Effect of handwashing with soap at critical times and home based water treatment in combating hot spot areas of childhood diarrhea in Ethiopia

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Abstract

Introduction

Effective intervention needed to reduce childhood diarrhea, a significant cause of morbidity in resource-limited settings. This intervention aimed to evaluate the effectiveness of handwashing with soap at critical times, home-based water treatment and both combinations to reduce childhood diarrhea in hotspot areas of southwestern Ethiopia.

Methods

Community randomized control with the factorial design was conducted in southwestern Ethiopia from July to October 30/2020. About 720 households were maintained and equally allocated for handwashing with soap at critical times, home-based water treatment, and both combined interventions having 180 households that were followed up for four months. Baseline data were collected at the first two weeks from 720 households of intervention groups. Data was processed and entered into EPI data version 3.02. Homogeneity of the baseline characteristics of the participant in both groups was checked at a p-value less or equal to 0.05. The incidence of childhood diarrhea per 100 per two weeks was measured in both groups. Mann-Kendall trend test was performed to check the statistical significance patterns of childhood diarrhea. Intention-to-treat analysis was used to compare the incidence of childhood diarrhea for both groups. A generalized estimating equation with a logit-link Poisson distribution family and the exchangeable working correlation, with robust standard error estimation, was used for the analysis of repeated observations of the incidence of childhood diarrhea in individuals over time. An unadjusted and adjusted incidence rate along with the corresponding 95% CI was analyzed by using a multivariable analysis to control potential confounders on Stata 14 software.

Results

Childhood diarrhea significantly decreased in all intervention groups but increasing in control groups. Particularly, handwashing with soap at critical times has reduced childhood diarrhea incidence by 45% (IRR = 0.55, 0.48, 0.61, P < 0.001). Similarly, home-based water treatment reduced by 52% (IRR = 0.48, 0.42, 0.54, P < 0.001). Likewise, a combination of handwashing with soap and home-based water treatment has reduced childhood diarrhea by 60% (AOR = 0.40, 0.36, 0.47, P < 0.001) after adjusting potential confounders.

Conclusion

This study indicated single and combined interventions reduced childhood diarrhea. Promoting these effective or promising intervention effects in rural communities would save many lives of children from diarrhea.

Trial registration
Introduction

Childhood diarrhea (CHD hereafter) is caused by enteric pathogenic bacteria, viruses, and parasites [1, 2]. CHD remains a major public health threat with nearly 1.7 billion cases occurring annually in the second for 578,000 deaths [3]. CHD spreads from person to person, aggravated by poor personal hygiene [4] and poor quality of water, sanitation and hygiene that account for 1.7 million deaths, with a significant majority of deaths in developing countries [5].

Global estimates of deaths from CHD have shown a decline from 2.5 million in 2000 to 1.4 million in 2010 [6] which is still spread all over the world, especially in developing regions such as Africa, South East Asia, and the Eastern Mediterranean, where there is rapid population growth, increased urbanization, limited infrastructures and health system [2, 7]. While mortality rate declined globally but in Africa, the region is seven times higher than that in the European region [8, 9]. Although mortality attributed to CHD has decreased significantly over the past 15 years, the morbidity has changed little, but in 2013, 578,000 died from CHD [10], 54% of these deaths were in Sub-Saharan and 25% in Nigeria [11, 12], that the third leading cause of death in children in Ghana [13].

However, in Ethiopia, annually, CHD kills half a million children next to pneumonia that affected by poor sanitation, shortage of clean water supply and poor personal hygiene, responsible for 90% of CHD occurrence [14]. The 2011 Demographic and Health Survey Ethiopia (EDHS) findings showed that 13% of the children had a CHD in two weeks including South Nation Nationality and People Region (SNNPR) [15]. The proportion of CHD morbidity in Ethiopia is about 22.6% in the different regions with a median of 45%. Similarly, in the northwest parts of Ethiopia, the annual incidence rate was 155.3 per 1,000 populations at risk with varied greatly across the study districts [16]. The previous study in this study area reported that socio economic and environmental factors contributed CHD in Sheko district, Bench Maji Zone, southwest Ethiopia [17]. Additionally this study area is noticed as a CHD hotspot areas due to multiple factors that need due attentions (Fig. 1).

To curve the burden of CHD, improvements in water, sanitation, and hygiene have been considered key public health interventions in low- and middle-income countries [18]. Among various interventions of CHD, handwashing is the simplest and most effective way to prevent diarrhea on under five children [19]. Mainly, hand wash with soap has significant effects on CHD that reduce by 42–47% [20]. The level of CHD risk is too variable like higher among children whose mothers did not wash hand with soap before food preparation, feeding and after leaving the toilet [21]. Moreover, hygiene interventions, particularly the provision of soap for handwashing, effectively reduce diarrhea morbidity, and there does not appear to be evidence that compliance falls over time.

A study revealed that the prevalence of CHD was 18.3% that is affected by individual and community level factors, summarized as the following, not washing hands during critical times were 4.6 times risk for CHD while sharing the same residence with domestic animals were 2.87 times more at risk for CHD.
Particularly obtaining drinking water from unimproved sources was 2.53 times riskier for CHD. In addition, mothers with limited knowledge about diarrhea were 76% less likely at risk for CHD, and starting supplementary child feeding at age less than six months were 35% less likely risky for CHD [22]. This factor implies multiple interventions are required to prevent CHD with factorial design.

Several interventional studies were done like p-value a cluster randomized control trial in Pakistan on the effectiveness of handwashing promotion in CHD high-risk communities that decreased the incidence of diarrhea by 39% [23]. Similarly, WASH interventions showed CHD reductions between 27% and 53% among children [24]. In another study conducted in Dabat district northwestern Gonder, cluster-randomized control trial on the intervention of SODIS as a water treatment for household, diarrhea incidence decreased 40% [25]. Similarly, at Jijiga district eastern Ethiopia community-based cluster randomized control trial on handwashing with soap and WASH education has decreased the incidence of CHD by 35% [26]. Moreover, mainly household water treatment has been recognized as a cost-effective means of reducing the burden of CHD and other waterborne diseases, especially among populations without access to improved water supplies [27], where strategies to improve the microbial quality of drinking water can be applied at the source or in the household. Water source includes protected wells, boreholes and public tap stands [28]. Whereas household strategies include improved water storage or approaches for treating water, such as chlorination, solar disinfection, filtration, or combined flocculation and disinfection [24].

Despite the availabilities of few studies on interventions on CHD, there are no or limited evidence of handwashing with soap at a critical time and home-based water treatment at the household level in this study area. Additionally, combination effects the intereventions that aimed to control the prevailing burden of CHD through community randomized control trial (cRCT) also limited. Thus, the cRCT interventional trial was planned to significantly reduce the peaking of CHD in hotspot areas.

The rationale for designing the cRCT intervention is due to the CHD burden prevailing in southwest Ethiopia based on research findings and related empirical evidence [22]. As a result, we have found a high burden (36.1 per 1,000) of CHD with significant variation between the districts in southwest Ethiopia. To respond to the CHD effects, the cRCT is claimed to be used to identify the cause-effect relation between the outcomes and reduced CHD burden. Mainly, avoid any population bias, easier to blind analyzed with well-known statistical tools; populations of participating individuals are identified in-group.

Evidence needed on all potential intervention measurements with handwashing intervention at a critical time, where the intervention households benefited directly with gain health education and soap for handwashing purpose to prevent the incidence of CHD. Since the intervention is simple and costs useful for all family members, specifically low-income countries like Ethiopia can apply the results to prevent CHD and other communicable diseases. Furthermore, it was used for concerned bodies, policymakers’ executive/implementers and governmental or non-governmental bodies to focus on specific CHD prevention intervention and contribute to the future research hypothesis. Thus, this intervention aimed to
evaluate the effectiveness of handwashing with soap at a critical time and home-based water treatment to CHD in hotspot areas of southwestern Ethiopia, 2020.

Methods

Study setting and period

The study was conducted in North Bench district, Bench Maji zone, southwestern Ethiopia, which is found 550km from Addis Ababa, from February to July 30/2020. The projected populations are 148,285 of which 71,177 men and 77,108 women. The district has 24 kebeles with 29,610 households with an average family size of 4.14 persons (Fig. 2).

Study design and sample size calculation

A factorial community based clustered RCT was used to conduct an intervention in southwestern Ethiopia. The intervention households were selected randomly for RCT based on the established criteria. The sample size was determined based on the method developed by Hayes and Bennett [29] and using the following assumptions: 6.3 episodes/100 person week observation among control group from previous similar trials [26], 80% statistical power, a 95% confidence and considered both type I and type II errors. As per the guidelines of cluster-randomized trials in health service research, intracluster coefficient (ICC) is an appropriate way to estimate cluster variability and 0.02 was maintained. About 720 households were selected that expected to detect forty percent (40%) difference in episodes between the intervention and control groups, including design effects of 1.38 [25]. Finally, 720 households have been equally allocated with a ratio of 1:1 for each arm. The study has four arms as households used only handwashing with soap at a critical time, households provided Wuha Agar (a solution used for water treatment) for home-based water treatment, both combinations of handwashing with soap at six critical times and home-based water treatment, and control, which have no any intervention activity.

Participants eligibility criteria

Baseline characteristics of households (HH) with children were assessed before the intervention. The baseline data included HH characteristics (socioeconomic and WASH status), child status (age, gender, vaccine status, time for supplementary feeding). Oral informed consent was obtained from the mother/caregivers of the selected child. A household was considered eligible if the following criteria are met: 1) least one child aged 0–59 months living in the home, 2) not being a model household, (households that successfully implement all 16 packages of the Health Extension Program (HEP) are officially certified as a model health extension household, 3) mothers/caregivers of U5 children living in the study area for at least four months and have no plan of migrating during the study period, 4) the children was excluded, when they are seriously sick by an other disease at the time of study and are referred to a near health facility, 5) the communities using only untreated drinking-water sources, 6) unavailability of drinking water-quality management and diarrhea intervention programs in the community.
Randomization process and masking

A randomization process was done to address the targeted children in both groups. The proportions of the households were 1:1 ratio for groups and 720 households with under-five children were randomized and followed for four months (Fig. 3).

The North Bench district was among the hotspot areas of CHD selected using the lottery method that have 29610 households. About 720 households were selected based on the eligibility criteria. The purpose of the study did not inform field workers and the study participant. The randomization was performed based on CONSORT (Consolidated Standards of Reporting Trials) statement flow chart designed to conduct effective randomization such as enrollment of participants, allocations of intervention, following up and analysis from the trial (Fig. 3).

Intervention approaches

Interventions were given after preparing an activity protocol designed to prevent CHD at the HH level. The intervention activity was a key message that was provided to eligible HHs bi-weekly for the next four months after a practical demonstration and providing key health messages at the individual HH level by assigning fieldworkers. Identical Plain soap, *Wuha agar*, and both plain soap and *Wuha agar* were provided for eligible HHs after an active demonstration. Printing materials (leaflets) were prepared in Amharic stating six critical times of HW with key messages. Pictorial depiction of the critical times was provided for those who could not read print materials. The message was reinforced every two weeks of visiting, one bar of soap and one bottle of *Wuha agar* was provided to the families in the intervention HHs. In contrast, in the control HHs there is no interventions provide for the prevention of CHD, but the field workers collect and record the incidences of diarrhea every two weeks for four months. Impression materials (leaflets) were prepared with critical messages in Amharic stating the critical HW time and amount of WuhaAgar for water treatment. The pictorial representation of the critical times and water treatment for those unable to read printed materials were provided. The message was enforced every two weeks of stay, and the families were supplied with one bar of soap and Wuha agar for respective HHs. There is no intervention for the control groups to minimize the incidence of diarrhea. Field workers were collected, recorded the incidence, managed the case for the consecutive four months, and reported the incidence of diarrhea every two weeks. The intervention was undertaken based on intervention modality such as washing hands with soap at six critical times (demonstrated & health educations give), using 20 liter jerry can or pot to treat the water with Wuha agar solution, providing key messages on CHD meaning, ways of transmission, methods of prevention and controlling diarrhea at HH level through HW.

Data collection and outcome assessment

Assigned field workers from June 15–30 /2020, collected the baseline data. At each visit, the fieldworker was collecting data of incidence Diarrhea happen on under-five children from the mother/caregiver of the child. The primary outcome was the incidence of diarrhea, from both receiving the intervention and control groups. CHD data were recorded and following the recommended standard definition of diarrhea.
[2]. The primary caretakers were instructed to follow and report the occurrence of diarrhea within two weeks. CHD is defined as the passage of the loose or watery stool at least three or more times in a day occurring and recorded for both intervention and control groups [2].

Follow up and data management

The questionnaire was initially prepared in the English language and then, it was translated into Amharic and then back to English language-by-language Experts to check the consistency. Data collectors were selected based on their experience and willingness then, three days of training was given separately on the data collection format, procedure, and demonstration for intervention and control groups. Supervisors were assigned and monitor the data collection process. The collected data were checked for accuracy, consistency, and completeness. Any missed or incomplete data of response was correct at the time of data collection day. Close follow up was done with field workers for four months. Upon closing the intervention, data were cross-checked by supervisors and baseline and follow-up visit data forms was checked for completeness and consistency.

Statistical analysis

Data was entered into EPI data version 3.02 and exported to StataSE14 software for statistical analysis. Intention-to-treat analysis was used to compare the incidence of CHD for intervention and control groups. The baseline data was analyzed to check the homogeneity of both study groups, such as continuous variables with non-normal distribution were reported as medians (IQRs), and tested with Fisher’s exact test and discrete variables were presented as percentages. The incidence of CHD (IRR) (per 100 person-two weeks) children was measured for the intervention and control groups. Mann-Kendall trend test was performed to check the statistical significance of whether the incidence of CHD increase, decrease, or constant during the intervention period. Generalized Estimating Equation (GEE) with a log-link Poisson distribution family and the exchange working correlation, with robust standard error estimation, was used for the analysis of repeated observations of CHD incidence in individuals over time to consider the clustered nature of the data. The unadjusted and adjusted incidence rate ratio (IRR) along with the corresponding 95% confidence intervals (CI) was analyzed by using a multivariable analysis to address or control potential confounders [25, 30].

Results

The baseline characteristics of the participants

The baseline characteristics of the study participants were presented in the following consecutive tables (Table 1). Baseline assessments of 720 households from four groups were interviewed before the actual intervention on June 16–30, 2020. The median age of the caretakers was $33\pm4.93$, $34\pm6$, $33\pm5.14$, and $33\pm4.3$ for the control, hand washing, home-based water treatment, and both combined groups, respectively. The p-value revealed there is no significant difference between control and treatment groups in terms of socioeconomic variables.
Table 1
Baseline characteristics of the study participants

| Variables                        | Study participants(n = 180, N = 720) | Control | Hand washing | Home-based water treatment | Combined | p-value |
|----------------------------------|-------------------------------------|---------|--------------|-----------------------------|----------|---------|
|                                  |                                     | F (%)   | F (%)        | F (%)                       | F (%)    |         |
| Age of caregivers (Median + SD)  |                                     | 33±4.93 | 34±6         | 33±5.14                     | 33±4.3   | 0.134   |
| Mean family size (Median + SD)   |                                     | 4±0.75  | 3±0.76       | 4±0.87                      | 3±0.96   | 0.075   |
| The education level of caregiver |                                     |         |              |                             |          | 0.053   |
| No formal education              |                                     | 73(40.6)| 91(50.6)     | 100(56.6)                   | 82(45.6) |         |
| Primary education                |                                     | 72(40)  | 54(30)       | 52(28.9)                    | 72(40)   |         |
| More than secondary education    |                                     | 35(19)  | 31(17.2)     | 28(15.6)                    | 35(19.4) |         |
| Mothers/caregivers’ occupation  |                                     |         |              |                             |          | 0.076   |
| Farmer                           |                                     | 40(22.2)| 39(21.7)     | 39(21.70)                   | 33(18.3) |         |
| Merchant                         |                                     | 24(13.3)| 26(14.4)     | 27(15)                      | 25(13.9) |         |
| Student                          |                                     | 23(12.8)| 25(13.9)     | 32(17.8)                    | 25(13.9) |         |
| Government employee             |                                     | 7(3.90) | 6(3.3)       | 10(5.6)                     | 22(12.2) |         |
| House wife                       |                                     | 86(47.8)| 84(46.7)     | 82(45.6)                    | 75(41.7) |         |

*F: Frequency, SD: standard deviation

Drinking water supply among the study participants

Table 2 indicates drinking water sources, the average time to fetch water in a minute, water storage container, water storage washing frequency, average water users per individual per day per litter, water drawn and mean distance from the latrine to home were not significantly different among all study groups.
| Variables | Study participants (n = 180, N = 720) | Control F (%) | Handwashing F (%) | Home-based water treatment F (%) | Combined F (%) | P-value |
|-----------|--------------------------------------|--------------|------------------|----------------------------------|---------------|---------|
| Drinking water sources | | 0.307 | | | | |
| Protected spring | 151(83.9) | 138(76.7) | 154(85.6) | 148(82.2) | | |
| Unprotected spring | 21(11.7) | 25(13.9) | 18(10) | 20(11.1) | | |
| River | 17(9.4) | 8(4.4) | 8(4.4) | 12(6.7) | | |
| Time to fetch water minute(Median + SD) | 26±4.98 | 20±5.67 | 25±54 | 26±6.54 | 0.646 | |
| Water storage container | Jerry can | 110(61.1) | 128(71.1) | 116(64.4) | 125(69.4) | 0.110 |
| | Clay pot | 10(5.6) | 0 | 6(3.3) | 6(3.3) | | |
| | Plastic bucket | 60(33.3) | 52(28.9) | 58(32.3) | 49(27.2) | | |
| Water storage washing frequency | Every day | 129(71.7) | 118(56.6) | 111(61.7) | 128(71.1) | 0.131 |
| | Once a week | 35(19.4) | 39(21.7) | 40(22.2) | 39(21.7) | | |
| | Twice a week | 16(8.9) | 23(12.8) | 29(16.1) | 13(7.2) | | |
| water use p/c/d (Median + SD) | 12±1.40 | 12±1.22 | 15±3.22 | 15±1.52 | 0.106 | |
| Water drowns | Dipping | 65 | 62 | 72 | 82 | 0.126 |
| | Pouring | 115 | 118 | 106 | 98 | | |
| Distance from latrine to home(Median + SD) | 4±0.39 | 4±0.66 | 4±0.28 | 4±0.74 | 0.088 | |

F: Frequency, SD: standard deviation

### Children characteristics and handwashing practices of the participants

Table 3 indicates there is no significant difference in study groups, like a number of children per household, caregiver awareness on handwashing, handwashing practices at critical times, and COVID-
Table 3
Children characteristics and handwashing practices of the participants

| Descriptions of variables | Study participants (n = 180, N = 720) | p. value |
|---------------------------|---------------------------------------|----------|
|                           | Control                              | Hand washing | Home based water treatment | Combined |           |
|                           | Yes (%)                              | Yes (%)     | Yes (%)                   | Yes (%)  |           |
| Number of U5 children per household | 1 95(52.8)                          | 98(54.4)    | 95(52.8)                  | 108(60)  | 0.662    |
|                           | 2 85(47.2)                          | 82(45.6)    | 85(47.2)                  | 72(40)   |           |
| Care givers knows benefit of hand washing | 110(61.1)                          | 104(57.8)   | 117(65)                   | 110(61.1)| 0.576    |

Handwashing practices at critical times

| After caring /cleaning the baby | 50(20.8) | 37(20.7) | 51(28.3) | 47(26.1) | 0.312 |
| After contact with dirty matter | 53(29.4) | 54(30)   | 45(25)   | 50(27.8) | 0.718 |
| Before feeding child           | 129(71.7) | 117(65)  | 131(72.8) | 113(62.8)| 0.111 |
| Hand after toilet              | 47(26.1) | 41(22.8) | 51(28.3) | 43(23.9) | 0.629 |
| Before preparing food          | 88(48.9) | 79(43.9) | 83(46.1) | 76(42.2) | 0.611 |
| Before eating food             | 175(97.2) | 172(95.6)| 170(94.4)| 176(97.8)| 0.321 |
| Knowledge on COVID-19(Good)    | 64(35.6) | 81(45)   | 71(39.4) | 59(32.8) | 0.093 |
| Prevention practices of COVID-19 (Good) | 55(30.6) | 61(33.9) | 41(22.8) | 46(25.6) | 0.086 |

Incidence of childhood diarrhea during the intervention

Figure 4 indicates the incidence of CHD bi-weekly versus weeks of observation. There is a statistically significant decrease of incidence of CHD among handwashing with soap, home-based water treated, and in both combined groups, however, there is a statistically significant increasing trend in the incidence of CHD among control households.
Multivariable analysis of the effects of interventions on CHD

Table 3 shows the multivariable analysis of the effects of the intervention on CHD. Children age greater than 6 months was 60% (AIR = 40, 0.33, 0.50, p < 0.001) likely have developed diarrhea than the children age less than 6 months. Those households with no handwashing facilities were 62% (IRR = 0.38, 0.40, 0.42, P < 0.001) likely at risk of CHD than those with their counterparts did. Similarly, households consuming water less than 20 l/c/d were 28% at risk for CHD compared with households using more than 20 l/c/d (IRR = 0.72, 0.63, 0.82, P < 0.001). Whereas, households time to fetch water from sources greater than 30 minutes were 30% (IRR = 0.70, 0.61, 0.79, P < 0.001) likely have CHD than those households fetch water less than 30 minutes from sources. Similarly, households no formal education were 44% (IRR = 0.56, 0.51, 0.75, P < 0.001) have developed CHD and also being primary education level were 38% at risk for CHD than those households with more than secondary education level (IRR: 0.62, 0.53, 0.73, < P < 0.001). However, respondents with the occupational status of farmer, merchant, student and housewife were more at risk of CHD than the government employee.
### Table 3
Multivariable analysis of the effect of the intervention on the incidence of CHD

| Variables                        | CIRR (95% CI) | P-value | IRR(95% CI) | P-value |
|----------------------------------|---------------|---------|-------------|---------|
| **Age of child in a month**      |               |         |             |         |
| < 6                              | 0.16(0.15, 0.17) | < 0.001 | 0.40(0.33, 0.50) | < 0.001 |
| > 6                              |               |         |             |         |
| **Availability of handwashing facility** | No           | 0.92(0.89, 0.95) | < 0.001 | 0.38(0.40, 0.42) | < 0.001 |
| Yes                              | 1             |         |             |         |
| **Water consumption l/c/d**      |               |         |             |         |
| < 20                             | 0.96(0.93, 0.98) | 0.001   | 0.72(0.63, 0.82) | < 0.001 |
| > 20                             |               |         |             |         |
| **Time to fetch water, minute**  |               |         |             |         |
| < 30                             | 0.98(0.96, 1.01) | 0.25    | 0.70(0.61, 0.79) | < 0.001 |
| > 30                             |               |         |             |         |
| **Handwashing a critical time**  |               |         |             |         |
| No                               | 0.94(0.92, 0.97) | < 0.001 | 0.79(0.70, 0.89) | < 0.001 |
| Yes                              | 1             |         |             |         |
| **Caregivers’ education**        |               |         |             |         |
| Not formal                       | 0.89(0.86, 0.93) | < 0.001 | 0.56(0.51, 0.75) | < 0.001 |
| Primary                          | 0.86(0.83, 0.90) | < 0.001 | 0.62(0.53,0.73) | < 0.001 |
| More than secondary level        |               |         |             |         |
| **Caregivers’ occupational status** | Farmer       | 0.16(0.15,0.18) | < 0.001 | 0.38(0.32, 0.45) | < 0.001 |
| Merchant                         | 0.19(0.16, 0.23) | < 0.001 | 0.44(0.35,0.55) | < 0.001 |
| Student                          | 0.16 (0.14, 0.19) | < 0.001 | 0.38(0.31, 0.46) | < 0.001 |
| Housewife                        | 0.13(0.13, 0.18) | < 0.001 | 0.36(0.29,0.45) | < 0.001 |
| Employed                         |               |         |             |         |

Significant at p-value < 0.05, **CIRR**: Crude Incidence rate ratio, **IRR**: Adjusted incidence rate ratio; **CI**: Confidence interval
| Variables | CIRR (95% CI) | P-value | IRR(95% CI) | P-value |
|-----------|--------------|---------|-------------|---------|
| Family size | > 5 | 0.15(0.11, 22) | < 0.001 | 0.82(0.68,1.00) | 0.056 |

Significant at p-value < 0.05, CIRR: Crude Incidence rate ratio, IRR: Adjusted incidence rate ratio; CI: Confidence interval

**Effects of intervention on CHD adjusted for effects of potential confounders**

Table 4 shows the results of Generalized Estimating Equation (GEE). Handwashing at critical times reduced incidence of CHD by 45% (IRR: 0.55, 0.48, 0.61, P < 0.001) as compared with control groups. Similarly home based water treatment reduced incidence of CHD by 48% (IRR = 0.52, 0.42, 0.54, P < 0.001) as compared with control groups. Additionally, 60% (IRR = 0.40, 0.36, 0.46, P < 0.001) of CHD have been reduced from households intervened with both interventions after adjusting potential confounders.

| Treatment | CIRR (95% CI) | P-value | IRR(95% CI) | P-value |
|-----------|--------------|---------|-------------|---------|
| Hw        | 0.99( 0.96,1.02) | 0.595 | 0.55(0.48, 0.61) | < 0.001 |
| HWT       | 0.97(0.94 .99) | 0.043 | 0.48(0.42, 0.54) | < 0.001 |
| HW + HWT  | 0.93(0.90, 0.96) | < 0.001 | 0.40(0.36, 0.47) | < 0.001 |
| Control   | 1            |        |             |         |

Significant at p-value < 0.05, Hw: Hand washing, HWT: Home based water treatment, CIRR: Crude incidence rate ratio, IRR: Adjusted incidence rate ratio; CI: Confidence interval

**Discussion**

This study revealed that there was a 45% (IRR: 0.55, 0.48, 0.61, P < 0.001) reduction of CHD incidence among households intervened with handwashing with soap at critical times, which is constituent with previous findings reported a 42–47% reduction [31]. Another finding from Pakistan indicated a 53 %, diarrhea reduction [32] and a 33% in Malawi [33] despite the level of reduction varied. The variation in reduction might be due to caregivers’ handwashing practices and knowledge on diarrhea prevention. Moreover, different findings were reported different results across the RCT that might be due to adherence to intervention, earlier handwashing behavior, awareness on handwashing benefits and education level of the study participants that affect the intervention [34, 35]. Insights suggest that preventive interventions
tend to be adopted more slowly as benefits are difficult to observe and users presumably discontinue treatment [36].

Evidences noticed that handwashing with soap eliminates transient potentially pathogenic organisms from the hands through the influences of microbial effectiveness [35], despite a complete change of handwashing behavior remains challenged [37]. Particularly handwashing before preparing food is a mostly imperative opportunity to avert CHD that appears to be a primary means of prevention where intervened households had a lower prevalence of CHD [38, 39]. Moreover, compared with controls, children in households with plain soap had a 53% lower incidence of CHD in Karachi, Pakistan [40].

Our result suggested a 52% (IRR = 0.48, 0.42, 0.54, P < 0.001) reduction in CHD from home based water treatment households, which is comparable to the findings of a 48.0% reduction in Zambia [41], but higher than a 36% reduction in Dire Dawa, eastern Ethiopia [42]. It is evidenced that home based water treatment minimizes the risk of recontamination despite the improved water supply system [43–45]. Mostly, improved drinking water source alone is implausible to prevent CHD unless attention is also given to improving household water storage, and handling practices [46]. Besides, finding suggest a positive association between Escherichia coli counts in drinking water, (water as a vector for pathogens) and CHD [47]. More findings noted that 1.8 billion people globally use a source of drinking water suffered from faecal contamination. Moreover, drinking water is found to be a 41% more often contaminated in rural areas than in urban settings where a 53% contamination is most prevalent in Africa [48]. As a result, home based water treatment is the most cost effective among all water quality interventions that could be affordable for many of the households if they have access to the service [49] and a promising strategy to reach the under resourced areas with high CHD. Adopting household water treatment and safestorage systems, such as chlorination and filtration, in both development and emergencies to support reductions in CHD.

Despite numerous studies demonstrated the effectiveness of home based water treatment and preventing diarrhea, the magnitude of CHD reduction were varied across the studies. For instance, a 23.0% and 11% reported from Ghana [50], 90.0% in Liberia [51], 59.0% in Haiti, Kenya, and Nicaragua [52], 58.0% in Kersa District, Ethiopia [53]. The reason might be due to adherence and compliance with treatment, water-handling practices to the extent of preventing recontamination [54]. Likewise, there might be the presence of chlorine-resistant parasitic protozoa such as oocysts of the Cryptosporidium species and cysts of Giardia lamblia [55]. In other parts, discontinuous use of the water treatment product due to the odor and taste of sodium hypochlorite may be a reason for these disparities in magnitude of the reduction [42]. Moreover, the correct and consistent usage of treated water relies almost exclusively on the consumer behavior [43]. In addition, households received the intervention might have been grateful and, out of courtesy, reported no or less CHD [56]. Mainly a 35% baseline imbalance reported in quantifying bias in randomized controlled trials [57] that might be several reasons for variations of findings from unique intervention.
Our finding indicated a 60% (IRR = 0.40, 0.36, 0.47, P < 0.001) CHD reduction among households intervened with both handwashing with soap and home based water treatment. This study was constituent with the previous findings that the combination of home based water treatment and handwashing with soap have an additive effect, or synergistic effect of tackling multiple transmission routes simultaneously [58]. In addition, the magnitude of CHD reduction was consistent with the previous evaluations result [59]. In fact combining intervention could yield synergistic benefits, where coupling home based water treatment and handwashing intervention reduced recontamination of treated water through cleaner hands [60]. It is indicated that, with more-intensive promotion of behavioral changes, the combined interventions would have had greater effects, as seen in small scale trials of handwashing and chlorination of household water [38]. The highest magnitude of the protective effect in this study could be attributed to the high compliance of the intervention as observed during both scheduled and unannounced visits as compared with the previous findings.

In contradictory, findings revealed that there were no detectable interaction effects of the combined intervention, that does not seem to be additive [61]. The reason might be due to the slow implementation of intervention, lack of focus or lack of sufficient attention being given in combination and relied on single intervention, and courtesy bias, which might mask slight additive benefits [59].

Moreover, this study has noted some factors such as educational status sub-category no formal education level, WASH facilities like lack of handwashing facilities, less than 20 liter per capita water consumption, time to fetch water greater than 30 minutes from sources, and not washing hands at critical times were affected CHD. Several studies reported improved WASH practice reduced CHD in less developed countries [59]. But, now a day, there is increasing demands on water and sanitation everywhere, that highlighted the need for basic WASH in households as well as public places [62].

The limitation of this study was, it has not assessed both residual chlorine and microbial quality of drinking water that has an association between them in developing countries [43]. In addition, sub-group analysis within the intervention arms were not considered despite the observed reduction effects of both single and combined interventions.

Conclusion

This finding showed that handwashing with soap at critical times, home based water treatment, and both combinations have reduced CHD. Thus promoting this effective and promising result of intervention in rural communities would save many lives of children from diarrhea.

Declarations

Authors’ contribution

AA, BTA, and BA participated in the research design, carried out data preparation and statistical analysis, interpreted the data. BA prepared the manuscript. AA, BTA, and BA offered major revisions.
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Not applicable

Availability of data and materials

Study materials including questionnaires and the data sets used are available online.

Ethics approvals and consent to participate

Ethical clearance was obtained from Institutional Review Board (IRB) of Jimma University with references ID of IRB000343/2012, date 29/10/2012. Then the protocol was registered in the Pan African Clinical Trial Registry and PACTR202008856063947 unique identification number was obtained for this intervention.

Consent for publication

This manuscript does not contain any individual person’s data in any form.

Computing interest

The authors have no competing interest

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