ajfand
SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2019; 19(4): 14971-14993 DOI: 10.18697/ajfand.87.17785

INTEGRATION OF WATER, SANITATION, HYGIENE AND NUTRITION PROGRAMMING IS ASSOCIATED WITH LOWER PREVALENCE OF CHILD STUNTING AND FEVER IN OROMIA, ETHIOPIA

Head JR[1*], Pachón H[2], Tadesse W[3], Tesfamariam M[3] and MC Freeman[1]

Jennifer Head

*Corresponding author email: jrhead6@gmail.com

[1]Department of Environmental Health, Rollins School of Public Health, Emory University, Atlanta, GA, USA

[2]Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA, USA

[3]Catholic Relief Services, Addis Ababa, Ethiopia

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

The difference in prevalence of undernutrition and two-week disease history in women and children in Oromia, Ethiopia was compared between two intervention groups: nutrition only (comparison group) and integrated water, sanitation, and hygiene (WASH) and nutrition (integrated group). In both groups, health care workers were trained in community management of acute malnutrition and infant and young child feeding practices. Health care workers in turn organized events and household visits to identify and treat acutely malnourished infants and children, convey messaging regarding proper infant and young child feeding, and provide vegetable seeds for household gardens. The integrated group additionally received water tap construction and community-led total sanitation and hygiene. Four years post initiation, a household and child anthropometric survey (n=1,007) of mothers of children 0-59 months was conducted in 12 villages (6 per group). Accounting for sample design, logistic regression was used to determine adjusted odds ratios for child nutritional outcomes and child and maternal two-week disease history by intervention group. At follow up, intervention groups were similar in demographics, diet and feeding practices, immunization, supplementation, and access to water and hygiene. Access to an improved sanitation facility was greater in the integrated group (48%) than in the comparison group (28%) (p=0.02). Children from the integrated group had a 16 percentage point (95% CI: 0-32 percentage points) and 14 percentage point (95% CI: 5-22 percentage points) lower prevalence of stunting and fever, respectively, than children from the comparison group. The adjusted odds of stunting and fever in children from the integrated group were 50% (OR: 0.50, 95% CI: 0.26, 0.97) and 49% (OR: 0.51, 95% CI: 0.36, 0.74) lower than the odds of stunting and fever in children from the comparison group. Stratifying by intervention group, mean height-for-age Z-score increased with sanitation facility among children from the comparison group only. There was no difference in maternal history of disease between groups. Integration of WASH and nutrition was associated with less stunting and disease in children 0-59 months in a setting with poor WASH conditions. Differences in sanitation may contribute to the gains in growth seen among children in the integrated group.

Key words: growth, sanitation, stunting, wasting, underweight, fever, diarrhea, WASH, HAZ

DOI: 10.18697/ajfand.87.17785

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

INTRODUCTION

Sub-optimal growth is responsible for an estimated 2.2 million deaths annually in children under five years of age [1]. In 2018, stunting and wasting affected 149 million and 49 million children, respectively, increasing their susceptibility to mortality from infectious disease [2]. Stunting during childhood can have irreversible, long-term sequelae, such as decreased adult productivity, depressed cognitive function, and increased risk for obesity and low-birth-weight offspring [3]. In Ethiopia, the problem is severe with 38% of children under five years being stunted and nearly 10% wasted [4].

In environments with poor water, sanitation, and/or hygiene (WASH), children's growth may be mediated by exposure to enteric pathogens via both symptomatic and asymptomatic pathways [5]. Diarrhea, considered the most important infectious disease determinant of linear growth, has been associated with growth faltering and acute weight loss, due in part to reduced appetites, withholding of food, poor absorption, and hastened intestinal tract times [6, 7]. Other infectious diseases, such as acute respiratory infection (ARI), whose transmission could be slowed by improved hand hygiene [8] or reduced diarrhea [9], may contribute to malnutrition due to reduction of appetites and diversion of nutrients for immune system response [10]. Moreover, poor sanitation and hygiene have been associated with environmental enteric dysfunction [5, 11, 12], a prevalent asymptomatic disorder of the small intestine characterized by villous atrophy, crypt hyperplasia, increased gut permeability, and infiltration of inflammatory cytokines [13], which may lower overall nutrient absorption in the gut, leading to stunted linear growth even in the absence of diarrhea [5, 11, 14].

Analysis of observational studies support the purported link between access to a sanitation facility and reduced prevalence of stunting [15-18] and suggest that elimination of diarrhea in children under two years would increase average length-for-age scores by 0.13 points. However, programmatic evidence of this impact is limited. A 2013 Cochrane Review found no difference in the mean weight-for-height Z-scores (WHZ) and weight-for-age Z-scores (WAZ) scores between those that received WASH interventions and controls, though the studies were limited to five experimental and nine non-randomized trials [19]. The only study in the review to show a significant improvement in height-for-age Z-scores (HAZ) did so in the intervention arm that included WASH only, and no improvement in the intervention arm that included integrated WASH and nutrition [20]. A 2017 review and meta-analysis of 14 studies, including both randomized control trials and observational intervention studies found a borderline significant improvement in mean HAZ in children with improved sanitation compared to unimproved sanitation, but no effect for WHZ or WAZ [21]. There have been several large-scale randomized controlled trials (two in India, one in Indonesia, one in Kenya and Bangladesh, and one in Zimbabwe) that have reported a null effect between household-based sanitation and stunting or diarrhea [22-24] In the India and Indonesia trials, sanitation was very poor at baseline, but uptake of the intervention was modest [25-27]. The WASH Benefits trial in Bangladesh and Kenya, and the SHINE trial in Zimbabwe were both two-year randomized control trial that compared the change in HAZ scores of children under 2 years at baseline and endline between a control and intervention arm (WASH (improvement of household or compound latrines from unimproved to improved latrines in WASH Benefits and new latrines in SHINE; promotion of point-of-use water treatment; handwashing stations not connected to water supplies; and promotion of handwashing); nutrition (counseling on infant and young child feeding and provision of lipid based supplement for children above 6 months); and WASH and nutrition). All three quantified improvements in mean HAZ score in the nutrition arm, with little impact due to WASH [22-24], leading study authors to conclude that modest improvements to WASH infrastructure and practices at the household level are unlikely to reduce stunting in rural communities with access to unimproved latrines at baseline [28]. In contrast, a trial in Mali that randomized groups to a community led total sanitation and hygiene (CLTSH) intervention, that sought to eliminate open defecation at the community level, demonstrated an increase in mean HAZ of 0.18 points in the intervention group compared to the control group [29]. Some researchers argue that more sweeping WASH improvements at the community level such as elimination of open defecation in communities with little to no latrine use at baseline as well as increased total consumption of improved water is needed to sufficiently reduce exposure to fecal pathogens and thereby cause meaningful changes in stunting [30, 31]. Few observational studies have examined the complementary impact of integrating sanitation and nutritional components on health in settings with extremely poor WASH conditions [20, 32]. Understanding the impact of community-level WASH interventions in such settings would have considerable policy and public health relevance.

The purpose of this study was to compare the prevalence of stunting, wasting, underweight and two-week history of acute respiratory infection (ARI) in children 0-59 months and prevalence of two-week history of diarrhea and fever in children and their mothers between two interventions: nutrition only (herein referred to as the comparison group) or integrated WASH and nutrition (herein referred to as the integrated group). Interventions were implemented in 2011 as part of Catholic Relief Services' Development Food Aid Program.

METHODS

Ethical Approval

Oral consent to participate was obtained from all survey participants and a second oral consent for taking anthropometric measurements of children 0-59 months was obtained from the mother of the child. The study was approved by the institutional review board at Emory University in Atlanta, USA.

Program description

The Development Food Aid Program (DFAP) is a USAID-supported initiative in Ethiopia which begun in 2011 with the objective of sustaining and building upon food security initiatives achieved under the ongoing Government of Ethiopia Productive Safety Net Program (PSNP) [33]. The DFAP covers 7 *woredas* (districts), which includes 188,500 PSNP recipients. Through DFAP, Catholic Relief Services (CRS) assigned *kebeles* (villages, **Figure 1**) to receive one of two interventions: nutrition only (referred to as the comparison group) or integrated WASH and nutrition (referred to as the integrated group). *Kebeles* were assigned to intervention groups based on various administrative factors, such as: technical knowledge and current workload of local

DOI: 10.18697/ajfand.87.17785

implementing partners and desire to mix intervention groups evenly among administrative zones. All interventions utilized existing community platforms of health centers and agricultural centers, located in each *kebele,* for the dissemination of materials and educational messaging. In Ethiopia, each *kebele* contains two community health workers and agricultural workers who live in the *kebele* and perform routine home visits and provide treatment/advice at the affiliated center. To implement DFAP activities and disseminate educational messaging, health and agriculture workers were trained on behavioral change communication (BCC) and good practices, and responsible for coordination of activities and educational campaigns. Monitoring of worker training was conducted through a supportive supervision process.

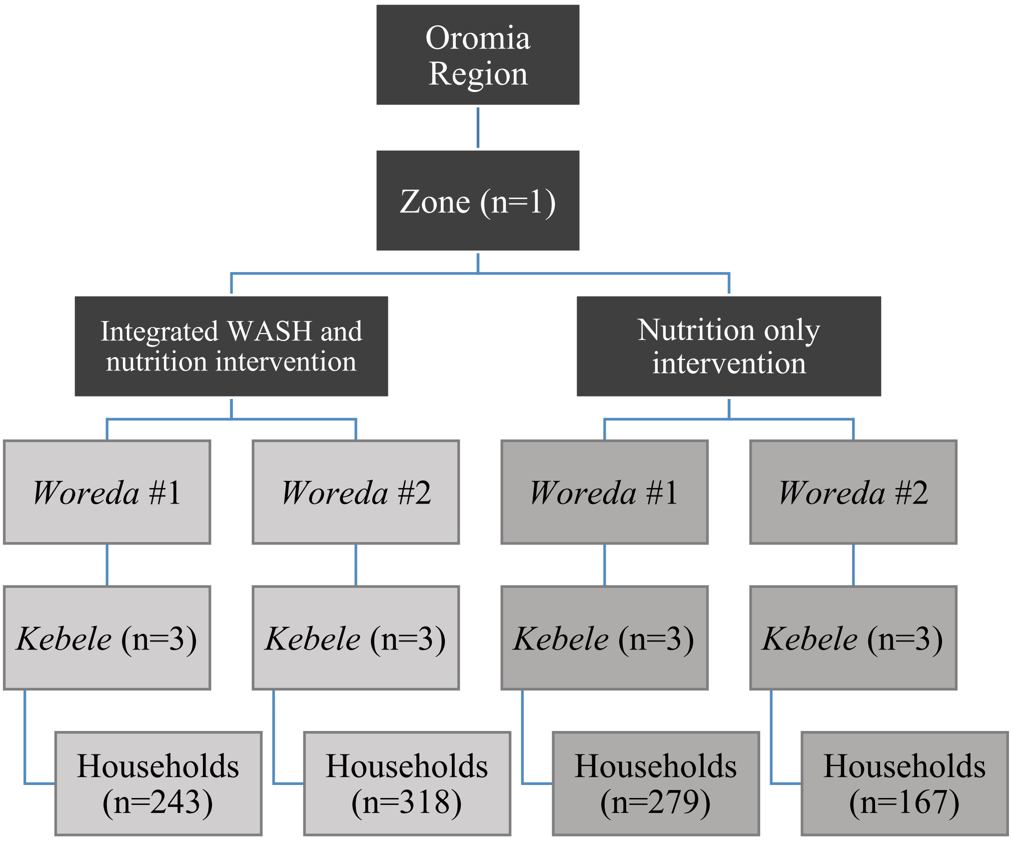

Figure 1: Household sampling strategy

The nutrition intervention consisted of screening and treatment of severe malnutrition; vegetable seed provision; promotion of backyard gardening; and education on infant and young child feeding practices through food preparation and cooking demonstrations and through meetings for pregnant and lactating women. At meetings, women were taught the Essential Nutrition Actions (ENA) and Essential Hygiene Actions framework [34]. As part of the ENA framework, community health workers deliver messages to encourage a set of sixteen "small and doable" actions that promote "nutrition through the lifecycle", from good nutrition during adolescence and while pregnant and lactating, to proper breastfeeding and complementary feeding, care of sick and malnourished children, and diet and supplemental sources of vitamin A, iron, and iodine. Community health workers conducted monthly meetings for pregnant women and visited households of pregnant women and women with children under the age of five at least once a month.

The integrated intervention utilized the same dissemination platforms for the health and nutrition activities but added community-led total sanitation and hygiene (CLTSH) activities, as well as the construction of new or rehabilitation of existing water points. The CLTH approach is a participatory approach that mobilizes communities to eliminate open defecation, build and/or upgrade their own toilets, and practice proper sanitation and hand hygiene.

The region encompassing all study *kebeles* is characterized by low rainfall and frequent drought. The survey was conducted at the beginning of the 2015-2016 El Niño-linked drought, during which all *kebeles* had experienced crop shortages subsequent to the failure of the short rainy season (*Belg*) and a delayed onset of the main rainy season (*Kiremt*).

Study site and design

A cross-sectional matched control evaluation was conducted to examine if the integrated intervention was associated with growth and disease outcomes in children and women. Between June and July 2015, a household survey (n=1,007) was administered in two *woredas* (districts) of one administrative zone within Oromia Region, Ethiopia. The administrative zone was chosen by the implementing partners as a zone that was both geographically accessible and believed to be representative of the entire DFAP catchment area. *Kebeles* (neighborhoods) had to be classified as both CRS and PSNP beneficiaries to be included for selection (see Figure **2**). Twenty-nine *kebeles* in the study zone met these criteria, from which twelve were chosen randomly after stratifying the eligible *kebeles* by *woreda* and intervention (three per *woreda* per intervention, Figure 1). *Kebeles* are divided into four subzones and two or three subzones per *kebele* were randomly selected for surveying, based on the size of the subzone. Households to be surveyed were selected following the Modified Expanded Program on Immunization (EPI) method, outlined elsewhere [35]. The modified EPI method is used to select households by a more random sampling method, which is simple, widely known by WHO for Expanded Program for Immunization activities, easy to train, rapid, and improves the representativeness of the sample. According to EPI rules, data collectors stood in the subzone center and walked outward in a direction determined by a random pen spin, selecting the household located the nearest to them on the right-hand side as their next household. All respondents were mothers of children 0-59 months. If households contained more than one mother with a child 0-59 months, or more than one eligible child, one mother and one of her children were chosen randomly to be the survey subjects.

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

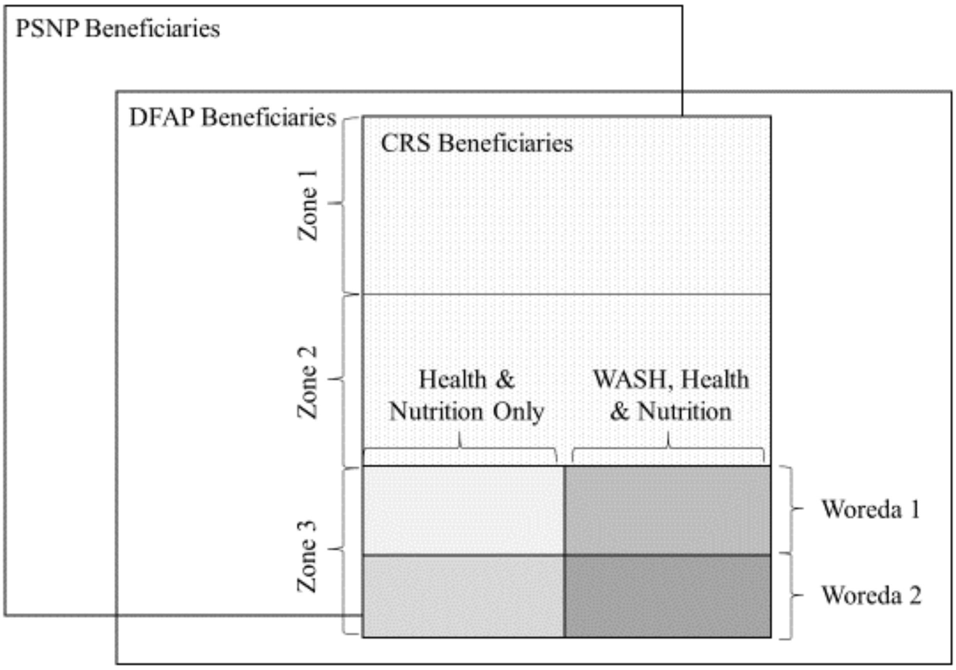

Figure 2: Structure of PSNP and DFAP. Gray boxes indicate area covered by current survey. Note: drawing not to scale and only kebeles covered by both PSNP and DFAP areas were eligible for the survey. CRS = Catholic Relief Services; DFAP = Development Food Aid Program; PSNP = Productive Safety Net Program; WASH = Water, sanitation, and hygiene

The sample size was estimated based on the ability to detect a difference of 6% in stunting between intervention groups at 95% confidence level and 80% power. A listing of the total number of households in each *kebele* was available from 2011 health center data. It was assumed that the proportion of households containing children under 5 years old was roughly similar in each *kebele* and therefore the number of households sampled per *kebele* was roughly proportional to the total number of households per *kebele*. The survey was piloted in a *kebele* that met the criteria for the survey but was not selected for this study. Data were collected on mobile tablets and cleaned with SAS version 9.3 [36]. Enumerators were not blind to intervention group.

Measurement of diet and disease

The UNICEF conceptual framework for undernutrition was applied to guide selection of survey variables for the analysis (**Figure 3**) [37]. Household food security was measured by the reduced Coping Strategies Index (CSI), which sums the weighted weekly total of a set of pre-defined behaviors families use to meet their food needs [38]. Woman and child dietary diversity scores (DDS) were calculated for each respondent and child, respectively, by summing the number of food groups consumed in the past 24 hours, out of a total of seven and nine defined groups, respectively [39].

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

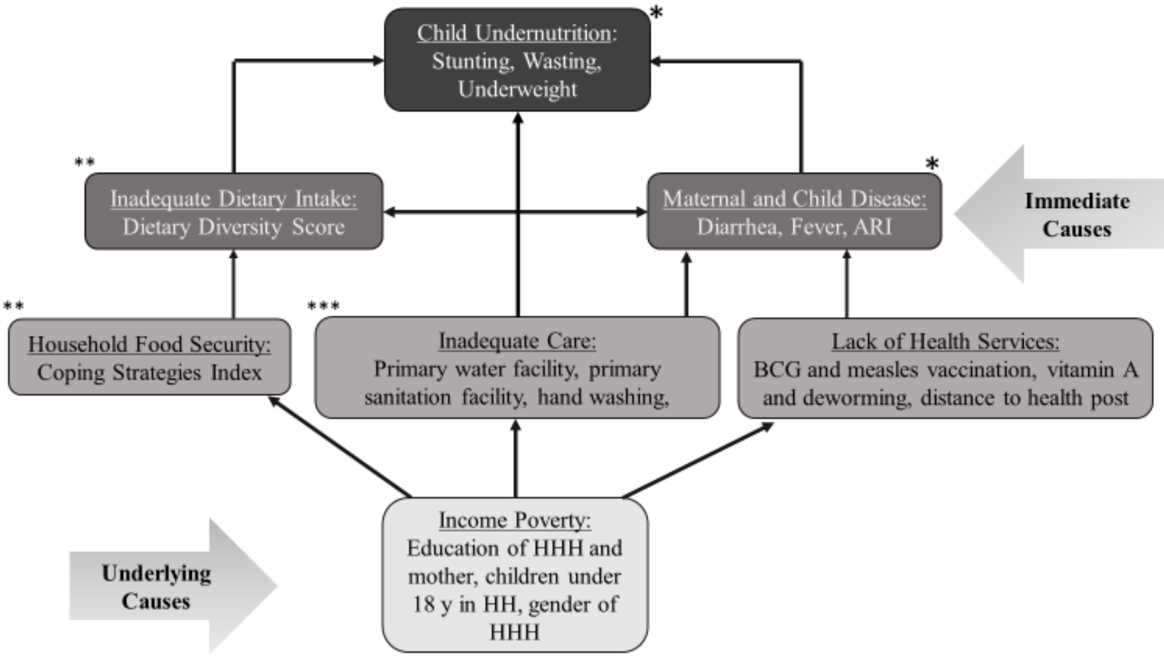

Figure 3: Survey indicators, adapted from UNICEF's framework for maternal and child undernutrition [37]. *Primary outcome variables; **Variables addressed through both interventions; ***Additional variables addressed through integrated WASH and nutrition intervention; HH=household; HHH=head of household. ARI = Acute respiratory infection; BCG = Bacillus Calmette–Guérin

Two-week history of fever and diarrhea for women and children was obtained by self-report and caretaker-report, respectively. Diarrhea was defined as three or more loose stools or one bloody stool in less than 24 hours. Two-week history of acute respiratory infection (ARI) was determined for children through a series of questions used by the Ethiopian Demographic and Health Survey (DHS) [4].

Measurement of WASH conditions

Access to improved drinking water source and improved sanitation source was determined by asking mothers their primary and secondary drinking water sources and primary facility for defecation. If indicated to exist, structured observations were made of household latrines to observe indicators of use: presence of worn path to latrine, presence of wet feces in and around the hole, or presence of water for flushing, if applicable. If respondents indicated they had a designated location for hand washing, the area and type of cleaning agent present at the time of visit was observed. Observations were also made on whether the household had a designated place for livestock (chickens, goats, and sheep) and on the presence of feces—animal or human—surrounding the house. Definitions for "improved" and "unimproved" sanitation and drinking water were taken from the Joint Monitoring Program (JMP) for water supply and sanitation [40], which defines an improved sanitation source as one that hygienically separates human feces from human contact, and includes pit latrine with slab, composting toilet, ventilated improved pit latrine, flush/pour-flush to pit latrine, septic tank, or piped sewer system.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

An unimproved sanitation facility includes no facility, pit latrine without slab, bucket, or a shared facility. An improved water source is one that, by nature of construction, separates water from outside contaminants, and includes piped water, borehole, protected spring or well, and rainwater. Unimproved water sources include unprotected spring or well, and surface water.

Anthropometry

The selected child was measured using standard methods [37]; supine length (for children less than 24 mo) or standing height (for children 24-59 mo) was measured with 1 cm precision using a height board and weight was taken to the nearest 0.1 kilogram using a hanging Salter Scale. The child's age in months was determined from yellow health cards. These yellow health cards containing child information, such as birthdays, were available for roughly half of the households. For those without health cards, enumerators asked the mother for the child's age in years and months and probed with important dates, holidays, and harvest cycles to confirm. HAZ, WAZ, and WHZ were determined based on the World Health Organization's 2006 child growth standards using WHO Anthro version 3.2.2 [41].

Statistical analysis

Sampling weights were calculated for each observation in the dataset as the inverse probability of selection. For analyses involving outcomes at the household (such as water or sanitation source, CSI, and others) or mother level (such as maternal disease) sampling weights were a product of the quotient of the total number of eligible *kebeles* per *woreda* by the number chosen and the quotient of the number of households in the observation's *kebele* by the number of households surveyed in that *kebele* (Eqn 1). For analyses involving outcome at the child level (such as anthropometric indicators, child's history of disease, and others), these weightings were multiplied by the number of children under 5 years in the household (Eqn 2). Data were analyzed using SUDAAN® [42] to account for stratification of the *woredas* and clustering at the primary sampling unit, the *kebele*.

$$Household\ weighting = \left(\frac{Kebeles\ in\ woreda}{Kebeles\ surveyed\ in\ woreda}\right)\left(\frac{houses\ in\ kebele}{houses\ surveyed\ in\ kebele}\right) \quad \{1\}$$

$$child\ weighting = (child's\ household\ weight)(number\ of\ children\ in\ house) \quad \{2\}$$

Demographic, dietary, and WASH factors and nutrition and disease status were compared by intervention received using *t*-tests (continuous variable) and X^2 tests (binary variable). Undernutrition and two-week history of disease were regressed against intervention group using GLM models, adjusting for various factors: age and sex of child, education of mother (none/illiterate, informal (can read or write), 1st-4th grade, 5th-8th grade, secondary school and above), and household size. Statistical significance was assessed using the Wald F-test. Education levels of the mother and the head of household was entered into the GLM models as a proxy indicator for socio-economic status (SES), based on results of previous study in Ethiopia which found good agreement between material education and household SES [43]. Other possible confounders considered for adjustment included distance to nearest town center, gender of household head, measles immunization status (as indicated by mother recall or vaccination card), Bacillus

Calmette-Guérin (BCG) immunization status (indicated by presence of BCG scar on arm), vitamin A supplementation (received/not received in the past six months for children ≥6 mo) and deworming (received/not received in the past six months for children ≥24 mo). None were significantly associated with the outcomes ($p<0.05$). The likelihood ratio test was used to test for interaction between all exposures of interest and the variables adjusted for. No interaction was found.

RESULTS AND DISCUSSION

There were 5,990 households in the selected comparison *kebeles* and 3,780 households in selected intervention *kebeles*. A total of 1,007 households were surveyed; 446 in the comparison group and 561 in the integrated group (Table 1). Response rate in both groups was high (>90%). Most variables were not significantly different between groups except primary sanitation facility. Forty six percent of the children included in the survey were female, and their mean age was 27 months. The mean age of the mother was 28 years and 58% had no formal education. In general, the survey showed that diets lacked diversity (<3 food groups) and were characterized by high consumption of cereals and legumes and low consumption of fruits and meat. A mean of 2.7 food groups had been consumed in the 24 hours prior to survey by both children aged 6-59 months and their mothers.

WASH Conditions

With the exception of sanitation facility, most WASH characteristics did not differ by intervention group (Table 1). Forty-eight percent (95% CI: 36.3, 60.0) of households in the integrated group used an improved sanitation facility, compared to 28% (95% CI: 18.8, 39.5) of households in the comparison group ($p=0.02$). Eighty-six percent of sanitation facilities had at least one recorded indicator of use.

Association between intervention type and nutrition and disease outcomes. Complete height/length and weight records were obtained for 96% of the children. Prevalence of stunting and two-week history of fever was significantly lower ($p<0.05$) in children from the integrated group (38% (95% CI: 26, 51) stunted, 21% (95% CI: 19, 23) with fever) compared to from the comparison group (54% (95% CI: 43, 64) stunted, 34% (95% CI: 27, 43) with fever) (Table 2). Adjusting for demographic factors often associated with nutritional and/or disease outcomes (here, child age in months, child age squared, child sex, household size, and education of mother), the odds of stunting for children in the integrated group was 50% lower than the odds of stunting for children in the comparison group (OR: 0.50, 95% CI: 0.26, 0.97). The findings presented here are consistent with a randomized controlled trial which estimated a prevalence ratio at 1.5 year follow-up of 0.86 (95% CI: 0.71, 1.00) for stunting and 0.88 (95% CI: 0.71, 1.08) for underweight for children under five years of age in Mali receiving a CLTS intervention compared to those receiving no intervention [29]. However, they are inconsistent with trials in Kenya, Bangladesh, and Zimbabwe, demonstrating a change in HAZ for children under two years of age among children receiving a nutrition intervention but no change in HAZ for children receiving a household-level WASH intervention and no additional improvements in HAZ for children receiving an integrated WASH plus nutrition intervention [22-24]. While our study and the Mali trial focused on community sanitation improvements, the other studies only improved sanitation in study households.

The proportion of children who were underweight was 16.6% in the intervention, compared to 23.8% in the control (aOR: 0.62, 95% CI: 0.30, 1.27). The proportion of children who were wasted was 7.8% in the intervention, compared to 9.8% in the control (aOR: 0.81, 95% CI: 0.40, 1.63). The lack of significant association between WASH or WASH and nutrition interventions and mean WHZ or WAZ and is consistent with previous observational studies and trials [19, 24, 29, 44].

Children in the integrated group had 49% lower odds of having had a fever in the past two weeks compared to children in the comparison group (OR: 0.51, 95 CI: 0.36, 0.74). There was no association between either diarrhea or ARI prevalence among these children. Few other studies have assessed the impact of sanitation on fever, a symptom for a broad range of infections, including both severe diarrhea and ARI. Young children are exposed to fever-causing pathogens present in the environment through play habits, closeness to the ground, and possible geophagy (soil eating), the latter of which has been associated with enteropathies in children [45]. However, mothers, being less prone to infection via these routes, may be more frequently colonized by pathogens via direct consumption of unsafe water. The lack of significant association between diarrhea and fever in women and intervention group could be because coverage of improved water source did not differ significantly between the integrated group (78%) and the comparison group (73%). The null findings in this study for diarrhea in children were similar to those from trials in India, Indonesia, Mali, Kenya, and Zimbabwe [25-29]. Only the WASH Benefits trial in Bangladesh demonstrated a reduction in diarrhea in hygiene, sanitation, and combined WASH arms (but not water only arm) [23]. That prevalence of stunting in children could differ by intervention group in the absence of a significant difference in diarrhea prevalence by intervention group is not unusual, given that environmental enteropathy, a causal pathway that need not include diarrhea, is thought to play a large role in the relationship between sanitation and stunting [5, 11, 14]. In other words, while the effect of improved sanitation on child growth outcomes is thought to be mediated by diarrhea, it is also hypothesized that there is a direct causal pathway between sanitation and growth that is not mediated by diarrhea.

Sanitation and Mean HAZ

Mean HAZ for children 0-59 months by sanitation facility was examined, stratified by intervention type (Figure 4). For the integrated group, there was little difference between sanitation facility and mean HAZ. However, for the comparison group—which had a worse sanitation profile than the integrated group at endline—mean HAZ increased with each incremental improvement in sanitation, though the difference between each adjacent improvement was only significant between open defecation and pit latrine without cleanable slab. Mean HAZ among children in households practicing open defecation was significantly higher in the integrated group compared to the comparison group. In the latter group, movement up the sanitation ladder was associated with increasingly higher HAZ scores. This finding suggests evidence of herd protection in sanitation. As pathogens introduced to the environment through poor sanitation can circulate throughout an entire community, the 'herd protection' benefits of improved sanitation may only be achieved at a certain threshold of coverage and use [46, 47]. As fewer households were practicing open defecation in the integrated group compared to the nutrition only group, those from the integrated group may have experienced the benefits of herd protection against enteric pathogens in the environment due to the better sanitation of their neighbors [46]. Coffey and Spears demonstrate that in regression analysis of two Indian Demographic Health Surveys, the fraction of households that openly defecate is associated with large differences in childhood stunting, but that once open defecation is controlled for, there is no effect associated with improvement of latrines from unimproved (such as. basic pit latrine) to improved (for example ventilated improved pit) [31].

Community-led total sanitation and hygiene (CLTSH, the approach employed in this study and in the Mali randomized control trial [29], is designed to eliminate open defecation at the community level, and has been associated with improved height outcomes [46]. However, sanitation interventions which target individual improvements in household latrines while ignoring neighbors' latrines or open defecation practices may underestimate the effect of sanitation on childhood growth. For example, the WASH Benefits and SHINE trials, which reported no difference in HAZ between a WASH and nutrition arm and a nutrition only arm, limited sanitation improvements to the household of the randomly selected child, ignoring the effect of neighboring compounds on child pathogen exposure [22-24]. Nevertheless, authors of these trials argue that formative research shows that among children under 18 months, the majority of fecal exposure occurs within their compound [48].

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4 November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

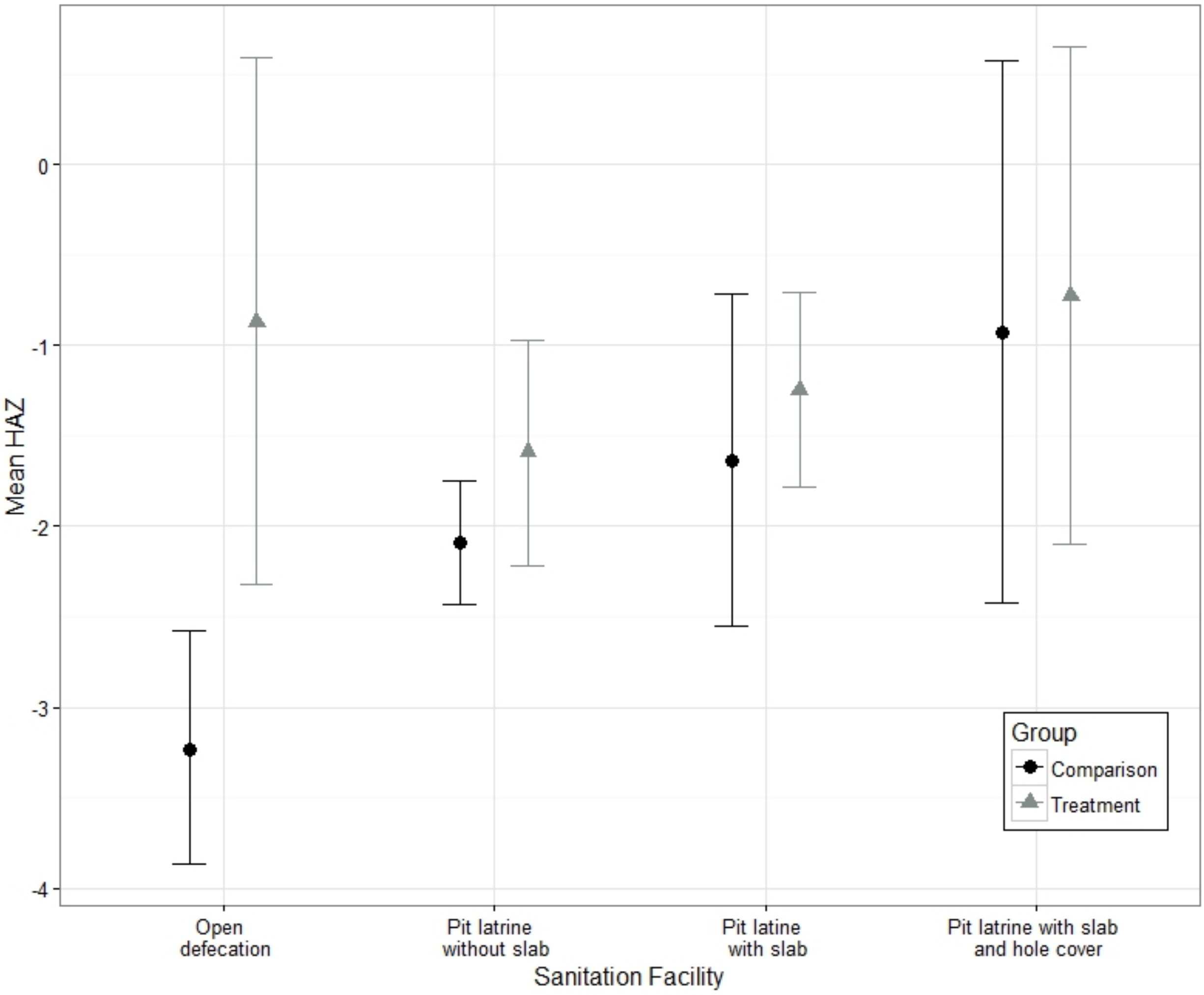

Figure 4: Dose-Response relationship between mean HAZ and sanitation facility, stratified by intervention group. The comparison (nutrition only) intervention involved training of health workers on community management of acute malnutrition, community education on infant and young child feeding, and provision of vegetable seeds; the integrated (WASH and nutrition) intervention added water tap construction and community-led total sanitation and hygiene. Lines indicate 95% confidence intervals

Limitations

Lack of baseline data specific to the study region prevented observation of the true change in study outcomes since program initiation and the percent reduction attributable to the intervention versus other underlying factors or differences in variables of interest at baseline. The cross-sectional design of the study and non-experimental allocation of interventions further prevents the ability to make causal inferences regarding the program's impact. Authors of the WASH Benefits trial warn against analysis of the relationship between sanitation and stunting using observational data, demonstrating that re-analysis of children in the control arm shows a significant association between improved sanitation at enrollment and reduced stunting [48]. The discrepancy between

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

these observational results and the trial's null effect suggests that there may be uncontrolled confounding of latrine ownership and childhood stunting by household general well-being.

Despite this limitation, Habicht and colleagues [49] define plausibility as, "the program appears to have some effect above and beyond the influence of non-program influences", or confounders. It is plausible that the observed differences are attributable to the integrated intervention, and not to other outside causes, for several reasons. First, characteristics of the *kebele* stratified by intervention do not differ significantly at endline by any of the following potential confounders: demographics, dietary intake, household food security, or access to health services, such as vitamin A supplementation, deworming medication, measles and TB vaccination, and distance to health facility (Table 1). This similarity lends confidence to there being no significant differences among *kebeles* at baseline. As CRS did not consider WASH conditions or nutrition or disease profiles in the *kebeles* when assigning intervention types (W. Tadesse, personal communication, June, 2015), and all *kebeles* received the nutrition intervention, it was expected that the only differences observed among non-outcome variables at endline would be among household WASH characteristics, as was observed here. Second, CRS utilizes CLTSH in their intervention, a participatory method that mobilizes communities to eliminate open defecation, build their own toilets, and/or upgrade their existing toilet. A clear dose-response relationship was observed between household participation in the CLTSH intervention, represented by type of sanitation facility used, and mean HAZ in the comparison group. No such relationship was seen in the intervention group, where increased coverage and use of basic and improved sanitation may have resulted in herd protection of households without any toilet (Figure 4). Stratifying sanitation option by type (in other words, open defecation, pit latrine without cleanable slab, pit latrine with cleanable slab, and pit latrine with cleanable slab and hole cover), the odds of stunting among children in the comparison group decreased as households moved up the sanitation ladder, controlling for all the same demographic factors controlled for in the original analysis (data not shown). Given that the intervention groups differed only by their access to improved sanitation facility, it is plausible that the differences in stunting prevalence by intervention can be attributed to the improvements in sanitation in the integrated group due to CLTSH initiatives that target community sanitation coverage.

This study has several other limitations. Education level of the head of the household was considered a proxy for socioeconomic status (SES). However, results from a study conducted in the Amhara region of Ethiopia that found education to be a good proxy for SES when considering nutritional outcomes [43]. Education of head of household was not significantly associated with sanitation facility, suggesting the relationship between sanitation and HAZ is not confounded by SES. While enumerators and respondents were not explicitly told which village belonged to which intervention group, it may have been possible to deduce this information based on observed WASH infrastructure. As respondents in both groups received visits from community health workers, it is not expected that knowledge of intervention group may bias self-report of dietary history; however, measurement of anthropometry could have been influenced. To minimize this bias, supervisors were present in each village, and observed each team at least once per day to ensure quality in measurements. This survey relied on self-report and maternal-report of disease, which is subject to recall bias, as studies have shown that recall accuracy begins to drop after 2-3 days to one week of the event [50]. However, Pickering and colleagues found no difference in diarrhea prevalence between a two-week self-report and a two-day self-report [29]. Finally, the EPI method of household selection used may have resulted in an over representation of houses in the center of the village; and sub-zone was not accounted for in calculation of sampling weights; however, this is non-differential by intervention group as selection methods were consistent by group so the effect measure of the intervention is not expected to be biased away from the null.

CONCLUSIONS

Evidence suggests that reduction in exposure to fecal pathogens vis-à-vis improvements to WASH could improve growth outcomes in children, but programmatic evidence of this benefit is limited. Integration of WASH and nutrition components in a non-controlled, programmatic setting with extremely poor initial WASH conditions was associated with less stunting and fever in children compared to nutrition components alone. Previous WASH interventions evaluated by the five randomized-controlled trials used for Cochrane review meta-analysis were limited to drinking water and/or hand hygiene interventions [19], and WASH interventions evaluated by the SHINE and WASH Benefits trials were focused on sanitation improvements only among study households [28]. This evaluation suggests that elimination of open defecation may be a stronger predictor of stunting in young children than drinking water source and hygiene.

As integrated programs are now being recommended by USAID and other multilateral organizations, it is of importance to better understand the complementary impact of integrating WASH and nutritional components on health [51]. In areas where undernutrition is high and access to safe WASH is low, joint promotion of WASH and nutrition may be conducted simultaneously through existing community platforms, saving both time and resources. More research is needed to quantify the complementary effect of integrated community level programs on growth and disease outcomes.

ACKNOWLEDGEMENTS

Catholic Relief Services – Ethiopia provided administrative support, feedback on study design, and covered all in-country costs associated with this study. Emory University Global Field Experience Fund provided financial travel support for Jennifer Head. Meki Catholic Secretariat arranged for data collectors and anthropometry measurement tools; and Professor Paul Weiss from Emory University provided input on sampling methodology.

COMPETING INTERESTS

WT and MT were employees for Catholic Relief Services (CRS), the organization that implemented the intervention, at the time of publication.

ROLE OF FUNDING: Time for this study was funded through a co-agreement between the Emory University and Catholic Relief Services. The funding source had no role in the study design, analysis, preparation of the manuscript, or decision to publish the manuscript. Catholic Relief Services – Ethiopia covered administrative and data collection costs; Emory University Global Field Experience Fund provided international travel support for Jennifer Head.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 19 No. 4 November 2019 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 1: Characteristics of the study population, stratified and compared by intervention group, in percentage or mean ± SE

Characteristic	Comparison (Nutrition Only) (%) N=446	Integrated (WASH and Nutrition) (%) N=561	P-Value[1]
Child, 0-59 months			
Female	45.7	51.7	0.10
Age, in months (mean ± SE)	26.7 ± 0.8	26.9 ± 0.47	0.50
Dietary Diversity Score[2] (mean ± SE)	2.7 ± 0.10	2.7 ± 0.08	0.55
Received vitamin A supplementation in past 6 months	91.0 (77.2, 96.8)	95.6 (94.6, 96.4)	0.27
Received deworming medication in past 6 months	53.1 (37.3, 68.3)	57.6 (48.4, 66.6)	0.58
Ever vaccination of measles			
Recall	40.8 (35.1, 46.7)	38.3 (33.7, 43.1)	0.47
On card	46.9 (42.0, 51.8)	50.2 (44.1, 56.3)	0.36
Presence of BCG scar (indicating TB vaccination)	71.2 (64.5, 77.0)	72.8 (66.7, 78.2)	0.67
Mother			
Age, in years (mean ± SE)	27.5 ± 0.5	27.6 (27.1, 28.2)	0.82
Dietary Diversity Score[2] (mean ± SE)	2.7 ± 0.1	2.7 ± 0.1	0.55
Education level			
No education	53.9 (43.1, 64.4)	63.8 ± 0.2	0.15
Can read or write (informal education)	0.8 (0.3, 2.2)	1.4 (0.7, 2.6)	0.28
Primary school (grades 1-4)	22.2 (16.3, 29.5)	17.4 (15.0, 20.0)	0.16
Primary school (grades 5-8)	19.4 (13.0, 27.9)	13.9 (8.0, 23.0)	0.26
Secondary school or above (≥ grade 9)	3.8 (2.3, 6.2)	3.6 (1.5, 8.0)	0.90
Household			
Coping Strategies Index[3] (mean ± SE)	13.9 ± 1.1	13.0 ± 0.6	0.49
Distance to nearest health post, km (mean ± SE)	2.98 ± 0.55	2.96 ± 0.50	0.97
Education level of head of household			
No education	25.2 (22.2, 28.5)	27.7 (20.7, 35.9)	0.51
Can read or write (informal education)	6.7 (4.8, 9.3)	9.0 (4.2, 18.4)	0.48
Primary school (grades 1-4)	22.1 (17.3, 27.8)	26.7 (23.7, 29.7)	0.12

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4 November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Primary school (grades 5-8)	34.8 (29.4, 40.6)	26.9 (19.9, 35.2)	0.09
Secondary school or above (> grade 9)	11.2 (6.7, 17.6)	9.9 (5.8, 16.4)	0.69
Household WASH			
Water Source			
Access to an improved primary water source	73.1 (24.8, 95.7)	77.7 (32.6, 96.2)	0.85
Number of days in past week with access to an improved water source (mean ± SE)	4.8 ± 1.4	5.0 ± 1.1	0.89
Number of months per year with access to an improved water source (mean ± SE)	8.6 ± 2.3	7.4 ± 2.1	0.71
Treats water at household	15.5 (4.6, 41.5)	22.5 (7.7, 50.6)	0.58
Access to improved sanitation facility	28.0 (18.8, 39.5)	48.1 (36.3, 60.0)	0.02
Hand washing knowledge and practice			
Number of critical hand washing times known4 (mean ± SE)	3.5 ± 0.1	3.7 ± 0.02	0.09
Existence of designated hand washing location with observable cleaning agent present	3.5 (1.9, 6.5)	6.9 (4.6, 10.3)	0.06
Observed presence of feces (including animal) around compound	54.1 (39.3, 68.3)	51.7 (40.7, 62.3)	0.77
Existence of separate enclosure for domestic farm animals5	45.4 (30.5, 61.1)	37.0 (31.3, 43.1)	0.28

[1]p-value comparing the two intervention groups by t-test or X^2 test; [2]Calculated by summing the number of food groupings consumed in the past 24 hours A maximum of nine food groupings are possible and are defined by Food for Peace [39] ; [3]Calculated by a weighted average of times per week a family must resort to a pre-defined coping strategy to meet their food needs [38]. Higher numbers indicate lower food security; [4]Maximum of five critical hand washing times were possible; [5]Chicken, sheep and goats

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 19 No. 4
November 2019
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Comparison of disease and nutrition outcomes in children 0-59 months and mothers of children 0-59 months by intervention group

Outcome	Intervention Group, proportion (95% CI)		aOR[1] by Intervention Group (95% CI)
	Comparison (Nutrition Only) N=446	Integrated (WASH and Nutrition) N=561	
Child 0-59 months			
Anthropometric measurements[2]			
Proportion stunted (HAZ < -2)	54.0 (43.3, 64.3)	37.8 (26.4, 50.7)	0.50 (0.26, 0.97)*
Proportion underweight (WAZ < -2)	23.8 (16.7, 32.7)	16.6 (9.2, 28.1)	0.62 (0.30, 1.27)
Proportion wasted (WHZ < -2)	9.8 (5.8, 15.9)	7.8 (4.9, 12.2)	0.81 (0.40, 1.63)
Two-week history of disease			
Diarrhea	24.6 (21.6, 27.8)	22.0 (17.5, 27.30)	0.74 (0.51, 1.07)
Fever	34.3 (26.7, 42.6)	20.8 (18.7, 23.0)	0.51 (0.36, 0.74)*
ARI	16.8 (13.0, 20.5)	15.9 (11.7, 21.2)	0.94 (0.56, 1.59)
Mother of child (respondent)			
Two-week history of disease			
Diarrhea	8.9 (5.2, 14.8)	7.0 (4.6, 10.6)	0.75 (0.35, 1.63)
Fever	17.3 (11.0, 26.1)	14.1 (10.1, 19.4)	0.78 (0.41, 1.45)

aOR = adjusted odds ratio; ARI = acute respiratory infection; CI = confidence interval; HAZ = height/length-for-age z-score; WAZ = weight-for-age z-score; WHZ = Weight-for-height/length z-score

[1]Models comparing the adjusted odds of the outcome by intervention group, where the nutrition only group is used as the reference group. Models with child outcomes are adjusted for child age in months, age squared, child sex, household size, and education of mother. Models with maternal outcomes are adjusted for education level of the mother and family size

[2]Full measurements obtained for 96% of the children

*p-value <0.05. Wald F-test used to test the null hypothesis that the odds ratio is equal to 1.0

REFERENCES

1. **Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, Mathers C and J Rivera** Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* 2008; **371(9608)**: 243-260.

2. **World Health Organization.** WHO Global Database on Child Growth and Malnutrition. 2019, WHO: Geneva.

3. **Victora CG, Adair L, Fall C, Hallal PC, Martorell R, Richter L and HS Sachdev** Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008; **371(9609)**: 340-357.

4. **Central Statistical Agency** Ethiopia Demographic Health Survey. 2016, Central Statistical Agency: Addis Ababa.

5. **Ngure FM, Reid BM, Humphrey JH, Mbuya MN, Pelto G and RJ Stoltzfus** Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Ann N Y Acad Sci* 2014; **1308**: 118-28.

6. **Checkley W, Buckley G, Gilman RH, Assis AM, Guerrant RL, Morris SS, Mølbak K, Valentiner-Branth P, Lanata CF and RE Black** Multi-country analysis of the effects of diarrhoea on childhood stunting. *Int J Epidemiol* 2008; **37(4)**: 816-830.

7. **Lima A, Moore S, Barboza M, Soares A, Schleupner M, Newman R, Sears C, Nataro J, Fedorko D and T Wuhib** Persistent diarrhea signals a critical period of increased diarrhea burdens and nutritional shortfalls: a prospective cohort study among children in northeastern Brazil. *J Infect Dis* 2000; **181(5)**: 1643-1651.

8. **Warren-Gash C, Fragaszy E and AC Hayward** Hand hygiene to reduce community transmission of influenza and acute respiratory tract infection: a systematic review. *Influenza Other Respir Viruses* 2013; **7(5)**: 738-49.

9. **Schmidt W-P, Cairncross S, Barreto ML, Clasen T and B Genser** Recent diarrhoeal illness and risk of lower respiratory infections in children under the age of 5 years. *Int J Epidemiol* 2009; **38(3)**: 766-772.

10. **Cunha AL** Relationship between acute respiratory infection and malnutrition in children under 5 years of age. *Acta Paediatr* 2000; **89(5)**: 608-9.

11. **Humphrey JH** Child undernutrition, tropical enteropathy, toilets, and handwashing. *Lancet* 2009; **374(9694)**: 1032-1035.

12. **George CM, Oldja L, Biswas SK, Perin J, Lee GO, Ahmed S, Haque R, Sack RB, Parvin T and IJ Azmi** Fecal markers of environmental enteropathy are essociated with animal exposure and caregiver hygiene in Bangladesh. *Am J Trop Med Hyg* 2015; **93(2)**: 269-275.

13. **Crane RJ, Jones KD and JA Berkley** Environmental enteric dysfunction: An overview. *Food & Nutrition Bulletin* 2015; **36(Supplement 1)**: 76S-87S.

14. **Weisz AJ, Manary MJ, Stephenson K, Agapova S, Manary FG, Thakwalakwa C, Shulman RJ and MJ Manary** Abnormal gut integrity is associated with reduced linear growth in rural Malawian children. *J Pediatr Gastroenterol Nutr* 2012; **55(6)**: 747-50.

15. **Daniels DL, Cousens SN, Makoae LN and RG Feachem** A study of the association between improved sanitation facilities and children's height in Lesotho. *Eur J Clin Nutr* 1991; **45(1)**: 23-32.

16. **Spears D, Ghosh A and O Cumming** Open defecation and childhood stunting in India: an ecological analysis of new data from 112 districts. *PLoS One* 2013; **8(9)**: e73784.

17. **Merchant AT, Jones C, Kiure A, Kupka R, Fitzmaurice G, Herrera MG and WW Fawzi** Water and sanitation associated with improved child growth. *Eur J Clin Nutr* 2003; **57(12)**: 1562-8.

18. **Richard SA, Black RE, Gilman RH, Guerrant RL, Kang G, Lanata CF, Molbak K, Rasmussen ZA, Sack RB, Valentiner-Branth P and W Checkley** Diarrhea in early childhood: short-term association with weight and long-term association with length. *Am J Epidemiol* 2013; **178(7)**: 1129-38.

19. **Dangour AD, Watson L, Cumming O, Boisson S, Che Y, Velleman Y, Cavill S, Allen E and R Uauy** Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. *Cochrane Database Syst Rev* 2013; **8**: Cd009382.

20. **Fenn B, Bulti AT, Nduna T, Duffield A and F Watson** An evaluation of an operations research project to reduce childhood stunting in a food-insecure area in Ethiopia. *Public Health Nutr* 2012; **15(9)**: 1746-54.

21. **Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, Penakalapati G, Anderson D, Mahtani AG, Grimes JET, Rehfuess EA and TF Clasen** The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *Int J Hyg Environ Health* 2017; **220(6)**: 928-949.

22. **Null C, Stewart CP, Pickering AJ, Dentz HN, Arnold BF, Arnold CD, Benjamin-Chung J, Clasen T, Dewey KG, Fernald LCH, Hubbard AE, Kariger P, Lin A, Luby SP, Mertens A, Njenga SM, Nyambane G, Ram PK and JM Colford Jr.** Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. *The Lancet Global Health* 2018; **6(3)**: e316-e329.

23. **Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, Stewart CP, Begum F, Hussain F, Benjamin-Chung J, Leontsini E, Naser AM, Parvez SM, Hubbard AE, Lin A, Nizame FA, Jannat K, Ercumen A, Ram PK, Das KK, Abedin J, Clasen TF, Dewey KG, Fernald LC, Null C, Ahmed T and JM Colford Jr.** Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *The Lancet Global Health* 2018; **6(3)**: e302-e315.

24. **Humphrey JH, Mbuya MNN, Ntozini R, Moulton LH, Stoltzfus RJ, Tavengwa NV, Mutasa K, Majo F, Mutasa B, Mangwadu G, Chasokela CM, Chigumira A, Chasekwa B, Smith LE, Tielsch JM, Jones AD, Manges AR, Maluccio JA, Prendergast AJ and SHINE Trial Team** Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. *The Lancet Global Health* 2019; **7(1)**: e132-e147.

25. **Patil SR, Arnold BF, Salvatore AL, Briceno B, Ganguly S, Colford JM, Jr. and PJ Gertler** The effect of India's total sanitation campaign on defecation behaviors and child health in rural Madhya Pradesh: A cluster randomized controlled trial. *PLoS Med* 2014; **11(8)**: e1001709.

26. **Clasen T, Boisson S, Routray P, Torondel B, Bell M, Cumming O, Ensink J, Freeman M, Jenkins M and M Odagiri** Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *Lancet Glob Health* 2014; **2(11)**: e645-e653.

27. **Cameron L, Olivia S and M Shah** Scaling up sanitation: evidence from an RCT in Indonesia. *Journal of development economics* 2019; **138**: 1-16.

28. **Pickering AJ, Null C, Winch PJ, Mangwadu G, Arnold BF, Prendergast AJ, Njenga SM, Rahman M, Ntozini R, Benjamin-Chung J, Stewart CP, Huda TMN, Moulton LH, Colford JM, Luby SP and JH Humphrey** The WASH Benefits and SHINE trials: interpretation of WASH intervention effects on linear growth and diarrhoea. *The Lancet Global Health* 2019; **7(8)**: e1139-e1146.

29. **Pickering AJ, Djebbari H, Lopez C, Coulibaly M and ML Alzua** Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: a cluster-randomised controlled trial. *Lancet Global Health* 2013; **3(11)**: e701-e711.

30. **Cumming O and V Curtis** Implications of WASH Benefits trials for water and sanitation. *The Lancet Global Health* 2018; **6(6)**: e613-e614.

31. **Coffey D and D Spears** Implications of WASH Benefits trials for water and sanitation. *The Lancet Global Health* 2018; **6(6)**: e615.

32. **Alelign T, Degarege A and B Erko** Prevalence and factors associated with undernutrition and anaemia among school children in Durbete Town, northwest Ethiopia. *Arch Public Health* 2015; **73(1)**: 34.

33. **Kirby A** Development Food Aid Program (DFAP). 2014, Secure Nutrition: Addis Ababa.

34. **USAID.** Essential nutrition actions and essential hygiene actions. 2017; Available from: https://www.spring-nutrition.org/publications/series/essential-nutrition-actions-and-essential-hygiene-actions.Accessed Oct 2018.

35. **SMART.** Sampling Methods and Sample Size Calculation for the SMART Methodology. 2012.

36. **SAS Institute Inc.** SAS. 2013, SAS Institute Inc.: Cary, NC.

37. **Boyd E** Nutrition in emergencies. 2011, UNICEF: New York.

38. **Maxwell D and R Caldwell** The Coping Strategies Index: Field Methods Manuel. 2008, World Food Programme: Rome.

39. **Food For Peace** FFP Standard Indicator Handbook. 2011, USAID: Washington DC.

40. **World Health Organization.** WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation. 2015; Available from: www.wssinfo.org Accessed Jul 2019.

41. **Bloem M** The 2006 WHO child growth standards. *BMJ : British Medical Journal* 2007; **334(7596)**: 705-706.

42. **RTI International** SUDAAN. 2005, RTI: Research Triangle Park, NC.

43. **Doocy S and G Burnham** Assessment of socio-economic status in the context of food insecurity: Implications for field research. *World Health Popl* 2005; **8(3)**: 32-42.

44. **Arnold BF, Null C, Luby SP, Unicomb L, Stewart CP, Dewey KG, Ahmed T, Ashraf S, Christensen G, Clasen T, Dentz HN, Fernald LC, Haque R, Hubbard AE, Kariger P, Leontsini E, Lin A, Njenga SM, Pickering AJ, Ram PK, Tofail F, Winch PJ and JM Colford.** Cluster-randomised controlled trials of individual and combined water, sanitation, hygiene and nutritional interventions in rural Bangladesh and Kenya: the WASH Benefits study design and rationale. *BMJ Open* 2013; **3(8)**: e003476.

45. **George CM, Oldja L, Biswas S, Perin J, Lee GO, Kosek M, Sack RB, Ahmed S, Haque R and T Parvin** Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh. *Am J Trop Med Hyg* 2015; **92(6)**: 1117-1124.

46. **Fuller JA and JNS Eisenberg** Herd Protection from Drinking Water, Sanitation, and Hygiene Interventions. *The American Journal of Tropical Medicine and Hygiene* 2016; **95(5)**: 1201-1210.

47. **Fuller JA, Villamor E, Cevallos W, Trostle J and JN Eisenberg** I get height with a little help from my friends: herd protection from sanitation on child growth in rural Ecuador. *Int J Epidemiol* 2016: dyv368.

48. **Arnold BF, Null C, Luby SP and JM Colford Jr.** Implications of WASH Benefits trials for water and sanitation – Authors' reply. *The Lancet Global Health* 2018; **6(6)**: e616-e617.

49. **Habicht JP, Victora CG and JP Vaughan** Evaluation designs for adequacy, plausibility and probability of public health programme performance and impact. *Int J Epidemiol* 1999; **28(1)**: 10-8.

50. **Boerma JT, Black RE, Sommerfelt AE, Rutstein SO and GT Bicego** Accuracy and completeness of mothers' recall of diarrhoea occurrence in pre-school children in demographic and health surveys. *Int J Epidemiol* 1991; **20(4)**: 1073-80.

51. **World Health Organization.** Improving Nutrition Outcomes with Better Water, Sanitation and Hygiene: Practical solutions for policies and programmes. WHO, Editor. 2015, WHO: Geneva.