oromo, and re-translated into English to ensure the quality of the translation. The applicability of the questionnaire and the observation format was verified in a pre-test at baseline (N = 20) and follow-up (N = 28).

2.4.1. Change in self-reported stool- and food-related handwashing

Self-reported handwashing was measured by eight items in the format ‘In general, how frequently do you wash your hands with soap before eating/after defecation?’, its response options were 5-point Likert scales which were transformed into a value range of
0–1 (0 = almost never to 1 = almost always; Ram, 2013). Surveyed key times were those usually promoted in handwashing interventions focusing on diarrhoea prevention. Confirmatory factor analysis verified the separability of stool-related handwashing (SRH) and food-related handwashing (FRH; cf. Contzen and Mosler, 2013). For SRH, the three surveyed key times were handwashing after defection, wiping a child’s bottom, and other kinds of contact with stool (Cronbach’s α [baseline/follow-up] = 0.88/0.90). The five FRH key times were before eating, preparing food (i.e. cooking, cutting or preparing food), breastfeeding or feeding a child, and handling water (Cronbach’s α [baseline/follow-up] = 0.89/0.91). To examine changes in self-reported handwashing from baseline to follow-up, baseline values were subtracted from follow-up values for each individual. Response scales ranges from −1 = 100% reduction in handwashing over 0 = 0% change in handwashing to 1 = 100% increase in handwashing. These change scores elucidate the extent and direction of change but do not reveal the absolute value in behaviour.

2.4.2. Handwashing proxy-measures
As approximations for handwashing behaviour, participants were asked whether they have a designated place and facility for handwashing (yes/no; Ram, 2013). In addition, at follow-up only, participants were asked to show their designated place for handwashing or – in case no such place existed – to show their most common place for handwashing; data collectors recorded whether water and soap was present (neither/only one/both present; Ram, 2013).

2.4.3. Script-based covert handwashing recall
At follow-up, in addition to conventional self-reports, a script-based covert handwashing recall was developed and applied. Short sequences of daily routines representing handwashing key times (i.e. scripts) were presented to the respondents, who were asked to explain in as much detail as possible how they usually carry out these routines. Because respondents were not explicitly asked about their handwashing behaviour (i.e. covert), it was expected that this measure would be little affected by socially desirable responding. Further, asking for a course of events (i.e. scripts) instead of a single target event is said to ease the recall of the target event (Weisberg, 2005). An example item would be:

Imagine you have just finished feeding the goats. Now your child is hungry and you have to feed it. Please describe exactly what you do from leaving the goats’ house until you feed the child.

Data collectors recorded whether the respondent mentioned handwashing with soap during the description of their routine. Four items were applied for SRH and FRH each and were later averaged. Sum-scores ranged from 0 = handwashing mentioned at 0% to 1 = handwashing mentioned at 100%.

2.4.4. Observed handwashing
The same key times as those measured by self-reports were observed (see above). In case a key event occurred, it was noted in a structured format along with the information on whether both hands were washed with water before or after the event and whether soap was used. During data processing, observed handwashing was calculated for each type of key event separately (e.g. food preparation; different steps in food preparation were counted as one event unless unrelated behaviours were performed in between two steps) as the percentage of times both hands were washed with soap out of all the times handwashing would have been necessary (e.g. food was prepared). Analogous to the self-reports, observational data concerning stool or food were averaged to form observed SRH and FRH. Response scales ranged from 0 = 0% handwashing to 1 = 100% handwashing. While 139 households were observed both at baseline and follow-up, not all key events occurred in all 139 observed households during observation. As a result, longitudinal data for stool-related events were available for only 38 primary caregivers and only one was out of the control arm. With 136 longitudinally observed events, data availability was better for food-related behaviours; however, only six originated from the control arm. As a consequence, observational data could not be used for the main longitudinal analyses. Rather, these had to be realized by using self-reported data.

2.5. Interventions
One female and nine male health promoters employed and supervised by the local NGO were responsible for the implementation of the interventions, which were delivered during community meetings from October 2012 to January 2013. To each meeting, 20–30 primary caregivers of one or several hamlets in a kebele were invited through home visits during which the interventions’ object and content was explained. The interventions were approved by the kebele leaders and elders, who explicitly endorsed participation. The interventions are described in brief as follows. Detailed descriptions can be found in the Supplementary Material 2.

2.5.1. Education intervention
As an education intervention, the f-diagram exercise, an often applied intervention tool (e.g. David et al., 2009; Global WASH Cluster, 2011), was implemented by means of a one-hour group sorting task at a community meeting.

2.5.2. Public-commitment intervention
Referring to previous research (Inauen and Mosler, 2013) community meetings were held at which primary caregivers gave an oral pledge of their commitment to always wash hands at key times. A commitment sign (i.e. a head scarf) and a certificate were distributed.

2.5.3. Infrastructure-promotion intervention
Instead of simple provision, households were encouraged to construct a family handwashing-station, namely a tippy-tap, by themselves to enhance the commitment for use (see the Supplementary Material 2 for more detail on the tippy-tap). Construction took place right after a community meeting, at which the construction was demonstrated, and jerry-cans used for the station were distributed.

2.5.4. Intervention supervision
To maximise fidelity, all interventions were specified by detailed written instructions provided by the first author. The promoters were trained in a two-day workshop outlined by the first author and held by supervisors of the local NGO, a local research collaborator and representatives of a collaborating international NGO. The supervisors, supported by the local collaborator, assisted the promoters throughout the interventions and ensured quality by field visits and by revising delivery documentation (i.e. monitoring and attendance forms).

2.6. Human subject protection
As written informed consent was not attainable due to high illiteracy, verbal informed consent was obtained from every participant prior to data collection and interventions. The study was conducted in strict compliance with the ethical principles of the
American Psychological Association (APA) and the Declaration of Helsinki and was approved by the Ethiopian National Research Ethics Review committee and the ethics board at the Faculty of Arts of the University of Zurich.

2.7. Data analyses

To get an initial evaluation of the interventions’ effects, chi-square tests were applied to check whether frequencies in proxy-measures at baseline and follow-up (having a designated place and facility for handwashing) or at follow-up only (observed presence of water and soap at the designated or most common place for handwashing) were associated with the intervention arms. Analyses testing for differences at baseline and follow-up were controlled for the familywise error rate (Bender and Lange, 2001) by means of Bonferroni adjustment (α = 0.025). For all chi-square tests, in case of significant results, contingency tables with standardized residuals were inspected to determine the arms with the highest differences between observed and expected frequencies.

To investigate tendencies in change in observed handwashing behaviour between intervention arms, means in observed SRH and FRH were computed for baseline and follow-up.

Between-subjects multivariate analysis of covariance (MANCOVA) was conducted to test for group differences between the intervention arms with regard to change in self-reported SRH and FRH. These were followed up by separate univariate analyses of covariance (ANCOVAs) with Bonferroni adjustment (α = 0.025; Bender and Lange, 2001). To test H1 to H5, planned simple contrasts were controlled for the familywise error rate (Bender and Lange, 2001). To test H1 to H5, planned simple contrasts compared the control arm to the three educ þ arms and the full intervention arm to educ + pub and educ + infr.

Because the script-based covert handwashing recall measure violated the assumptions for parametric tests, Kruskal–Wallis tests were applied to investigate group differences again with Bonferroni adjustment (α = 0.025; Bender and Lange, 2001). To test H1 to H5, these were followed-up by five Mann–Whitney tests with Bonferroni adjustment (α = 0.01; Bender and Lange, 2001) for SRH and FRH each that compared the control arm to the educ + arms and the full intervention arm to educ + pub and educ + infr.

3. Results

3.1. Intervention fidelity

With regard to the public-commitment intervention, despite intervention supervision, some protocol deviations were noted. More precisely there are indications that the intended link between the head scarf and commitment was not communicated properly. The researchers’ main idea of introducing a commitment sign was that people would express their commitment to the community by wearing the scarf so as to continuously trigger social norms. As a side benefit it was expected that the scarf would serve as a reminder. However, there is anecdotal evidence that in the promoter training the reminding-function was more emphasized than the commitment-function. Consequently, conveyed to the communities was primarily that the scarf serves as a reminder. Further, in the educ + pub arm, there is evidence to suggest that in some cases the basic idea of wearing the scarf to foster handwashing was completely overridden: respondents said that they were told to wear the scarf to be given a lift, or simply to always wear the scarf when people from outside visited the kebele. That is, the link between scarf and handwashing was removed, rendering the scarf impotent for eliciting handwashing.

3.2. Preliminary analyses

With regard to differences between intervention arms, no differences were found in socio-demographics. However, intervention arms differed in self-reported baseline behaviour. As these baseline differences are not taken into account within the change scores, the baseline values were entered as covariates in the MANCOVA on changes in self-reported behaviour. Attrition did not differ between arms, and no significant differences in socio-demographics, behavioural factors and observed and self-reported behaviour were found between study remainders and dropouts. Further, participants who were observed at baseline did not differ in socio-demographics, behavioural factors or self-reported behaviour from those who were not observed.

3.3. Initial intervention assessment: differences in proxy-measures

In the infrastructure-promotion arms, 94% (educ + pub + infr) and 99% (educ + infr) of the households actually constructed a tippy-tap. That is, almost 100% followed the promotion and invested material and time in the construction.

At baseline, only few respondents stated to have a designated place and facility for handwashing (typically the place where the jerry-can with water and a jug was stored; see Table 2). The occurrence was associated with the intervention arms, \(\chi^2(3) = 22.99, p < 0.001\), Cramer’s \(V = 0.24\); that is, of those with a designated place and facility significantly more than expected were located in the educ + pub arm; for the other arms expected and observed frequencies did not differ. At follow-up, occurrence was again associated with the intervention arms, \(\chi^2(3) = 301.59, p < 0.001\), Cramer’s \(V = 0.86\); however, now in the educ and educ + pub arm significantly less households than expected and in the infrastructure-promotion arms significantly more households than expected (almost 100%) stated to have a designated place and facility for handwashing, what supports H2 to H4 (see Table 2). Thus, in the latter arms, nearly 100% not only constructed a tippy-

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Table 2

Households with a designated place and facility for handwashing at baseline and follow-up: frequency in percent per intervention condition and standardized residuals.

<table>
<thead>
<tr>
<th></th>
<th>Educ</th>
<th>Educ + pub</th>
<th>Educ + infr</th>
<th>Educ + infr + pub</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No designated place</td>
<td>100% (0.4)</td>
<td>82.6% (−1.1)</td>
<td>95.8% (0.4)</td>
<td>96.5% (0.5)</td>
</tr>
<tr>
<td>With a designated</td>
<td>0% (−1.3)</td>
<td>17.4% (3.8)</td>
<td>4.2% (−1.5)</td>
<td>3.5% (−1.6)</td>
</tr>
<tr>
<td><strong>Follow-up</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No designated place</td>
<td>100% (5.6)</td>
<td>84.3% (9.9)</td>
<td>0% (−6.9)</td>
<td>6.2% (−5.0)</td>
</tr>
<tr>
<td>With a designated</td>
<td>0% (−3.9)</td>
<td>15.7% (−6.9)</td>
<td>100% (4.8)</td>
<td>93.8% (3.5)</td>
</tr>
<tr>
<td><strong>Total n</strong></td>
<td>23</td>
<td>121</td>
<td>150</td>
<td>113</td>
</tr>
</tbody>
</table>

* SR = Standardized residuals. Standardized residuals in bold (with values outside ±2.24) are significant at the Bonferroni adjusted α’ = 0.025.
tap, but also recognized it as their designated place for handwashing.

Associations with intervention arms were also found at follow-up for observed presence of water and soap at the designated or most common place for handwashing (see Table 3). \( \chi^2 (3) = 81.39, p < 0.001 \), Cramer’s \( V = 0.29 \). In the educ \( + \) infr arm water and soap were observed in significantly more households than expected while the opposite is true for the educ \( + \) pub and educ arms, supporting H2.

### 3.4. Differences in observed behaviour

Figs. 2 and 3 show the mean rate in observed SRH and FRH. These have to be interpreted with caution, especially for the educ arm for which baseline sample size is minimal.

In arms with infrastructure-promotion, observed SRH was substantially higher at follow-up than at baseline (see Fig. 2). In the control arm (educ), the handwashing rate was also higher at follow-up compared to baseline (where the handwashing rate was 0%), but still lower than the rates in arms with infrastructure-promotion. In contrast to expectations, in the educ \( + \) pub arm, the handwashing rate was lower at follow-up than at baseline.

Observed FRH was rather low in all intervention arms and, against expectations, it was even lower at follow-up than at baseline (see Fig. 3). This drop was somewhat more pronounced in the educ \( + \) pub and the educ arms (see discussion).

### 3.5. Changes in self-reported behaviour

Changes in self-reported handwashing are presented in Table 4. While small positive changes were found for educ \( + \) pub \( + \) infr, behaviour did not change for educ \( + \) infr. Unexpectedly, behaviour decreased slightly for educ \( + \) pub and more pronouncedly in the control arm (educ).

A MANCOVA tested for differences between intervention arms while controlling for baseline behaviour. Wilks’ statistic revealed a significant effect of the promotion activities on changes in self-reported handwashing, \( \Lambda = 0.94, F(6, 802) = 4.45, p < 0.001 \), \( \eta^2 = 0.03 \). The covariates achieved significant effects as high baseline behaviour was associated with less positive behaviour change, baseline SRH \( \Lambda = 0.68, F(2, 401) = 95.90, p < 0.001 \), \( \eta^2 = 0.32 \) and baseline FRH \( \Lambda = 0.67, F(2, 401) = 100.29, p < 0.001 \), \( \eta^2 = 0.33 \).

Separate univariate ANCOVAs on changes in self-reported handwashing behaviour revealed significant intervention effects on SRH, \( F(3, 402) = 4.77, p = 0.003 \), \( \eta^2 = 0.03 \) and FRH, \( F(3, 402) = 8.79, p < 0.001 \), \( \eta^2 = 0.06 \). In line with H1 to H3, simple contrasts revealed that changes in SRH and FRH were significantly more positive in all educ \( + \) arms compared to the educ arm (see Table 4). Further, behaviour changes in educ \( + \) pub \( + \) infr were more positive compared to changes in educ \( + \) pub, supporting H4. In contrast to H5, however, changes in educ \( + \) pub \( + \) infr and educ \( + \) infr did not differ significantly from each other. The largest differences were found between educ and educ \( + \) pub \( + \) infr, with large effect sizes of \( d = 0.77 \) for SRH and \( d = 0.98 \) for FRH.

### 3.6. Differences in script-based covert handwashing recall

Median rates in SRH and FRH were highest for the two infr arms and lowest for the educ arm (see Table 5). Kruskal–Wallis tests showed that handwashing was significantly affected by the intervention arms, SRH, \( H(3) = 33.33, p < 0.001 \) and FRH, \( H(3) = 29.28, p < 0.001 \).

![Fig. 2](image1.png)

**Fig. 2.** Mean rates in observed SRH. * Rate was zero at baseline. Sample sizes were as follows: Educ \( n_{\text{baseline}} = 2 \), Educ \( n_{\text{follow-up}} = 61 \); Educ \( + \) pub \( n_{\text{baseline}} = 25 \), Educ \( + \) pub \( n_{\text{follow-up}} = 60 \); Educ \( + \) infr \( n_{\text{baseline}} = 27 \), Educ \( + \) infr \( n_{\text{follow-up}} = 52 \); Educ \( + \) pub \( + \) infr \( n_{\text{baseline}} = 26 \), Educ \( + \) pub \( + \) infr \( n_{\text{follow-up}} = 41 \).

![Fig. 3](image2.png)

**Fig. 3.** Mean rates in observed FRH. Sample sizes were as follows: Educ \( n_{\text{baseline}} = 7 \), Educ \( n_{\text{follow-up}} = 125 \); Educ \( + \) pub \( n_{\text{baseline}} = 46 \), Educ \( + \) pub \( n_{\text{follow-up}} = 119 \); Educ \( + \) infr \( n_{\text{baseline}} = 46 \), Educ \( + \) infr \( n_{\text{follow-up}} = 148 \); Educ \( + \) pub \( + \) infr \( n_{\text{baseline}} = 43 \), Educ \( + \) pub \( + \) infr \( n_{\text{follow-up}} = 110 \).

### Table 3

Households with observed water and soap present at the designated or most common place for handwashing at follow-up: frequency in percent per intervention condition and standardized residuals.

<table>
<thead>
<tr>
<th>Water and soap</th>
<th>Educ</th>
<th>Educ + pub</th>
<th>Educ + infr</th>
<th>Educ + infr + pub</th>
<th>Total n</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>28.2% (1.8)</td>
<td>28.2% (1.8)</td>
<td>3.4% (-4.6)</td>
<td>27.7% (1.7)</td>
<td>96</td>
</tr>
<tr>
<td>Only one of both</td>
<td>35.0% (1.9)</td>
<td>33.6% (1.7)</td>
<td>13.4% (-2.9)</td>
<td>25.0% (0.1)</td>
<td>121</td>
</tr>
<tr>
<td>Both</td>
<td>36.9% (-2.4)</td>
<td>38.2% (-2.3)</td>
<td>83.2% (4.8)</td>
<td>47.3% (-1.0)</td>
<td>257</td>
</tr>
<tr>
<td>Total n</td>
<td>103</td>
<td>110</td>
<td>149</td>
<td>112</td>
<td>474</td>
</tr>
</tbody>
</table>

\( ^a \) SR = Standardized residuals. Standardized residuals in bold are significant. Values outside \( \pm 1.96 \) are significant at \( p < 0.05 \), values outside \( \pm 2.58 \) are significant at \( p < 0.01 \) and values outside \( \pm 3.29 \) are significant at \( p < 0.001 \).
The present project tested the RANAS approach’s assumption that handwashing interventions that are not only theory- and evidence-based but also tailored to the target population (i.e. geared to the key behavioural determinants in a specific beneficiary-population) are more effective than standard interventions (Mosler, 2012). According to a baseline study applying the RANAS approach in four kebeles (smallest administrative units of Ethiopia, similar to wards) in the Borena Zone, Ethiopia, two population-tailored interventions were selected, namely a public-commitment intervention (comprising public commitment and reminder) and an infrastructure-promotion intervention (comprising facilitating resources, i.e. tippy-tap/handwashing-station promotion, and reminder). Their effectiveness was tested in comparison to an education-only intervention, an f-diagram exercise, in a quasi-experiment with pre-post design in the same four kebeles. In terms of infrastructure-promotion in combination with education (and with or without public-commitment), households not only accepted the invitation to construct a tippy-tap in high numbers, but also they recognized the tippy-tap as their designated place for handwashing. Additionally, at follow-up, in nearly 50–80% of the households, the tippy-tap was functioning, with water and soap being present. This is quite substantial, especially when considering that the interventions had ended three months prior to follow-up. In contrast, in groups having experienced education-only or in combination with public-commitment, water and soap was present at the place where they most often washed their hands in less than 40% of the households. Results referring to observed handwashing were mixed. Infrastructure-promotions seemed to have positively affected stool-related handwashing (SRH); the same is true to a smaller extent concerning education-only. Education combined with public-commitment, however, seemed to have a negative effect on SRH. Food-related handwashing (FRH) decreased for all intervention arms but less so for the infrastructure-promotion arms. Self-reported behaviour and script-based covert recall revealed a clearer picture, with lowest behaviour (change) in the education-only arm, followed by education combined with public-commitment, and highest behaviour (change) in infrastructure-promotion arms.

Combining the results, evidence is provided that the theory- and evidence-based, population-tailored interventions (public-commitment and/or infrastructure-promotion) outperformed the education-only intervention. Therewith, the power of population-tailored interventions is emphasized (Mosler, 2012; cf. Abraham, 2012) and today’s common practice in handwashing interventions, namely educational approaches, is questioned. The result is in line with previous research on well-switching in Bangladesh (Inauen and Mosler, 2013) and corresponds to a recent call to bring more theory and evidence into health programs in developing countries and to adjust interventions to its audience (Aboud and Singla, 2012).

The infrastructure-promotion intervention proved to be most effective in enhancing handwashing rates. Similarly, Zhang and colleagues (2013) found more behaviour change among school children when providing a tippy-tap compared to education-only. The infrastructure-promotion intervention’s positive effects are also in line with previous research showing that handwashing-station ownership is correlated with higher levels of handwashing (Biran et al., 2005; Devine and Koita, 2010).

In line with previous research and our expectations, the education-only intervention did not seem to be effective for changing behaviour (Biran et al., 2009; Scott et al., 2007; Zhang et al., 2013). Unexpectedly, however, self-reported handwashing even decreased in the education-only arm. There are two possible explanations for the decrease: (1) the intervention had no impact and (2) it had a negative one. The first explanation starts with the argument that a natural decrease in behaviour might have been at play in all research arms, explained as follows. In all four kebeles baseline data collection was preceded by a one-year handwashing promotion program that was planned and implemented independent of the present research project by the collaborating international and local NGOs. The applied interventions focused mainly on knowledge-formation and awareness-raising but also included material distributions (i.e. water buckets and soap). It may be assumed that due to this foregoing promotion program handwashing rates were rather high at baseline, especially as many interventions had been applied, and decreased subsequently because the induced behaviour change was unsustainable (cf. Arnold et al., 2009; Luby et al., 2009a). The presently tested education intervention, assumed to be ineffective, was incapable of slowing this decline; therefore behaviour decreased in the education-only arm.
Alternatively, the education intervention may have had a genuinely negative impact, explained as follows. The education intervention, meaning the f-diagram exercise, assessed the route of contamination as a whole. That is, it depicted not only how handwashing can prevent diarrhoea, but also how, amongst other things, sanitation and safe water are crucial. These are not comprehensively guaranteed in the area. It is credible that the sheer number of changes necessary and their potential infesibility over-challenged the participants that experienced only the f-diagram. This is in line with research showing that fear (aroused by stressing vulnerability and severity, which is done in the f-diagram exercise) results only in protective behaviour provided that one is confident in one’s ability to perform the protective behaviour (see Bartholomew et al., 2006). Lack of confidence, however, brings people to react defensively and may even lead to threat denial; that is, in our case, participants might have waived behaviour change instead of focusing on the feasible changes. This reasoning would imply that the f-diagram exercise should be implemented in combination with an intervention that enhances self-efficacy, such as the infrastructure-promotion. Indeed, research arms with infrastructure-promotion performed well, while education plus public-commitment, which is not thought to enhance self-efficacy, performed poorer (see below). To our knowledge, although often applied, the f-diagram exercise has never been formally tested; an in-depth analysis of the f-diagram exercise would be valuable.

While there is some evidence that the education plus public-commitment intervention was more effective than education-only, a behaviour decrease, although smaller, was also found for the former intervention. The first explanation outlined above for the education-only intervention may also explain this result, i.e. public-commitment had no impact and was thus not able to slow down a natural behaviour decline. Further, it can be reasoned that public-commitment without infrastructure-promotion was not effective because it was combined with the f-diagram exercise that aroused fear, which was not positively transformed into behaviour change due to a lack of self-efficacy (see above). It is less credible that public-commitment may have had a genuinely negative impact. If it were the public-commitment intervention in itself that caused the decrease, the infrastructure-promotion with public-commitment should have performed poorer than the infrastructure-promotion without public-commitment, which was not the case. However, it is possible that the intervention was unsatisfactorily implemented in the education plus public-commitment arm and was accordingly unable to fulfill its potential and to slow down a natural behaviour decline (see the first explanation above). In fact, it was exactly in the education plus public-commitment arm where most concerns around implementation fidelity had arisen (see the Results section above). The potential of the public-commitment intervention is thus uncertain. This contrasts research in other fields, where public-commitment was successfully applied (e.g. Kraemer and Mosler, 2012; Lokhorst et al., 2013; Perlini and Ward, 2000). Still, one very recent study also found detrimental effects of a public-commitment intervention on well-switching in Bangladesh (Jinauen and Mosler, 2013). Further research is required to test the potential of a public-commitment intervention in hygiene.

### 4.1. Strengths and limitations

The key strength of this study is the application and testing of population-tailored interventions. Further, to our knowledge, this is (1) the first study providing quantitative evidence of the effectiveness of a tippy-tap-promotion intervention in increasing handwashing among rural women, (2) the first application of a public-commitment intervention to promote handwashing, and (3) the first quantitative test of the f-diagram exercise.

While gearing the interventions to the key determinants of handwashing in the study population and to the specific local context contributes majorly to the study’s uniqueness, at the same time it limits the results’ generalizability.

As a further shortcoming, intervention allocation was not randomised. A randomised controlled trial (i.e. allocation of interventions to households) was not feasible because the interventions were public (public commitment and handwashing stations constructed at publicly visible places) so that information contamination would have been risked; interventions had to be allocated to clusters. A limited number of study kebeles precluded the implementation of a cluster-randomized controlled trial. For this reason, cluster effects might have blurred intervention effects. While we tried to level this shortcoming by controlling for baseline values in the MANCOVA, a replication by means of a cluster-randomized controlled trial would be preferable.

Due to premature termination of the baseline data collection, the control arm was small in sample size with regard to self-reported handwashing. This may have decreased the power to detect substantial intervention effects (Cohen, 1992). The fact that despite the small sample size significant effects were found, emphasizes the relevance of these effects.

Moreover, in terms of observed behaviour, the total baseline sample was rather small, which limited the options for conducting analyses with these data. Consequently, the main analyses relied on self-reported behaviour although it has been suggested to observe...
handwashing behaviour to minimize bias due to socially desirable responding (Biran et al., 2008; Halder et al., 2010). However, because self-reported handwashing was found to be associated with child diarrhea and pneumonia, child (diarrhoea) mortality, and cholera (Hutin et al., 2003; Luby et al., 2011; Rhee et al., 2008; Silk et al., 2010; Water Sanitation and Hygiene Research Group, 2012), it is relevant to be examined. Further, all participants, including those in the control condition, received an intervention and should thus have been equally inclined to socially desirable answers. Hence, if self-reported handwashing was solely contingent on social desirability, a behaviour increase should have been reported in all conditions. However, what was found were increases, decreases, and stability in self-reported handwashing. Moreover, additionally applied measures (such as proxy-measures or script-based covert handwashing recall) all pointed in the same direction. Still, the absolute handwashing rates in this study should be interpreted with caution, and future studies should aim at replicating the results by means of observational data.

5. Conclusions

Improved hand hygiene might save millions of children’s lives (Aiello et al., 2008; Cairncross et al., 2010), but changing handwashing behaviour is a challenging task, especially in water-scarce environments. In the present project, handwashing interventions that were based on theory and evidence and were tailored to the target population, namely primary caregivers from rural, water-scarce kebeles in southern Ethiopia, performed better than a standard education intervention. The tippy-tap-promotion is especially promising as it enables participants to a regular handwashing practice by means of a tangible handwashing device that eases behaviour performance, saves water, makes soap and water readily available, serves as a reminder, and enhances social norms (Biran, 2011; Devine and Peschiera, 2010; Scott et al., 2007; tippytap.org, n.d.). The research project emphasizes the importance of applying theory and evidence, combined with insights about the target population and environment, to improve common practice in handwashing interventions (Aboud and Singla, 2012).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2014.11.006.

References


