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RESEARCH ARTICLE

# Effects of a Water, Sanitation and Hygiene Mobile Health Program on Respiratory Illness in Democratic Republic of Congo (DRC): WASHmobile PICHA7 Program

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## ABSTRACT

**Background:** Globally, acute respiratory infections are a major cause of morbidity and mortality, particularly among young children. Water, sanitation and hygiene (WASH) interventions when combined with mobile health (mHealth) have the potential to reduce the burden of respiratory illness. The WASHmobile mHealth program is a targeted WASH program promoting handwashing with soap, drinking water treatment, and safe water storage to reduce diarrhoea and respiratory illness.

**Methods:** The WASHmobile PICHA7 program delivers weekly voice and SMS messages and quarterly home visits to diarrhoea patient households. In a two-arm cluster randomized controlled trial of the WASHmobile PICHA7 program conducted in Bukavu, South Kivu province, eastern Democratic Republic of the Congo, 2334 participants were randomized to two study arms: a standard arm, which received a standard message on oral rehydration solution and a basic WASH message delivered at the healthcare facility, and the WASHmobile PICHA7 arm (NCT05166850). During the 12-month surveillance period, self-reported respiratory symptoms were assessed through monthly clinical surveillance. Acute lower respiratory illness (ALRI) was defined as cough and rapid breathing or rapid breathing and difficulty breathing in the past 2 weeks.

**Results:** In total, 699 children under 5 years of age were included in the analysis. Compared to the standard arm, children under 5 years in the WASHmobile PICHA7 arm had significantly lower ALRI during the 12-month study period (Prevalence Ratio: 0.46, 95% Confidence Interval: 0.22, 0.94). Four percent (14/360) of children in the WASHmobile PICHA7 arm reported ALRI during the study period compared to 12% (39/339) of children in the standard arm.

**Conclusion:** These results demonstrate that the WASHmobile PICHA7 mHealth program reduced ALRI among children under 5 years old in diarrhoea patient households.

Kelly Endres and Presence Sanvura should be considered co-first authors.

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## 1 | Introduction

Globally, acute respiratory illness (ARI) remains a major contributor to child mortality, particularly for children under 5 years of age, resulting in 740,000 deaths annually [1, 2]. Fifteen percent of mortality for children under 5 years of age is estimated to be attributed to ARIs, with the majority of the burden in low- and middle-income countries (LMICs) [3]. Previous studies have highlighted several factors as potential contributors to ARI, including different respiratory viruses such as respiratory syncytial virus (RSV), influenza, rhinovirus and adenovirus, as well as bacterial pathogens such as *Streptococcus pneumoniae*, *Haemophilus influenzae* type b and *Staphylococcus aureus* [4–8]. The mortality burden of RSV falls overwhelmingly on LMICs, which account for more than 97% of all RSV-related deaths worldwide [4]. The Democratic Republic of the Congo (DRC) has among the highest mortality rates of children under 5 years of age in Sub-Saharan Africa [3]. Our recent cohort study conducted in South Kivu province of eastern DRC (June 2018–January 2019) found that 60% of children under 5 years had acute respiratory symptoms and 14% had acute lower respiratory illness (ALRI) [9]. Given this ARI burden, many countries in Sub-Saharan Africa face resource constraints in preventing and managing ARI, highlighting the need for scalable and effective interventions [3, 10–13].

Water, sanitation and hygiene (WASH) interventions present a promising strategy to reduce ARI by targeting key transmission pathways within households and communities. WASH interventions can reduce ARI prevalence by limiting pathogen transmission through contaminated hands, surfaces and shared household environments. Washing hands with soap and treating water are broadly endorsed as critical means of preventing the transmission of enteric and respiratory pathogens [14, 15]. Previous studies highlighted that improving water quality, sanitation and handwashing with soap significantly decreased ALRI symptoms [16, 17]. In addition, research has identified the quality of stored drinking water and household water-handling behaviours as central factors in pathogen spread, offering a clear basis for delivering water treatment through mHealth-supported WASH programs [16, 18–21]. Furthermore, a recent systematic review and meta-analysis of 26 studies across 15 countries found that handwashing with soap can reduce ARI by 17% [22]. In addition, a trial conducted in rural Bangladesh found that improving water quality, sanitation and handwashing with soap significantly decreased ALRI symptoms (35% versus 46%) in young children [23]. Consistent with this, a randomized controlled trial (RCT) in Pakistan showed that households receiving soap and handwashing promotion had a 50% lower incidence of pneumonia for children < 5 years old compared to control households [24], and a trial in Rwanda found that a water filter intervention significantly reduced ARI [25]. Together, these findings highlight the potential of WASH interventions to reduce ARI across diverse low-resource settings.

Digital health approaches, particularly mobile health (mHealth), have emerged as scalable tools to promote health behaviours, including those relevant to infectious disease prevention. A previous systematic review found that in 10 out of 12 RCTs reviewed, mHealth interventions resulted in significant improvements in health outcomes [26]. A recent scoping review of the use of mHealth approaches in Sub-Saharan Africa found the implementation of mHealth interventions in at least 21 countries, however, most studies focused on chronic diseases or HIV, with no WASH mHealth interventions [27, 28]. Globally, mHealth has not been extensively used to promote WASH behaviour change. In Bangladesh, our research group developed the WASHmobile Cholera Hospital-Based Intervention for 7 days (CHoBI7) program, which delivers voice and text messages from a doctor at a healthcare facility on water treatment and handwashing with soap to diarrhoea patient households [16, 29]. In our RCT, this programme resulted in significant reductions in respiratory illness, diarrhoea and stunting among young children [16, 29]. A study in Kenya evaluated an Information, Communication and Technology (ICT)-based diarrhoea prevention strategy in which mothers of children under 5 years received mobile phone voice calls on diarrhoea symptoms, underlying causes and preventive actions for 4 days each week for 3 months; participants in the intervention arm subsequently reported engaging in handwashing with soap and treating their drinking water more frequently than those in the comparison group [30]. This mHealth program significantly reduced diarrhoea prevalence in the experimental group from 28% to 19.6% ($p = 0.002$) compared to the control group, which remained unaffected [30]. However, a study conducted in Haiti found that a SMS campaign was not a reliable or cost-effective way to change water treatment behaviour. The researchers recommended that any future SMS efforts should be kept simple, and designed to match how the target population actually uses their phones [31]. These findings suggest that mHealth platforms present a promising approach for delivering WASH interventions to high-risk populations.

Building on this evidence, targeted WASH mHealth interventions may be particularly valuable in high disease burden and resource-constrained contexts such as the DRC. In an effort to reduce diarrhoea and ALRI among high-risk households for diarrhoea in the DRC, we developed the WASHmobile Preventative Intervention for Cholera for 7 days (PICHA7) programme, a sister programme to WASHmobile CHoBI7 in Bangladesh, through community-centred formative research including semi-structured interviews and a pilot of 518 participants [32]. The WASHmobile PICHA7 mHealth program is a targeted WASH program promoting handwashing with soap, drinking water treatment and safe storage of water to reduce diarrhoea and respiratory illness in urban Bukavu in eastern DRC. In our recent cluster-RCT of WASHmobile PICHA7, we found that this intervention significantly reduced diarrhoea and increased handwashing with soap, water treatment and safe stored drinking water in diarrhoea patient households [33]. The objective of this study was to expand upon the results from the original RCT and investigate the impact of the WASHmobile PICHA7 program on acute lower respiratory illness (ALRI) among diarrhoea patients and their household members in urban Bukavu, eastern DRC.

## 2 | Methods

### 2.1 | Study Design and Study Population

The WASHmobile PICHA7 program was a two-arm RCT conducted in urban Bukavu, South Kivu province, eastern DRC from December 22, 2021, to December 20, 2023 (NCT05166850)



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[33]. Daily in-person diarrhoea patient surveillance was conducted at 115 public and private healthcare facilities where diarrhoea patients were recruited over the study period. The RCT study design enables robust comparison between intervention and control groups to evaluate the effect of the intervention on ALRI prevalence [34, 35].

In this RCT of the WASHmobile PICHA7 program, 2334 participants were randomized by household to be in one of the two arms. The standard arm received the standard message on oral rehydration solution (ORS) and a basic WASH message that is given by the DRC government to diarrhoea patients. The WASHmobile arm received the standard message and the WASHmobile PICHA7 intervention, which included weekly voice and text mHealth messages and quarterly in-person visits for 12 months.

For a diarrhoea patient to be eligible, they needed to meet the following criteria: (1) be admitted to a healthcare facility with $\geq 3$ loose stools over a 24 h period; (2) have no running water inside their home (mostly informal settlement areas); (3) provide a blood and a stool sample within 24 h of enrolment (for aetiology of diarrhoea); (4) plan to reside in Bukavu for the next 12 months (assessed during screening prior to study enrolment); (5) have a child $< 5$ years of age in the household; and (6) have at least one working mobile phone in the household. The eligibility criteria for household members of the diarrhoea patient were as follows: (1) they shared the same cooking pot and resided in the same home with the diarrhoea patient for the last 3 days; and (2) they planned to reside with the diarrhoea patient for the next 12 months (assessed during screening prior to study enrolment).

A comprehensive description of the intervention procedures has been published previously [32, 33]. The WASHmobile PICHA7 intervention promotes five hygiene and safe drinking water practices: (1) making soapy water by mixing water with detergent powder or leftover pieces of bar soap; (2) washing hands with soap or ash during food-related and post-defecation occasions; (3) storing drinking water safely in a container that is fully covered; (4) household drinking water treatment with chlorine tablets; and (5) heating household drinking water until reaching a rolling boil after the initial 7-day high-risk period. Over a 12-month period, households enrolled in the WASHmobile PICHA7 arm received voice calls, interactive voice response (IVR) quizzes and SMS messages weekly using the engageSPARK platform [36]. Figure 1 provides examples of the three types (voice, IVR and SMS) of mobile messages sent to the WASHmobile PICHA7 households. The WASHmobile PICHA7 intervention and messages were delivered in the local Swahili dialect. The full set of messages sent during the program is published elsewhere [36].

## 2.2 | Assessment Procedures

Over the 12-month surveillance period, self-reported respiratory symptoms were assessed through monthly clinical surveillance. For the children under 5 years old, a monthly clinical surveillance questionnaire was completed by the primary caregiver. Respiratory illness outcomes were exploratory. ALRI was defined based on the WHO Integrated Management of Childhood Illness criteria for classifying pneumonia in children, requiring the presence of at least one of the following criteria: (1) coughing and rapid breathing or (2) difficulty breathing and rapid breathing [37]. Log-binomial regression was performed to estimate the

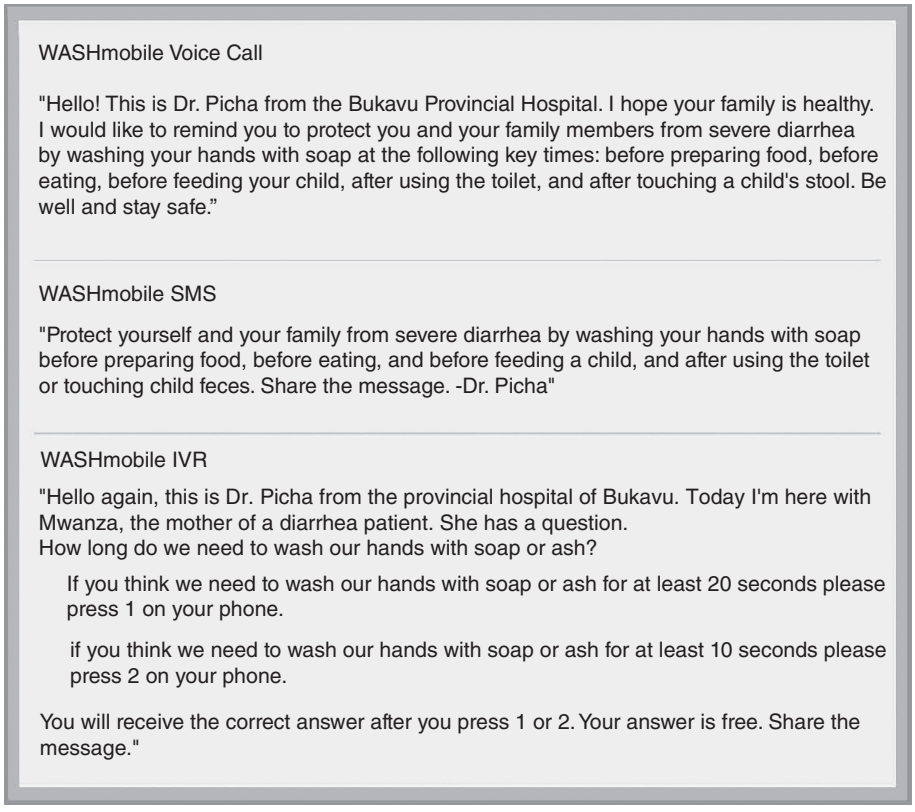


**FIGURE 1** | Example of WASHmobile PICHA7 voice, IVR and text messages.



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prevalence ratio (PR) for ALRI using generalized estimating equations (GEE) to account for clustering at the participant and household levels. We used SAS software version 9.4 to perform analyses (SAS Institute Inc., Cary, NC, USA). The outcome was self-reported (or caregiver-reported) ALRI at least once during follow-up (month 1 to month 12), with the predictor as study arm.

## 2.3 | Power Calculation

For this RCT, the number of participants needed was determined according to the study's primary outcome measure, which was diarrhoea prevalence. An overall diarrhoea prevalence of 10% across all age groups was estimated based on data from the Global Burden of Disease Study [38], and a diarrhoea prevalence of 22% among children under 5 years based on data from the DRC Demographic and Health Survey [39]. The power calculation was based on a type 1 error rate (α) of 0.05, statistical power (1-β) of 0.80, and assuming six individuals in each household (from WASHmobile PICHA7 pilot surveillance data). Given these assumptions, 250 households with a diarrhoea patient were needed per arm [40] (500 households total) and 3000 participants (six individuals per household). The resulting sample was powered to detect a 2.5% reduction in diarrhoea prevalence overall (all age groups) (10% in the standard arm versus 7.5% in the intervention arm) and a 5.5% reduction among children under 5 years of age (22% versus 16.5%).

## 2.4 | Ethical Review

The Université Catholique de Bukavu (7107) and the Johns Hopkins Bloomberg School of Public Health Institutional Review Board (9848) approved the study protocol.

## 3 | Results

The RCT of the WASHmobile PICHA7 program enrolled a total of 2334 participants across both study arms (1138 in the standard arm and 1196 in the WASHmobile PICHA7 arm). Baseline characteristics were similar across study arms (Table 1). At baseline, 34% (406/1196) of participants were under 5 years of age in the WASHmobile PICHA7 arm and 34% (388/1138) in

**TABLE 1** | Demographics information at baseline by study arm.

| Baseline Demographic Information | Standard arm | | | WASHmobile PICHA7 arm | | | *p* |
|---|---|---|---|---|---|---|---|
| | *%* | *n* | *N* | *%* | *n* | *N* | |
| Study participants | — | — | 1138 | — | — | 1196 | |
| Children under 5 years of age | 34% | 388 | 1138 | 34% | 406 | 1196 | 0.975 |
| Household member age | | | | | | | |
| Mean ± SD (min–max) (years) | 8.74 ± 13.31 (0.00–70.70) | | | 8.86 ± 13.82 (0.00–70.54) | | | |
| Gender | | | | | | | |
| Female | 58% | 663 | 1138 | 59% | 709 | 1196 | 0.646 |
| Household roof type | | | | | | | 0.225 |
| Concrete | 5% | 60 | 1100 | 5% | 61 | 1149 | |
| Tin | 93% | 1022 | 1100 | 92% | 1057 | 1149 | |
| Other | 2% | 18 | 1100 | 3% | 31 | 1149 | |
| Household wall type | | | | | | | 0.003 |
| Concrete | 23% | 251 | 1100 | 28% | 325 | 1149 | |
| Other | 77% | 849 | 1100 | 72% | 824 | 1149 | |
| Household floor type | | | | | | | < 0.001 |
| Concrete | 37% | 412 | 1100 | 53% | 607 | 1149 | |
| Other | 63% | 688 | 1100 | 47% | 542 | 1149 | |
| Any current household income | 92% | 1012 | 1100 | 97% | 1102 | 1141 | < 0.001 |
| Refrigerator ownership | 3% | 30 | 1100 | 5% | 52 | 1149 | 0.031 |
| Two or more sleeping rooms in home | 83% | 911 | 1100 | 90% | 1039 | 1149 | < 0.001 |
| At least one household member can read and write | 98% | 1080 | 1100 | 98% | 1130 | 1149 | 0.204 |

*Note: p* value calculated with Pearson's Chi-squared test with Yates' continuity correction.
Abbreviation: SD, standard deviation.



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**TABLE 2** | Baseline respiratory illness measures.

| Baseline respiratory illness in past 2 weeks | Standard arm | | | WASHmobile PICHA7 arm | | | p |
|---|---|---|---|---|---|---|---|
| | % | n | N | % | n | N | |
| All ages | | | | | | | |
| Coughing | 26% | 223 | 866 | 23% | 211 | 905 | 0.356 |
| Difficulty breathing | 4% | 36 | 858 | 4% | 37 | 902 | 1.000 |
| Rapid breathing | 5% | 45 | 858 | 4% | 32 | 901 | 0.106 |
| Wheezing | 2% | 18 | 857 | 2% | 21 | 905 | 0.879 |
| ALRI | 4% | 31 | 866 | 2% | 20 | 907 | 0.112 |
| Children under 5 years of age | | | | | | | |
| Coughing | 33% | 106 | 324 | 30% | 103 | 341 | 0.539 |
| Difficulty breathing | 8% | 26 | 321 | 5% | 17 | 338 | 0.151 |
| Rapid breathing | 7% | 23 | 320 | 5% | 16 | 321 | 0.247 |
| Wheezing | 4% | 13 | 320 | 5% | 17 | 338 | 0.684 |
| ALRI | 6% | 21 | 324 | 4% | 13 | 341 | 0.166 |

*Note:* ALRI (acute lower respiratory illness) was defined as cough and rapid breathing or rapid breathing and difficulty breathing in the past 2 weeks. Respiratory illness measurements assessed via self-report (caregiver-reported for children). *p* value calculated with Pearson's Chi-squared test with Yates' continuity correction.

the standard arm. Fifty-nine percent (709/1196) of participants were female in the WASHmobile PICHA7 arm compared to 58% (663/1138) in the standard arm. In both the WASHmobile PICHA7 arm and standard arm, 98% of participants (1130/1149 versus 1080/1100) resided in a household that had at least one household member that could read and write. Five percent of participants (52/1149) in the WASHmobile PICHA7 arm and 3% (30/1100) in the standard arm resided in households that reported refrigerator ownership (Table 1). Ninety-seven percent of participants (1102/1141) in the WASHmobile PICHA7 arm and 92% (1012/1100) in the standard arm reported residing in a household with any current source of income (Table 1).

Twenty-three percent (211/905) reported coughing in the WASHmobile PICHA7 arm versus 26% (223/866) in the standard arm, 4% (37/902) reported difficulty breathing in the WASHmobile PICHA7 arm versus 4% (36/858) in the standard arm, 4% (32/901) reported rapid breathing in the WASHmobile arm versus 5% (45/858) in the standard arm and 2% (21/905) reported wheezing in the WASHmobile PICHA7 arm versus 2% (18/857) in the standard arm (Table 2). For participants under 5 years of age at baseline, 4% (13/341) of participants had caregiver-reported ALRI in the WASHmobile PICHA7 arm compared to 6% (21/324) in the standard arm, 30% (103/341) had caregiver-reported coughing in the WASHmobile PICHA7 arm versus 33% (106/324) in the standard arm, 5% (17/338) had caregiver-reported difficulty breathing in the WASHmobile PICHA7 arm versus 8% (26/321) in the standard arm, 5% (16/321) had caregiver-reported rapid breathing in the WASHmobile PICHA7 arm versus 7% (23/320) in the standard arm, and 5% (17/338) had caregiver-reported wheezing in the WASHmobile PICHA7 arm versus 4% (13/320) in the standard arm.

The WASHmobile PICHA7 arm had a significantly lower prevalence of ALRI compared to the standard arm for children under 5 years of age during the 12-month surveillance period (PR: 0.46 [95% CI: 0.22, 0.94]) (Table 3). Four percent (14/360) of children in the WASHmobile PICHA7 arm reported ALRI during the study period compared to 12% (39/339) of children in the standard arm. There was no significant difference between the WASHmobile PICHA7 arm compared to the standard arm for all age groups (PR: 0.68 [95% CI: 0.35, 1.32]).

**TABLE 3** | Effects of WASHmobile PICHA7 program on ever having acute lower respiratory illness over study period.

| Study arm | n | N | % | Prevalence ratio (95% CI) |
|---|---|---|---|---|
| ALRI | | | | |
| All age groups | | | | |
| Standard arm | 35 | 1000 | 4% | — |
| WASHmobile PICHA7 arm | 25 | 1074 | 2% | 0.68 (0.35, 1.32) |
| Under 5 years | | | | |
| Standard arm | 39 | 339 | 12% | — |
| WASHmobile PICHA7 arm | 14 | 360 | 4% | 0.46 (0.22, 0.94) |

*Note:* ALRI (acute lower respiratory illness) was defined as cough and rapid breathing or rapid breathing and difficulty breathing in the past 2 weeks at least once over the study period from month 1 to 12 month follow up. Respiratory illness measurements assessed via self-report (caregiver-reported for children).

## 4 | Discussion

The WASHmobile PICHA7 mHealth program significantly reduced ALRI among children under 5 years of age in eastern



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DRC. This result suggests that weekly voice and text messages and quarterly home visits are sufficient to reduce ALRI over a 12-month period in our humanitarian context in the DRC. These findings complement our previous findings from the RCT of WASHmobile PICHA7 that found this intervention significantly reduced healthcare facility visits for diarrhoea, diarrhoea prevalence, serological markers of cholera, and stunting, and led to sustained increases in handwashing with soap and water treatment [33]. These findings demonstrate the broader health benefits of the WASHmobile PICHA7 program across multiple health outcomes.

Our findings are consistent with prior evidence demonstrating the effectiveness of mHealth interventions in improving health behaviours and reducing infectious disease outcomes [16], and demonstrate that mHealth messaging can be used as a valuable tool to reduce respiratory illness. In the RCT of the WASHmobile CHoBI7 program in Bangladesh, a sister program to WASHmobile PICHA7, weekly voice and text messages and only a single home visit were sufficient to significantly reduce acute respiratory illness, diarrhoea, and stunting among young children, as well as lead to sustained improvements in stored drinking water quality and handwashing with soap [16]. Our findings are also consistent with previous studies that have found that mHealth interventions can improve behaviours important for transmission of respiratory illness such as mask wearing, handwashing with soap and using hand sanitizer [41]. For example, in Brazil, text messages were sent on COVID-19 preventative hygiene behaviours, which resulted in improved adherence to mask wearing and increased knowledge of correct social distancing [42]. This supports the use of mHealth as a scalable platform for promoting behaviours that reduce respiratory disease transmission.

We attribute the success of the WASHmobile PICHA7 mHealth program in reducing ALRI to several key features of our intervention. First, the community-centred formative research conducted for intervention development, which included semi-structured interviews, focus group discussions and a pilot study to tailor the intervention specifically to the communities at our study site [32]. Second, mobile messages coming from Dr. Picha, a doctor at a local hospital, who encouraged participants to perform handwashing with soap behaviours. Third, the use of a combination of voice and text messages, which allowed participants to both listen to voice calls and read and save text messages to share later with other household members. The IVR messages also actively engaged household members and assessed if they understood the different WASH guidance provided during the WASHmobile PICHA7 sessions. Our recent process evaluation of the WASHmobile PICHA7 program found that 84% of households received the unique text messages sent and 90% of unique voice and IVR messages were answered [36]. Future studies are needed of WASHmobile in different contexts and populations to evaluate the impact of this mHealth intervention on ARI globally and its overall generalizability.

This study has some limitations that should be considered when interpreting study findings. First, the WASHmobile PICHA7 program utilized participant and caregiver-reported respiratory symptoms defined based on the WHO Integrated Management of Childhood Illness criteria. No clinical diagnosis of respiratory symptoms was conducted. Future studies should consider collecting clinical specimens and testing for the aetiology of infections. Second, the WASHmobile PICHA7 program was focused on diarrhoea patients and their household members. Future studies should broaden the scope of this intervention to focus on high-risk areas for respiratory illness such as areas with limited WASH infrastructure available. Third, this exploratory analysis was underpowered to detect true differences in respiratory infections. Future studies should further investigate these differences in respiratory infections.

This study has three important strengths. First, most of the previous research on the effect of WASH on respiratory illness has been conducted in rural areas [9, 23, 43]. This research study builds on these previous studies by assessing WASH activities on the respiratory illness in an urban setting, focusing on a population that previous studies rarely assessed [22, 23, 44]. Second, the RCT of WASHmobile PICHA7 was conducted over a 12-month period, which allowed us to address the potential impact of seasonality on study findings. Third, monthly clinical surveillance was conducted at all timepoints, which helped our study to closely assess ALRI over the study period. These strengths enhance the validity and relevance of the study findings for similar urban, low-resource settings.

In conclusion, the WASHmobile PICHA7 mHealth program was effective in significantly reducing ALRI among children under 5 years of age over a 12-month period (4% versus 12%). Our results suggest that the WASHmobile PICHA7 program can be used in our humanitarian context to reduce ALRI. This complements our findings demonstrating that WASHmobile PICHA7 significantly reduced healthcare facility visits for diarrhoea, diarrhoea prevalence, serological markers of cholera, and stunting, and improved WASH behaviours among household members of diarrhoea patients including drinking water chlorination, handwashing with soap and safe storage of drinking water [33]. These findings support the potential for scaling WASHmobile interventions to reduce both ALRI and diarrheal disease burdens in similar settings.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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## Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Effects of WASHmobile PICHA7 program on ever having acute lower respiratory illness over study period adjusted for SES factors.



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