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Plausibility Evaluation of Integrated WASH, Health, and Nutrition Programming on Childhood Growth and Maternal and Child Illness in Oromia, Ethiopia

By

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Plausibility Evaluation of Integrated WASH, Health, and Nutrition Programming on Childhood Growth and Maternal and Child Illness in Oromia, Ethiopia

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Washington University in St. Louis

2013

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Abstract

Background

Exposure to poor water, sanitation, and hygiene (WASH) may reduce absorption and utilization of essential nutrients, leading to sub-optimal growth. The Development Food Aid Program in Ethiopia targets maternal and child undernutrition through programs of one of two types: 1) health and nutrition only, or 2) integrated WASH, health, and nutrition. The health and nutrition only intervention involved training of health workers and community nutrition education; the integrated intervention added installation of water taps and community-led total sanitation and hygiene (CLTSH). Four years post program initiation, our objectives were to compare prevalence of undernutrition and two-week disease history in women and children 0-59 months between intervention groups and to examine the contribution of intervention components by quantifying associations between diet and WASH conditions targeted by the intervention and nutritional and disease outcomes.

Methods

A cross-sectional household survey (n=1,007) of mothers of children 0-59 mo was conducted in the Oromia Region of Ethiopia. Household selection followed a three-stage random-selection process. Household WASH conditions and diet and disease history were measured for each mother and one randomly selected child per household, and anthropometry was measured for this child. Data were analyzed using logistic regression, accounting for clustering at the kebele level. Baseline data were not representative of the area surveyed in this study due to resource constraints and were not used in analysis.

Results

Children in kebeles receiving the integrated intervention had a 16 percentage point lower prevalence of stunting (HAZ≤-2) and a 13.5 percentage point lower prevalence of caretaker-reported fever than children in kebeles receiving the health and nutrition intervention ($p<0.05$). Household sanitation facility was the strongest predictor of stunting, underweight and diarrhea in children, controlling for education level of mother and head of household, diet, child age and sex, and other environmental conditions. Factors associated with reduced disease in women included increased household food security, access to an improved water source, and a separate enclosure for livestock ($p<0.05$).

Conclusion

Integration of WASH activities and health and nutrition interventions was associated with less stunting and fever in children within the Oromia Region. Improvements in sanitation, targeted through CLTSH, may have contributed.

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Introduction

In 2011, stunting and wasting affected 165 million and 52 million children, respectively [1]. Worldwide, sub-optimal growth is responsible for an estimated 2.2 million deaths annually in children under five years of age [2]. Stunted and wasted children are at higher risk of mortality from infectious disease [1], and 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, 40% of children under five are stunted and 9% are wasted [4].

Among populations with poor water, sanitation, and/or hygiene (WASH), children's growth may be mediated by exposure to enteric pathogens via both clinical and sub-clinical pathways [5, 6]. Diarrhea is considered the most important infectious disease determinant of linear growth [7] and has been shown to be associated with both short and long-term linear growth faltering [7-10] and acute weight loss [9, 11]. Moreover, poor sanitation and hygiene has been associated with environmental enteropathy (EE) [5, 12-14], a prevalent subclinical disorder of the small intestine characterized by villous atrophy, crypt hyperplasia, increased gut permeability, and infiltration of inflammatory cytokines [15, 16]. Such physiological changes are shown to lower overall nutrient absorption in the gut, leading to stunting of linear growth [5, 13, 17].

Several studies document an association between access to an improved sanitation facility and reduced prevalence of stunting [18-23]. However, actual programmatic evidence of this benefit is limited. While a 2013 meta-analysis of five cluster randomized controlled trials suggested that WASH interventions may confer a small benefit in height (mean difference HAZ: 0.0 – 0.16, $p = 0.08$) [24], the trials involved in the meta-analysis emphasized hand washing

and/or water treatment only, with none addressing sanitation. Since 2013, three randomized controlled trials to evaluate interventions targeting sanitation through latrine access, all implemented as a part of national government initiatives in Mali or India, have been published, with mixed effects [18, 25, 26]. Only one evaluation of an operations research project found significant improvements in height-for-age Z-score following a WASH intervention in Ethiopia; however this same evaluation saw no improvement in HAZ in the intervention arm that included an integrated WASH, health, and nutrition intervention [27].

The objective of this study was to compare, four years post initiation, the association between an integrated WASH, health and nutrition intervention and a health and nutrition only intervention on the prevalence of undernutrition and disease in women and children 0-59 mo in the Oromia Region of Ethiopia. Both interventions were run by Catholic Relief Services' Development Food Aid Program. We examined aspects of the intervention that were most strongly associated with reduced prevalence of child undernutrition and maternal and child disease.

Literature Review

Worldwide, sub-optimal growth in infants and children is responsible for an estimated 2.2 million deaths annually in children under five years of age [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 environments with poor water, sanitation, and/or hygiene (WASH), children's growth may be mediated by exposure to enteric pathogens via both clinical and sub-clinical pathways [5].

Undernutrition is estimated to be an underlying cause for 45% of global deaths of children under five years [1] and over 60% of global diarrheal deaths [1, 28, 29]. Malnourished

children are more susceptible to enteric disease due to a suppressed immune system, degraded mucosal linings, and loss of gut microbiota diversity [5, 16]. Additionally, episodes of diarrhea reduce nutrient uptake by causing malabsorption of nutrients through inflamed intestines, reducing intestinal tract time, and diverting energy needed for growth and immune-system response [17]. Diarrhea is considered the most important infectious disease determinant of linear growth [7] and has been shown to be associated with both short and long-term linear growth faltering [7-10] and acute weight loss [9, 11]. For example, a pooled analysis of 9 community-based studies from low-income countries found that the odds of stunting for children under 24 mo increases multiplicatively with each previous period of diarrhea, such that 25% of stunting at age 24 mo is attributed to having had at least five previous periods of diarrhea [7]. While catch-up growth is postulated to occur following periods of diarrhea [8], persistent (>14 days) or recurring episodes inhibit this response [11]. Hand washing with soap, improved water quality and proper disposal of excreta are associated with diarrhea risk reductions of 48%, 17% and 36%, respectively [30]. Previous studies have also suggested a link between acute respiratory infection (ARI), poor WASH conditions, and undernutrition, documenting a reduction in ARI with increased hand washing [31] and an elevated prevalence of diarrhea and undernutrition in children with a history of ARI [32-34].

Even in the absence of active infection, prevalent subclinical disorders are suspected to play an important role in the link between WASH and nutrition [13]. Sanitation and hygiene are associated with environmental enteropathy (EE) [12], a disorder of the small intestine characterized by villous atrophy, crypt hyperplasia, increased gut permeability, and infiltration of inflammatory cytokines [15, 16], all of which may lower overall nutrient absorption [5, 13, 17]. Several studies document elevated biomarkers of intestinal inflammation [35, 36], permeability

[37-39], and mucosal lesions [40, 41] in stunted or underweight children who are not actively infected. Lunn and colleagues estimate that up to 43% of growth faltering in Gambian children can be explained by mucosal lesions in the gut [40]. The association between access to an improved sanitation facility and reduced prevalence of stunting is documented by several studies [18-23]. For instance, a longitudinal study in Pakistan found that access to safe water and a toilet were the strongest predictors of stunting in children [19]. In children in Lesotho, odds of stunting were 18% lower for those belonging to households with a latrine [20]. An ecological study of country level statistics obtained from Demographic Health Surveys of 65 developing countries indicated a clear negative correlation between access to improved sanitation facility and prevalence of stunting at a national level, controlling for GDP [21]. The same study found a positive correlation between open defecation and stunting across 112 counties in India [21].

Co-programming of WASH with health and nutrition programs has been proposed to reduce the burden of undernutrition by breaking the cycle of disease and malnutrition [14, 42, 43]. However, programmatic evidence of integrated WASH programming is limited. A 2013 Cochrane Review examined five cluster randomized and nine non-randomized trials with control groups and found no difference in the mean WHZ and WAZ scores between intervention and control groups [24]. While meta-analysis of the randomized controlled trials suggested that WASH interventions may confer a small benefit in height (mean difference HAZ: 0.0 – 0.16, $p = 0.08$) [24], the only study to show a significant improvement in HAZ saw improvement in the intervention arm that included WASH only, and no improvement in the intervention arm that included integrated WASH, health, and nutrition [27]. Additionally, of the studies that included HAZ as the outcome (n=10), only two examined effectiveness, compared to efficacy, of an intervention [27, 44], only three were located in sub-Saharan Africa [27, 45, 46], and only two,

and none of the randomized trials, addressed sanitation [27, 47]. Since 2013, three randomized controlled trials to evaluate interventions targeting sanitation through latrine access, all implemented as a part of a national government initiative, have been published, with mixed effects [18, 25, 26]. For instance, Pickering and colleagues found significantly reduced prevalence of stunting and underweight for children under five years of age in Mali receiving a community-led total sanitation (CLTS) intervention compared to those receiving no intervention. However, two randomized controlled trials from India conducted by Clasen and colleages [25] and Patil and colleagues [26] documented no difference in child anthropometry or diarrhea between control households and intervention households that received a latrine. Finally, few studies beyond those cited here [27, 48] have examined the association between WASH and nutrition within Ethiopia, where 46% of the population lack access to an improved drinking water source, 90% lack access to an improved sanitation facility, and prevalence of stunting (40%, HAZ $\leq$-2), underweight (25%, WAZ$\leq$-2), and wasting (9%, WHZ$\leq$-2) in children is high [4].

The Development Food Aid Program (DFAP) is a USAID-supported initiative in Ethiopia begun in 2011 and administered through four NGO's (Catholic Relief Services, Save the Children-US, Food for Hungry, and Relief Society of Tigray), with the objective of sustaining and building upon food security initiatives achieved under the Government of Ethiopia (GoE) Productive Safety Net Program (PSNP) [49]. PSNP beneficiaries are households who receive direct food and cash transfers from GoE based on demonstrated chronic food insecurity, low agricultural productivity and low asset-holding [50]. PSNP beneficiaries reside in ecological zones characterized by low annual rainfall. The DFAP has been implemented in 33 administrative zones across Ethiopia, where the administrative structure of Ethiopia is shown in

Figure 1 [51]. Catholic Relief Services (CRS) – Ethiopia operates within three of these administrative zones and within seven woredas, subunits of zones (Figure 2).

Through the DFAP, CRS addresses underlying causes of food insecurity through community asset building and health, nutrition, and WASH interventions. Health and nutrition intervention components consist of community education, screening and treatment of severe malnutrition, seed provision, promotion of backyard gardening, and capacity building of community health extension workers and health center staff. WASH interventions focus on community-led total sanitation and hygiene (CLTSH) activities to eliminate open defecation and encourage hand washing, as well as the construction or rehabilitation of new or existing water points. CLTSH is a participatory approach that mobilizes communities to eliminate open defecation, build and/or upgrade their own toilets, and practice proper sanitation. Once CLTSH is "triggered" in a community, the community develops a community action plan for comprehensive sanitation coverage [52]. For dissemination of nutrition and WASH related messaging, CRS relies on existing community platforms, such as pregnant women's meetings and agricultural training centers, as well the national health extension program. This program provides universal access to primary health care and employs over 38,000 salaried female health workers, at least two per kebele across Ethiopia [53]. At initiation, some kebeles (smallest official administrative unit, see Figure 2) received a health and nutrition only intervention, while other kebeles received an integrated health, nutrition, and WASH intervention. A baseline survey was conducted in 2011 by an external agency, Dadimos Development Consultants, to capture baseline estimates of undernutrition, water and sanitation access, and other health-related indicators [51]. The baseline survey sampled from all 33 zones where the DFAP was implemented.

Four years post initiation of the intervention, our objective was to evaluate the plausibility that exposure to one of two CRS DFAP interventions: 1) health and nutrition only, or 2) integrated WASH, health, and nutrition, resulted in differences in the prevalence of stunting, wasting, and underweight in children 0-59 months and prevalence of two-week history of diarrhea, fever and ARI in children and mothers of children 0-59 mo. We then aimed to quantify the associations between WASH and diet outcomes targeted in the intervention and nutritional and disease outcomes in mothers and children to elucidate aspects of the program that were particularly effective and to contribute evidence to the plausibility of the intervention to produce the observed differences.

Manuscript

Abstract

Objective
To compare the difference in prevalence of undernutrition and two-week history of disease in women and children in Oromia, Ethiopia between two intervention groups: health and nutrition only, and integrated WASH, health, and nutrition intervention; to examine associations between intervention components and nutritional and disease outcomes.

Methods
Interventions were implemented in 2011 by Catholic Relief Services: Development Food Aid Program. The health and nutrition only intervention involved training of health workers and community education; the integrated intervention added water tap construction and community-led total sanitation and hygiene (CLTSH). Four years post initiation, a cross-sectional household survey (n=1,007) of mothers of children 0-59 mo was conducted. Household selection followed a three-stage random-selection process. Household WASH conditions and diet and disease history were recorded for each mother and one randomly selected child per household, and anthropometry was measured for this child. Data were analyzed in SUDAAN to account for clustering.

Results
Children from the integrated intervention arm had a 16 percentage point lower prevalence of stunting and a 13.5 percentage point lower prevalence of fever compared to the health and

nutrition only intervention arm ($p<0.05$). Controlling for various factors, sanitation facility was the strongest predictor of child stunting, underweight and diarrhea. Household food security, access to an improved water source, and a separate enclosure for livestock were associated with less disease in women ($p<0.05$).

Conclusion
Integration of WASH into the health and nutrition intervention was associated with less stunting and fever in children. Improved sanitation, targeted through CLTSH, may have contributed.

Introduction

In 2011, stunting and wasting affected 165 million and 52 million children, respectively [1]. Worldwide, sub-optimal growth is responsible for an estimated 2.2 million deaths annually in children under five years of age [2]. Stunted and wasted children are at higher risk of mortality from infectious disease [1], and 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, 40% of children under five are stunted and 9% are 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 clinical and sub-clinical pathways [5, 6]. Diarrhea is considered the most important infectious disease determinant of linear growth [7] and has been shown to be associated with both short and long-term linear growth faltering [7-10] and acute weight loss [9, 11]. Moreover, poor sanitation and hygiene has been associated with environmental enteropathy (EE) [5, 12-14], a prevalent subclinical disorder of the small intestine characterized by villous atrophy, crypt hyperplasia, increased gut permeability, and infiltration of inflammatory cytokines [15, 16]. Such physiological changes are shown to lower overall nutrient absorption in the gut, leading to stunting of linear growth [5, 13, 17].

Several studies document an association between access to an improved sanitation facility and reduced prevalence of stunting [18-23]. However, programmatic evidence of integrated WASH programming is limited. A 2013 Cochrane Review examined five cluster randomized and nine non-randomized trials with control groups and found no difference in the mean WHZ and WAZ scores between intervention and control groups [24]. While meta-analysis of the randomized controlled trials suggested that WASH interventions may confer a small benefit in height (mean difference HAZ: 0.0 – 0.16, $p = 0.08$) [24], the only study to show a significant improvement in HAZ saw improvement in the intervention arm that included WASH only, and no improvement in the intervention arm that included integrated WASH, health, and nutrition [27]. Additionally, of the studies that included HAZ as the outcome (n=10), only two examined effectiveness, compared to efficacy, of an intervention [27, 44], only three were located in sub-Saharan Africa [27, 45, 46], and only two, and none of the randomized trials, addressed sanitation [27, 47]. Since 2013, three randomized controlled trials to evaluate interventions targeting sanitation through latrine access, all implemented as a part of national government initiatives in Mali or India, have been published, with mixed effects [18, 25, 26]. Finally, few studies beyond those cited here [27, 48] have examined the association between WASH and nutrition within Ethiopia.

The purpose of this study was to compare the prevalence of stunting, wasting, and underweight in children 0-59 months and prevalence of two-week history of diarrhea, fever and ARI in children and mothers of children 0-59 mo between two intervention arms. The intervention arms were either health and nutrition only or integrated WASH, health, and nutrition. Interventions were implemented in 2011 as part of Catholic Relief Services' Development Food Aid Program. We quantified the associations between WASH and diet

outcomes targeted in the intervention and nutritional and disease outcomes in mothers and children to elucidate aspects of the program that were particularly effective and to contribute evidence to the plausibility of the intervention to produce the observed differences.

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 mo. was obtained from the mother of the child. This study was determined exempt from review by the institutional review board at Emory University in Atlanta, USA as it was classified as program evaluation and not research with human subjects.

Program description. The Development Food Aid Program (DFAP) is a USAID-supported initiative in Ethiopia begun in 2011 with the objective of sustaining and building upon food security initiatives achieved under the Government of Ethiopia (GoE) Productive Safety Net Program (PSNP) [49]. PSNP beneficiaries are households who receive direct food and cash transfers from GoE based on demonstrated chronic food insecurity, low agricultural productivity and low asset-holding [50]. The DFAP has been implemented in 33 administrative zones across Ethiopia [51]. Catholic Relief Services (CRS) – Ethiopia operates within three of these administrative zones and within seven woredas, subunits of zones (Figure 2). Through the DFAP, CRS addresses underlying causes of food insecurity through community asset building and health, nutrition, and WASH interventions. Health and nutrition intervention components consist of community education, screening and treatment of severe malnutrition, seed provision, promotion of backyard gardening, and capacity building of community health extension workers and health center staff. WASH interventions focus on community-led total sanitation and

hygiene (CLTSH) activities to eliminate open defecation and encourage hand washing, as well as the construction or rehabilitation of new or existing water points. CLTSH is a participatory approach that mobilizes communities to eliminate open defecation, build and/or upgrade their own toilets, and practice proper sanitation. Once CLTSH is "triggered" in a community, the community develops a community action plan for comprehensive sanitation coverage [52]. At initiation, some kebeles (smallest official administrative unit, see Figure 2) received a health and nutrition only intervention, while other kebeles received an integrated health, nutrition, and WASH intervention. A baseline survey was conducted in 2011 from all 33 zones where the DFAP was implemented.

Study site and design. We conducted a plausibility evaluation to examine the impact of two DFAP interventions on nutritional and disease outcomes on women and children. The interventions included either a health and nutrition only intervention (the reference group), or an integrated WASH, health, and nutrition (the treatment group). Between June and July 2015, a cross-sectional survey (n=1,007) was administered in two districts (*woredas*) of one administrative zone within Oromia Region, Ethiopia. The study region was chosen by convenience and kebeles had to be classified as both CRS and PSNP beneficiaries to be included for selection (see Figure 2). Twenty nine kebeles in the study region met this inclusion criteria, from which twelve were chosen randomly after stratifying the eligible kebeles by woreda and intervention type (three per woreda per intervention type, see Figure 1). Kebeles are divided into four administration regions called subzones. Two to three subzones per kebele were randomly selected for surveying, according to size of the subzone. Households to be surveyed were selected following the Expanded Program on Immunization (EPI) method outlined elsewhere [41]. Briefly, data collectors stood in the subzone center and walked outward in a direction

determined by a random pen spin, going to the nearest household that contained an eligible respondent. All respondents were mothers of children 0-59 months. If households contained more than one mother with a child 0-59 mo., or more than one child, one mother and one of her children were chosen randomly to be the survey subjects. 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 eligibility criteria for the survey but was not selected for this study. Data was collected on iPads and cleaned with SAS version 9.3.

Measurement of diet and disease (see Appendix A). We applied the UNICEF framework for undernutrition to guide the selection of survey variables for our analysis (Figure 3) [54]. Household food security was measured by the reduced Coping Strategy Index (CSI), which sums the weighted weekly total of a set of pre-defined behaviors families use to meet their food needs [55]. Dietary Diversity Score (DDS) was calculated for each respondent and child by summing the number of food groups consumed in the past 24 hours, according to groups defined by Food for Peace [56].

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 [57]. Two-week history of acute respiratory infection (ARI) was determined for children through a series of questions used by the Ethiopian Demographic Health Survey (DHS) [58].

Measurement of WASH conditions (see Appendix A). Mothers were asked their primary and secondary 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 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 surrounding the house.

Anthropometry. The selected child was measured using standard methods [54]; height (for child less than 24 mo) or supine length (for child 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. Mothers reported the child's age in months, and important dates and holidays were used to confirm. Height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) Z-scores were determined based on the World Health Organization's 2011 child growth standards using WHO Anthro version 3.2.2 [59].

Statistical analysis. Sampling weights were calculated for each observation in the dataset by dividing the number of households in the observation's kebele by the number of households surveyed in that kebele. A separate sampling weight was calculated for children-specific analyses that adjusted for the number of children under 5 years in the household. Data were analyzed using Survey Data Analysis (SUDAAN) [60] in Statistical Analysis Software (SAS) version 9.4 [61] to account for clustering at the kebele level.

We first compared the distribution of demographic, dietary, and WASH factors and nutrition and disease status by type of intervention received using an intention-to-treat analysis using t-tests and chi-squared tests. We modeled the odds of undernutrition and two-week history of disease with intervention type as the exposure of interest using logistic regression, adjusting for child age, child sex, number of children <18 y in the household, and mother's education status. Logistic regression was used to compute adjusted measures of association between

outcome variables and dietary and WASH variables targeted by the two interventions. Predictor variables for these models included coping strategy index (CSI), dietary diversity score (DDS), primary sanitation facility, primary water source, knowledge of critical hand washing times, presence of a hand washing agent in designated spot, existence of separate corral for domestic farm animals and presence of feces observed around the house. Statistical significance was assessed using the Wald-F test. Multicollinearity between each of the independent variables was examined. Education levels of the mother and the head of household were used as proxy indicators for socio-economic status (SES) [62]. Other possible confounders considered for adjustment included distance to nearest town center, head of household gender, 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 found to be confounders or associated with the outcome. We tested for interaction between any of the exposures of interest and the variables adjusted for, using the likelihood ratio test. No interaction was found.

Results

A total of 1,007 households were surveyed; 446 in the health and nutrition only kebeles and 561 in the integrated WASH, health and nutrition kebeles (Table 1). 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, 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 between the intervention groups (Table 1). Forty eight percent of households in the integrated WASH intervention kebeles used an improved sanitation facility, compared to 28% of households in the health and nutrition only intervention group ($p=0.02$). Eighty six percent of sanitation facilities had at least one recorded indicator of use (presence of worn path to latrine, presence of feces in and around hole, presence of water for washing or flushing; data not shown). The remaining WASH conditions did not differ significantly ($p<0.05$) by intervention group. Seventy eight percent of households in WASH intervention kebeles had access to an improved water source as their primary drinking water, compared with 73% of households in health and nutrition only kebeles. Less than a quarter of the respondents treated their drinking water. Mothers from integrated WASH intervention kebeles demonstrated greater knowledge and practice of proper hand washing as evidenced by knowledge of the five critical times for hand washing (mean of 3.5 times reported for health and nutrition only kebeles and mean of 3.7 times reported for WASH kebeles) and existence of a designated hand washing station with a cleaning agent present at the time of visit (3.5% of health and nutrition only kebeles and 6.9% of WASH kebeles), though the differences were not statistically significant. Forty five percent of households in the health and nutrition only intervention kebele had a separate enclosure for chickens, goats or sheep, compared to 37% of the WASH kebeles (note that maintaining separate enclosure for livestock was not an educational component of either intervention program). Presence of feces, primarily animal feces, was observed near and around roughly half of all households.

Association between intervention type and nutrition and disease outcomes. Height and weight measurements were obtained for 96% of the children. Prevalence of stunting and two-week history of fever in children 0-59 mo was significantly lower in WASH intervention kebeles (38%) compared to health and nutrition only kebeles (54%, p=0.04) (Table 2). Adjusting for demographic factors, the odds of stunting for children in WASH intervention kebeles was 50% lower than the odds of stunting for children in health and nutrition only intervention kebeles (OR: 0.50, 95% CI: 0.26, 0.97). Children in WASH intervention kebeles had 49% reduced odds of having had a fever in the past two weeks compared to children in the health and nutrition only intervention kebele (OR: 0.51, 95 CI: 0.36, 0.74).

Associations between WASH conditions and undernutrition. In adjusted models across all households, access to improved sanitation facility was the strongest predictor of stunting and underweight in children (Table 3). Children in households with an improved sanitation facility had 46% lower adjusted odds of stunting (OR: 0.54, 95% CI: 0.36, 0.80) and 45% lower adjusted odds of underweight (OR: 0.54, 95% CI: 0.31, 0.99) than children belonging to households practicing open defecation or utilizing an unimproved facility. Decreased household food security (decreased CSI) was also strongly correlated with increased odds of stunting in children (OR: 1.02, 95% CI: 1.01, 1.03). Knowledge of hand washing was also strongly associated with increased odds of stunting in children (OR: 1.14, 95% CI: 1.00, 1.30). Dietary diversity was highly correlated with wasting, with children who had consumed, on average, one more food group, having 0.78 times the odds of wasting than those who consumed one less (OR: 0.78, 95% CI: 0.62, 0.98).

Associations between WASH conditions and disease history. Access to an improved primary water source during at least four days in the past week were strongly associated with over 50%

reduction in the odds of two-week prevalence of diarrhea (OR: 0.41, 95% CI: 0.25, 0.67) and fever (OR: 0.46, 95% CI: 0.36, 0.61) in women (Table 4). Similarly, children living in households with an improved sanitation facility had a lower odds of diarrhea than children in households with an unimproved sanitation facility (OR: 0.71, 95% CI: 0.55, 0.91). Existence of a separate enclosure for domestic farm animals was significantly associated with a reduced odds of fever in women (OR: 0.56, 95% CI: 0.41, 0.76) and ARI in children (OR: 0.70, 95% CI: 0.51, 0.97). Knowledge of hand washing was also associated with decreased fever in women (OR: 0.85, 95% CI: 0.72, 1.00).

Discussion

There is growing interest in integrating water, sanitation, and hygiene components into health and nutrition interventions, but programmatic evidence is limited. Evidence from Ethiopia, a country with a high prevalence of stunting, is also scarce. We found that co-programming of WASH with health and nutrition interventions is associated with improved nutritional and disease outcomes in women and children compared to health and nutrition only interventions, even in a non-controlled, programmatic setting. WASH components of CRS Development Food Aid Program integrated WASH, health, and nutrition intervention included community-led total sanitation and hygiene (CLTSH), installation or reparation of water taps, and hand washing education. Kebeles receiving the integrated intervention had a 13.5 percentage point lower prevalence of fever in children 0-59 mo and a 16 percentage point lower prevalence of stunting in children than kebeles receiving the health and nutrition only intervention. The odds of stunting in children 0-59 mo who resided in kebeles having received the integrated intervention were 0.50 and 0.51 times that of children in kebeles having received the health and nutrition only intervention, respectively. Given the high global prevalence of stunting and its

important consequences for health and development, Black et al. argues that stunting is the best indicator for childhood undernutrition [1]. Our findings are consistent with a recent randomized controlled trial which estimated a prevalence ratio of 0.85 for stunting and 0.87 for underweight for children under five years of age in Mali receiving a CLTS intervention compared to those receiving no intervention [18].

We identified WASH and nutrition components of the intervention that were significantly associated with reduced prevalence of undernutrition and disease. Previous meta-analysis of the effect of randomized controlled trials of WASH interventions on children's nutritional status considered only those interventions that included drinking water improvements and/or hygiene education and soap provision [24]; here we show through associations derived from a programmatic setting, that sanitation is a stronger predictor of stunting, underweight and diarrhea in young children than drinking water source and hygiene, while access to an improved drinking water source was significantly associated with reduced odds of diarrhea and fever in adult women only. Sanitation facility was the strongest predictor of stunting and underweight in children, with the odds of stunting and underweight in children belonging to households with an improved sanitation facility nearly half the odds of stunting and underweight in children belonging to households practicing open defecation or utilizing an unimproved sanitation facility. Moreover, we found that roughly 41% of diarrhea cases in children can be attributed to improper sanitation facility. This is consistent with a study in Pakistan that found that access to safe water and a toilet were the strongest predictors of diarrhea in children [19].

Our results contrast those found by Pickering, et al. [18] and Clasen, et al. [25], both of whom document no association between latrine ownership and diarrhea in children. However, Clasen attributed lack of association to low latrine utilization, while the majority of latrines

observed in our study were positive for at least one indicator of use (i.e. worn path to latrine, presence of wet feces in or around hole, or availability of water for flushing; data not shown). Additionally, Pickering found a reduction in bloody diarrhea and diarrhea-caused mortality among households with latrines, indicating that CLTS interventions may reduce the burden of severe diarrhea, a variable not captured in our study [18].

Access to improved water source in the past week was associated with a reduction of nearly 60% in the odds of diarrhea and fever in women. The lack of significant reduction of diarrhea and fever in women between intervention groups could therefore be because not all women residing in the integrated intervention kebeles had access to an improved water source, while over 70% of the women residing in the health and nutrition only kebeles had access to an improved water source. The strong, positive association between mother's hand washing knowledge and childhood stunting is unexpected and in contrast with other studies showing a strong, protective association between hygiene and growth [12, 18, 22]. However, we observed in our study that hand washing knowledge did not reflect hand washing practice. For instance, 97% of respondents reported using soap, ash or other cleaning agents to wash their hands, but observations conducted for respondents who had a designated hand washing place revealed that a cleaning agent was available less than half of the time (data not shown).

Women and children with higher food insecurity, as measured by coping strategy index (CSI), were also found to have significantly higher odds of diarrhea and ARI, consistent with a study in Colombia that identified significant associations between household food insecurity and diagnoses of diarrhea and respiratory infections among preschool children [63]. Finally, the association between existence of a separate corral for animals and disease reduction is consistent

with studies implicating animal presence in the sleeping area and geophagy as disease-promoting [12, 38].

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. The cross-sectional design of the study and non-experimental allocation of study arms further limits our ability to make any causal inference regarding the program's impact. Habicht, Victora, and Vaughan define plausibility as "the program appears to have some effect above and beyond the influence of non-programme influences", or confounders [64]. We believe that 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 type do not differ significantly 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). As CRS did not consider WASH, nutritional or disease status in the kebeles when assigning intervention types (W. Tadesse, personal communication, June, 2015), and all kebeles received components of the health and nutrition intervention, we expect the only differences observed among non-outcome variables to be among household WASH characteristics. Second, CRS utilizes CLTS in their intervention, a participatory method that mobilizes communities to eliminate open defecation, build their own toilets, and/or upgrade their existing toilet. We observe a clear dose-response relationship between household participation in the CLTS intervention, represented by type of sanitation facility used, and mean Height-for-Age Z-score, even when controlling for intervention type (Figure 4). Stratifying sanitation option by type (i.e. open defecation, pit latrine

without cleanable slab, pit latrine with cleanable slab, and pit latrine with cleanable slab and hole cover), we find that the odds of stunting decreases as households move 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, and sanitation facility was the strongest predictor of stunting, it is plausible that the differences in stunting prevalence by intervention type can be attributed to the improvements in sanitation in the integrated WASH intervention kebeles due to community-led total sanitation and hygiene initiatives.

This study has several other limitations. No direct measure of socioeconomic status (SES) was captured in our survey. However, a study conducted in the Amhara region of Ethiopia found that education level of the head of the household was a good proxy for SES when considering nutritional outcomes [62]. Religion of respondent was also not captured in the survey, which may confound the relationship between diet and anthropometry, as the survey was conducted during fasting season for both Ethiopian Christians and Muslims. The survey was conducted before the start of the rainy season, when farm production is generally low, which may also result in lower recorded values for dietary diversity and food security. Some kebeles were visited on market days, during which a few mothers were absent from their homes, which may be a potential selection bias as mothers capable of visiting the market are likely better in health and have higher purchasing power. However, market days did not differ between intervention type so the result of this selection bias, if any, is expected to be small and bias the results towards the null (J. Head, observation, June 2015). Additionally, measurement tools for height were accurate to ± 1 cm only (instead of ±0.1 cm), leading to a lack of precision and possible over-estimation of the prevalence of stunting or differences in enumerator

measurements (Appendix B). However, analysis of variance (ANOVA) tests revealed no significant difference in height or weight measurements among the eleven data collectors, suggesting uniformity in technique, and misclassification, if any, is expected to be non-differential by intervention type. Standard deviations of HAZ, WHZ, and WAZ scores by enumerator were examined and logistic regression was repeated excluding values from the enumerator with the highest random error in measurement (Appendix C). We find that the results presented here are not sensitive to enumerator. Finally, this survey relied on self-report and maternal-report of disease, which is subject to recall bias, as studies have shown that the recall period begins to drop after 2-3 days to one week [65, 66]. However, a recall period of two weeks was chosen based on the standard interval used for Ethiopian DHS surveys [67] and the CRS baseline survey [51], and Pickering et al. found no difference in diarrhea prevalence between a two-week self-report and a two-day self-report [18].

This study has several strengths. The large sample size of the survey permits examination of the contribution of each part of the targeted intervention. Sampling of the survey population was done randomly so survey respondents are believed to be representative of the target population. Enumerators used in data collection had been employed by CRS prior to this survey to conduct other surveys for CRS, and were well trained in data collection. Finally, the placement of this study within the context of an existing national food security program contributes evidence to the effectiveness of WASH interventions even in non-ideal settings.

Conclusion

Integration of WASH activities into nutrition interventions was associated with significantly reduced chronic undernutrition in children 0-59 mo within the Oromia Region of Ethiopia. Compared to households in kebeles receiving a health and nutrition only intervention,

households in kebeles receiving integrated WASH interventions had significantly greater access to an improved sanitation facility, which was shown to be the strongest predictor of stunting, underweight and diarrhea in children 0-59 mo. While no significant differences were seen in disease outcomes of adult women by intervention type, targeted outcomes of the integrated WASH, health, and nutrition intervention, namely, household food security and access to safe water, were associated with reduced odds of fever and diarrhea in women. Initiatives such as community-led total sanitation and hygiene (CLTSH) aimed at eliminating open defecation, promoting latrine use, and reducing disease may have contributed. Integrated programs are now being recommended by USAID and other multilateral organizations [42]. 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.

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Conclusion and Recommendations

Assuming the integrated intervention is indeed responsible for the observed differences in children's height, there are several aspects of the intervention which we postulate contributed to its success. First, community structures and health services at the most decentralized level were

utilized for implementation, two platforms which Lemma and Matji argue are central toward achieving nutritional progress, highlighting Ethiopia as a positive example of an environment conducive to exploiting these mechanisms [53]. Second, CRS utilizes CLTS to encourage latrine use, which focuses on behavioral change as a means to sustainably achieve open defecation free status [68]. For instance, while Pickering attributes significant reduction in stunting to a CLTS intervention [18], Clasen observes no effect on diarrhea or anthropometry from an intervention that confers latrine ownership through a government plan to build latrines for community members, a distinctly antithetical CLTS approach [25]. In this study, Clasen and colleagues attribute lack of association to low latrine utilization, while the majority of latrines observed in our study were positive for at least one indicator of use (data not shown). Given the strength of sanitation as a predictor of stunting in this study, we feel further randomized controlled trials investigating the effect of CLTS on child growth is warranted.

In conclusion, while no significant differences were seen in disease outcomes of adult women by intervention type, perhaps due to incomplete distinction of access to WASH intervention components between the intervention groups, targeted outcomes of the integrated WASH, health, and nutrition intervention, namely, household food security and access to safe water, were associated with reduced odds of fever and diarrhea in women. Integration of WASH activities into nutrition interventions was associated with significantly reduced chronic undernutrition in children 0-59 mo within the Oromia Region of Ethiopia. Compared to households in kebeles receiving a health and nutrition only intervention, households in kebeles receiving integrated WASH interventions had significantly greater access to an improved sanitation facility, which was shown to be the strongest predictor of stunting, underweight and diarrhea in children 0-59 mo. Initiatives such as community-led total sanitation and hygiene

(CLTSH) aimed at eliminating open defecation, promoting latrine use, and reducing disease may there have contributed. Integrated interventions involving CLTSH should be examined in greater detail in future studies.

Figures and Tables

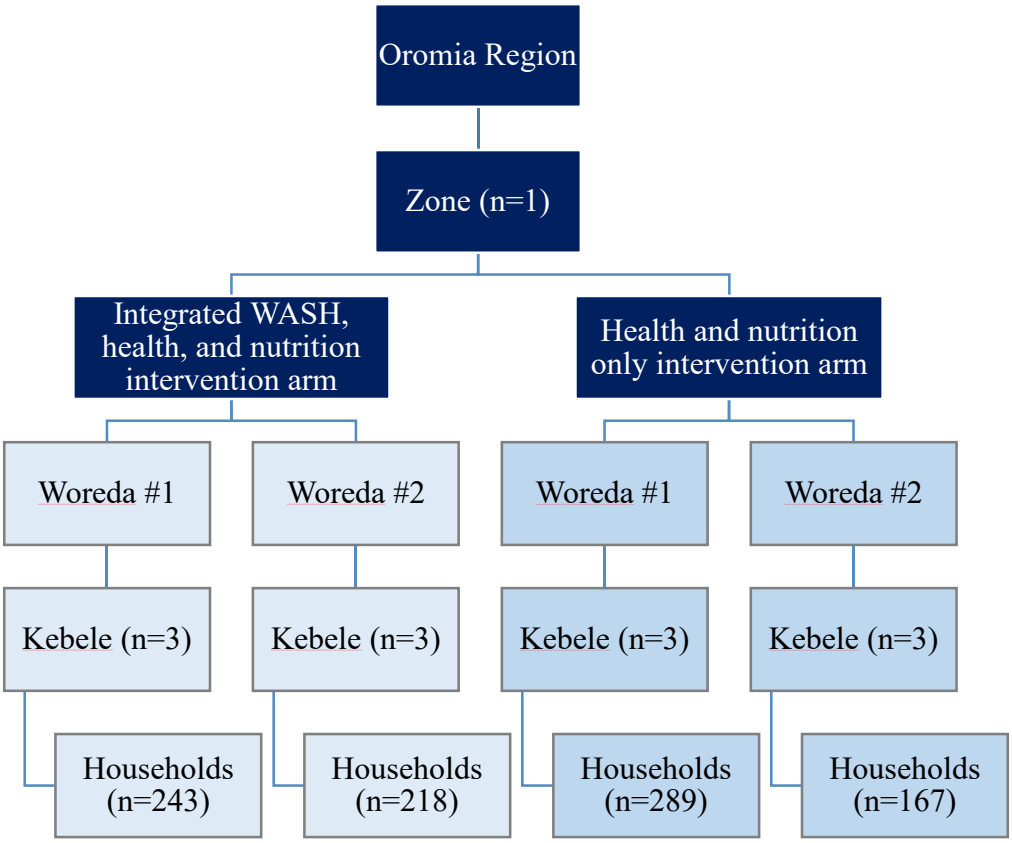

Figure 1. Household sampling strategy

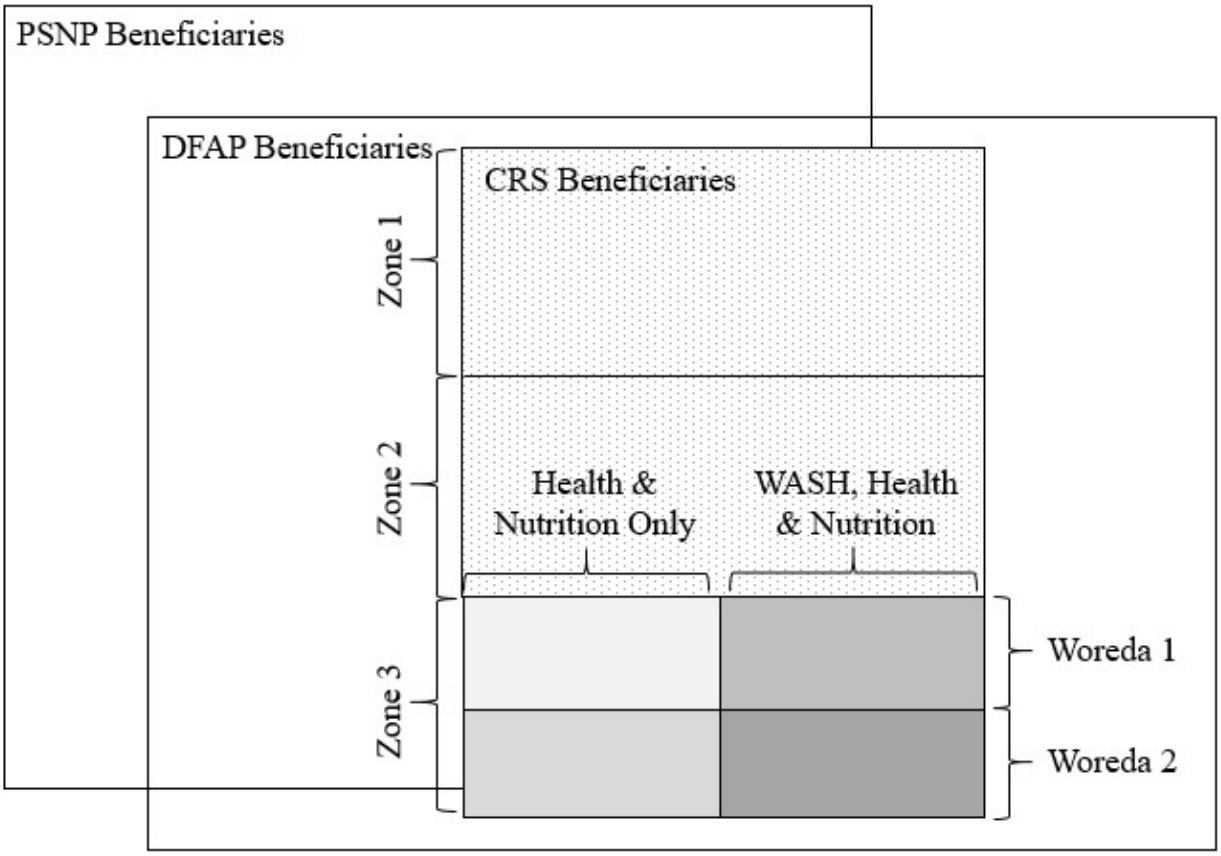

Figure 2. Structure of PSNP and DFAP. Baseline data was collected for all DFAP beneficiaries. Gray filled boxes indicate area covered by current survey. Note: drawing not to scale and only kebeles covered by both PSNP and DFAP areas were eligible for the survey. CRS = Catholic Relief Services ; DFAP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

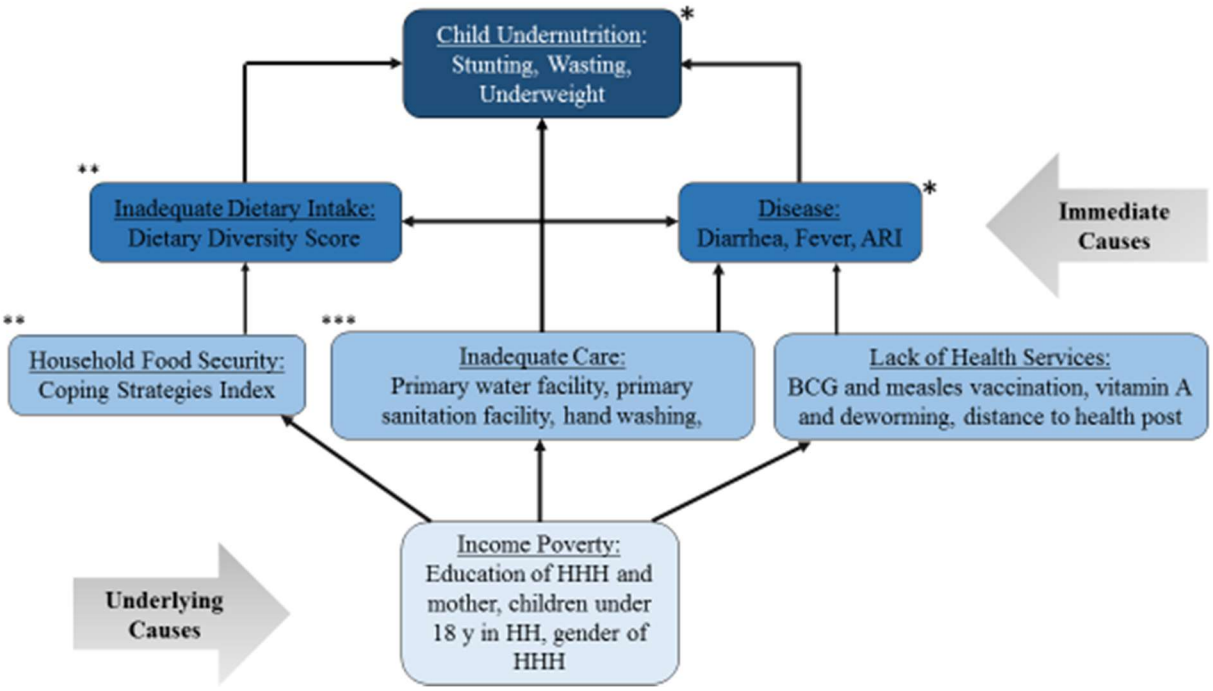

Figure 3. Survey indicators, adapted from UNICEF's framework for maternal and child undernutrition [54]. *Primary outcome variables; **Variables addressed through both interventions; ***Additional variables addressed through integrated WASH, health and nutrition intervention; HH=household; HHH=head of household. ARI = Acute respiratory infection; BCG = Bacillus Calmette–Guérin

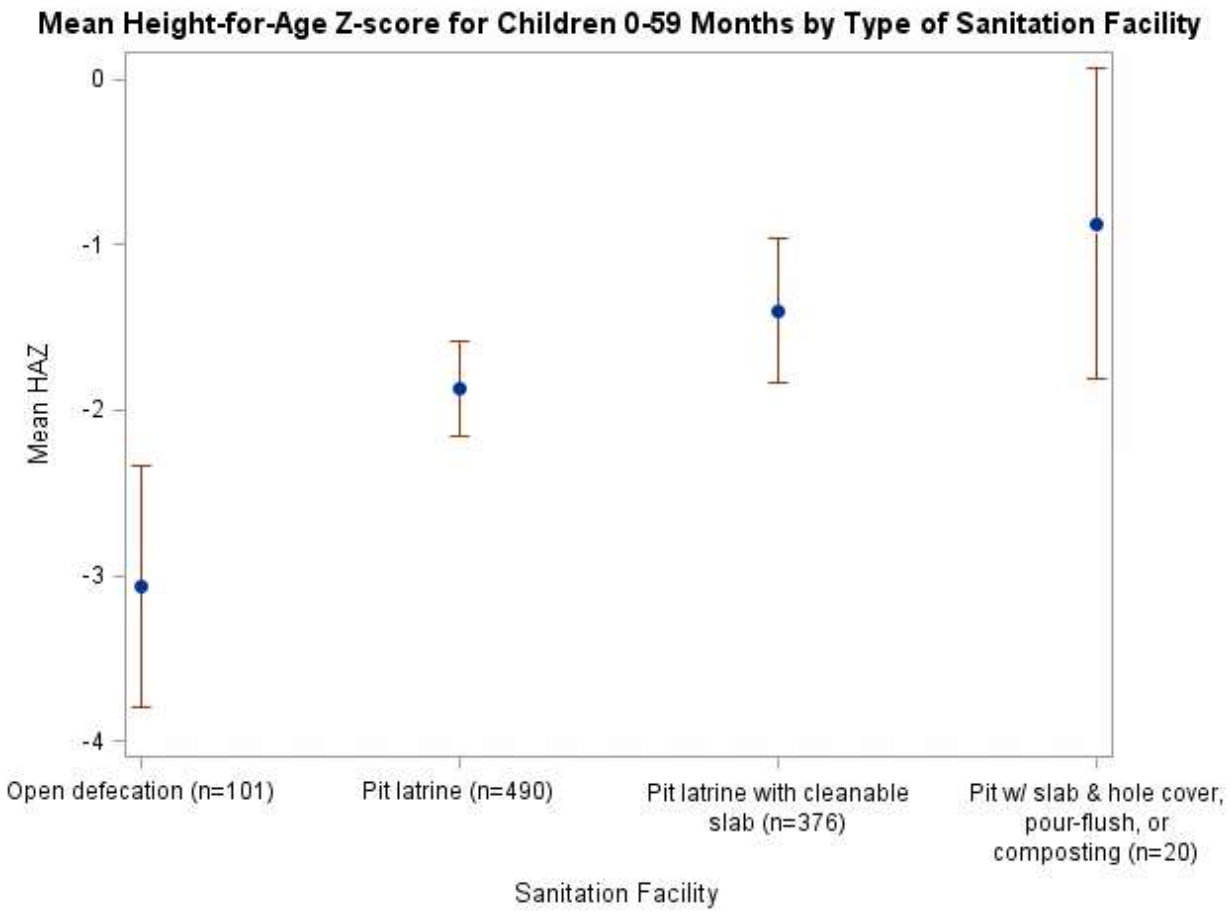

Figure 4. Dose-Response relationship between mean HAZ and sanitation facility

Table 1. Study population characteristics by intervention type, in percentage or mean ± SE

Characteristic	Health and Nutrition Only (%) N=446	Integrated WASH, Health 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
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 known[4] (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 animals[5]	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; [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[56]; [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 [55]. Higher numbers indicate lower food security; [4]Maximum of five critical hand washing times were possible; [5]Chicken, sheep and goats.

Table 2. Comparison of disease and nutrition outcomes by intervention type

Outcome	**Intervention Type, proportion (95% CI)**		**Adjusted OR[1] (95% CI)**
	Health and Nutrition Only N=446	**Integrated WASH, Health and Nutrition** N=561	
Child 0-59 months			
Anthropometric measurements			
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)

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; OR = odds ratio

[1]Health and nutrition only group is used as the reference group. For children, the measure is adjusted for age in months, age squared, sex, family size, and education of mother. For mothers, the measure is adjusted for education level and family size.

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

Table 3. Association between diet and WASH conditions and undernutrition

Variable	Proportion Stunted (HAZ≤-2) OR[1] (95% CI) N=902	Proportion Underweight (WAZ≤-2) OR (95% CI) N=904	Proportion Wasted (WHZ≤-2) OR (95% CI) N=896
Dietary Conditions			
Dietary Diversity Score[2]	0.87 (0.71, 1.07)	0.81 (0.60, 1.09)	0.78 (0.62, 0.98)*
Coping Strategy Index[3]	1.02 (1.01, 1.03)*	1.01 (0.99, 1.03)	1.00 (0.98, 1.02)
WASH Conditions			
Access to improved sanitation facility	0.54 (0.36, 0.80)*	0.55 (0.31, 0.99)*	1.38 (0.76, 2.49)
Access to improved water source for at least 4 days in past week	--	--	0.59 (0.33, 1.07)
Access to improved water source for at least 6 months of the year	0.80 (0.39, 1.61)	0.75 (0.39, 1.44)	--
Caretaker knowledge of critical hand washing times[4]	1.14 (1.00, 1.30)*	0.89 (0.73, 1.09)	1.14 (0.81, 1.62)
Existence of designated hand washing location w/ cleaning agent	0.85 (0.31, 2.30)	1.13 (0.38, 3.38)	2.11 (0.78, 5.73)
Existence of separate enclosure for domestic farm animals[5]	0.97 (0.61, 1.53)	0.83 (0.44, 1.56)	0.97 (0.64, 1.48)
Observed presence of feces around compound	0.97 (0.60, 1.56)	1.15 (0.66, 1.98)	0.75 (0.45, 1.26)

CI = confidence interval; HAZ = height/length-for-age z-score; WAZ = weight-for-age z-score; WHZ = Weight-for-height/length z-score; OR = odds ratio

[1]Adjusted for age in months, age squared, sex of child, education level of mother and head of household, family size, and listed exposures; [2]Compares the odds of outcome for a child who consumed one more food group in the past 24 hours to a child who consumed one less food group; [3]Compares the odds of outcome for a child living in a household with a CSI score 1 point higher than a child living in a household with a CSI score 1 point lower. CSI is calculated by a weighted average of times per week a family must resort to a pre-defined coping strategy to meet their food needs [55]. Higher numbers indicate lower food security; [4]Compares the odds of outcome for a child whose mother reported one additional of the five critical hand washing times; [5]Domestic farm animals considered were chicken, sheep and goats.

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

Table 4. Association between diet and WASH conditions and two-week history of disease in women and children 0-59 months

Variable	Diarrhea OR (95% CI)		Fever OR (95% CI)		ARI OR (95% CI)
	Child[1], 0-59 mo N=916	**Mother[2]** N=984	**Child, 0-59 mo** N=919	**Mother** N=983	**Child, 0-59 mo** N=918
Dietary Conditions					
Dietary Diversity Score[3]	0.77 (0.68, 0.87)*	0.93 (0.62, 1.41)	1.03 (0.82, 1.28)	0.84 (0.62, 1.14)	0.95 (0.79, 1.14)
Coping Strategy Index[4]	1.02 (1.01, 1.03)*	1.02 (1.01, 1.03)*	1.00 (0.98, 1.02)	1.01 (1.00, 1.03)	1.01 (1.00, 1.02)*
WASH Conditions					
Access to improved sanitation facility	0.71 (0.55, 0.91)*	0.68 (0.35, 1.31)	0.73 (0.46, 1.16)	0.57 (0.29, 1.12)	0.80 (0.56, 1.12)
Access to improved water source for at least 4 days in past week	0.74 (0.48, 1.14)	0.41 (0.25, 0.67)*	0.59 (0.35, 1.02)	0.46 (0.36, 0.61)*	0.81 (0.58, 1.13)
Knowledge of critical hand washing times[5]	0.94 (0.69, 1.28)	0.94 (0.74, 1.20)	0.88 (0.61, 1.27)	0.85 (0.72, 1.00)*	0.81 (0.57, 1.15)
Existence of designated hand washing location w/ cleaning agent	0.79 (0.46, 1.36)	1.51 (0.46, 4.88)	1.60 (0.77, 3.28)	0.95 (0.32, 2.83)	0.72 (0.18, 2.95)
Existence of separate enclosure for domestic farm animals[6]	0.61 (0.30, 1.25)	0.63 (0.27, 1.50)	0.73 (0.44, 1.21)	0.56 (0.41, 0.76)*	0.70 (0.51, 0.97)*
Observed presence of feces around compound	0.91 (0.64, 1.31)	1.29 (0.59, 2.86)	1.05 (0.71, 1.55)	0.82 (0.48, 1.41)	0.63 (0.35, 1.12)

ARI = Acute respiratory infection; CI = confidence interval; OR = Odds ratio;

[1]Adjusted for age in month, sex, education level of mother and head of household and family size; [2]Adjusted for age, education level of and family size; [3]Compares the odds of outcome for a child who consumed one more food group in the past 24 hours to a child who consumed one less food group; [4]Compares the odds of outcome for a child living in a household with a CSI score 1 point higher than a child living in a household with a CSI score 1 point lower. CSI is calculated by a weighted average of times per week a family must resort to a pre-defined coping strategy to meet their food needs [55]. Higher numbers indicate lower food security; [5]Compares the odds of outcome for a child whose mother reported one additional of the five critical hand washing times; [6]Domestic farm animals considered were chicken, sheep and goats.

*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, R.E., et al., *Maternal and child undernutrition and overweight in low-income and middle-income countries.* Lancet, 2013. **382**(9890): 427-51.
2. Black, R.E., et al., *Maternal and child undernutrition: global and regional exposures and health consequences.* Lancet, 2008. **371**(9608): 243-260.
3. Victora, C.G., et al., *Maternal and child undernutrition: consequences for adult health and human capital.* Lancet, 2008. **371**(9609): 340-357.
4. Central Statistical Agency, *Ethiopia Mini Demographic and Health Survey 2014*. 2014: Addis Ababa, Ethiopia.
5. Ngure, F.M., et al., *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. World Bank, *Environmental Health and Child Survival: Epidemiology, Economics, Experiences*, in *Environment and Development*. 2008, World Bank: Washington DC.
7. Checkley, W., et al., *Multi-country analysis of the effects of diarrhoea on childhood stunting.* Int J Epidemiol, 2008. **37**(4): 816-830.
8. Richard, S.A., et al., *Catch-up growth occurs after diarrhea in early childhood.* J Nutr, 2014. **144**(6): 965-71.
9. Kinyoki, D.K., et al., *Predictors of the risk of malnutrition among children under the age of 5 years in Somalia.* Public Health Nutr, 2015: 1-9.
10. Moore, S.R., et al., *Early childhood diarrhoea and helminthiases associate with long-term linear growth faltering.* Int J Epidemiol, 2001. **30**(6): 1457-1464.
11. Lima, A., et al., *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.
12. George, C.M., et al., *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. Humphrey, J.H., *Child undernutrition, tropical enteropathy, toilets, and handwashing.* Lancet, 2009. **374**(9694): 1032-1035.
14. Mbuya, M.N.N. and J.H. Humphrey, *Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries.* Matern Child Nutr, 2015.
15. Crane, R.J., K.D. Jones, and J.A. Berkley, *Environmental enteric dysfunction: An overview.* Food & Nutrition Bulletin, 2015. **36**(Supplement 1): 76S-87S.
16. Kane, A.V., D.M. Dinh, and H.D. Ward, *Childhood malnutrition and the intestinal microbiome.* Pediatr Res, 2015. **77**(1-2): 256-262.
17. Patwari, A.K., *Diarrhoea and malnutrition interaction.* Indian J Pediatr, 1999. **66**(1 Suppl): S124-34.
18. Pickering, A.J., et al., *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.
19. van der Hoek, W., S.G. Feenstra, and F. Konradsen, *Availability of irrigation water for domestic use in Pakistan: its impact on prevalence of diarrhoea and nutritional status of children.* J Health Popul Nutr, 2002. **20**(1): 77-84.

20. Daniels, D.L., et al., *A study of the association between improved sanitation facilities and children's height in Lesotho.* Eur J Clin Nutr, 1991. **45**(1): 23-32.
21. Spears, D., A. Ghosh, 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.
22. Rah, J.H., et al., *Household sanitation and personal hygiene practices are associated with child stunting in rural India: a cross-sectional analysis of surveys.* BMJ Open, 2015. **5**(2): e005180.
23. Merchant, A.T., et al., *Water and sanitation associated with improved child growth.* Eur J Clin Nutr, 2003. **57**(12): 1562-8.
24. Dangour, A.D., et al., *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.
25. Clasen, T., et al., *Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial.* Lancet Global Health, 2014. **2**(11): e645-e653.
26. Patil, S.R., et al., *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.
27. Fenn, B., et al., *An evaluation of an operations research project to reduce childhood stunting in a food-insecure area in Ethiopia.* Public Health Nutr, 2012. **15**(9): p. 1746-54.
28. Bryce, J., et al., *WHO estimates of the causes of death in children.* Lancet, 2005. **365**(9465): 1147-1152.
29. Caulfield, L.E., et al., *Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria, and measles.* Am J Clin Nutr, 2004. **80**(1): 193-198.
30. Cairncross, S., et al., *Water, sanitation and hygiene for the prevention of diarrhoea.* Int J Epidemiol, 2010. **39**(suppl 1): i193-i205.
31. Warren-Gash, C., E. Fragaszy, and A.C. 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.
32. Cunha, A.L., *Relationship between acute respiratory infection and malnutrition in children under 5 years of age.* Acta Paediatr, 2000. **89**(5): 608-9.
33. Geberetsadik, A., A. Worku, and Y. Berhane, *Factors associated with acute respiratory infection in children under the age of 5 years: evidence from the 2011 Ethiopia Demographic and Health Survey.* Pediatric Health Med Ther, 2015. **6**: 9-13.
34. Schmidt, W.-P., et al., *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.
35. Kosek, M., et al., *Fecal markers of intestinal inflammation and permeability associated with the subsequent acquisition of linear growth deficits in infants.* Am J Trop Med Hyg, 2013. **88**(2): 390-396.
36. Prendergast, A.J., et al., *Stunting is characterized by chronic inflammation in zimbabwean infants.* PLoS ONE, 2014. **9**(2): e86928.
37. Campbell, D., M. Elia, and P. Lunn, *Growth faltering in rural Gambian infants is associated with impaired small intestinal barrier function, leading to endotoxemia and systemic inflammation.* J Nutr, 2003. **133**(5): 1332-1338.

38. George, C.M., et al., *Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh.* Am J Trop Med Hyg, 2015. **92**(6): 1117-1124.
39. Liu, J.-R., et al., *Fecal calprotectin levels are higher in rural than in urban Chinese infants and negatively associated with growth.* BMC pediatrics, 2012. **12**(1): 129.
40. Lunn, P.G., C.A. Northrop-Clewes, and R.M. Downes, *Intestinal permeability, mucosal injury, and growth faltering in Gambian infants.* Lancet, 1991. **338**(8772): 907-910.
41. Weisz, A.J., et al., *Abnormal gut integrity is associated with reduced linear growth in rural Malawian children.* J Pediatr Gastroenterol Nutr, 2012. **55**(6): 747-50.
42. USAID, *WASH & Nutrition Water and Development Strategy Implementation Brief*. 2015: Washington DC.
43. Mahmud, I. and M. Mbuya, *Water, Sanitation, Hygiene, and Nutrition in Bangladesh: Can building toilets affect children's growth?*, W. Bank, Editor. 2016, World Bank: Washington DC.
44. Arnold, B., et al., *Evaluation of a pre-existing, 3-year household water treatment and handwashing intervention in rural Guatemala.* Int J Epidemiol, 2009. **38**(6): 1651-61.
45. Du Preez, M., K.G. McGuigan, and R.M. Conroy, *Solar disinfection of drinking water in the prevention of dysentery in South African children aged under 5 years: the role of participant motivation.* Environ Sci Technol, 2010. **44**(22): 8744-9.
46. Du Preez, M., et al., *Randomized Intervention Study of Solar Disinfection of Drinking Water in the Prevention of Dysentery in Kenyan Children Aged under 5 Years.* Environmental Science & Technology, 2011. **45**(21): 9315-9323.
47. Hasan, K.Z., et al., *Lack of impact of a water and sanitation intervention on the nutritional status of children in rural Bangladesh.* Eur J Clin Nutr, 1989. **43**(12): 837-43.
48. Alelign, T., A. Degarege, 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): 1-7.
49. Kirby, A. *Development Food Aid Program (DFAP)*. 2014.
50. World Food Programme. *Productive Safety Net Programme in Ethiopia*. 2012.
51. Tefera, M., et al., *Development Food Aid Program in Ethiopia: Baseline Survey*. 2012: Addis Ababa.
52. Federal Democratic Republic of Ethiopia Ministy of Health, *CLTSH Verification and Certification Protocol*. 2012: Addis Ababa.
53. Lemma, F. and J. Matji, *Delivery platforms for sustained nutrition in Ethiopia.* Lancet, 2013. **382**(9891): 488-9.
54. Boyd, E., *Nutrition in emergencies*. 2011.
55. Maxwell, D. and R. Caldwell, *The Coping Strategies Index: Field Methods Manuel*. 2008: Rome.
56. Food For Peace, *FFP Standard Indicator Handbook*. 2011: Washington DC.
57. Wright, J., S.W. Gundry, and R.M. Conroy, *A review of changing episode definitions and their effects on estimates of diarrhoeal morbidity.* J Health Popul Nutr, 2007. **25**(4): 448-455.
58. Central Statistical Agency, *Ethiopia Demographic Health Survey 2011*. 2012: Addis Ababa.
59. World Health Organization, *WHO Anthro 2.3.3*. 2011, WHO: Geneva.
60. RTI International, *SUDAAN*. 2005, RTI: Research Triangle Park, NC.
61. SAS Institute Inc., *SAS*. 2013, SAS Institute Inc.: Cary, NC.

62. Doocy, S. and G. Burnham, *Assessment of socio-economic status in the context of food insecurity: Implications for field research.* World health & population, 2005. **8**(3): 32-42.
63. Hackett, M., H. Melgar-Quiñonez, and M.C. Álvarez, *Household food insecurity associated with stunting and underweight among preschool children in Antioquia, Colombia.* Revista Panamericana de Salud Pública, 2009. **25**(6): 506-510.
64. Habicht, J.P., C.G. Victora, and J.P. Vaughan, *Evaluation designs for adequacy, plausibility and probability of public health programme performance and impact.* Int J Epidemiol, 1999. **28**(1): 10-8.
65. Baqui, A.H., et al., *Methodological issues in diarrhoeal diseases epidemiology: definition of diarrhoeal episodes.* Int J Epidemiol, 1991. **20**(4): 1057-63.
66. Boerma, J.T., et al., *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.
67. *Ethiopia Mini Demographic and Health Survey 2014*. 2014: Addis Ababa.
68. Sigler, R., L. Mahmoudi, and J.P. Graham, *Analysis of behavioral change techniques in community-led total sanitation programs.* Health Promot Int, 2015. **30**(1): 16-28.
69. Haddad, L., et al., *Estimating the interactions between household food security and preschool diarrhea.* Food Policy, 1998. **23**(3): 241-261.

Appendices for Thesis

Appendix A: Survey Used for Data Collection:

Household Interview Questionnaire - 2015

INTRODUCTION STATEMENT TO THE INTERVIEW

Good Morning/Good Afternoon.
My name is _____and I work for _____ (Name of organization and program). You have been selected by chance from the list of families containing children under the age of five. Is this correct? The purpose of this interview is to obtain information about DFAP to help us measure the impact of the program and to improve the program in any way we can. We are interested in interviewing mothers of children aged five or less. Are you the mother of the child? (*If no),* Is the mother of the child at home? (*If yes, wait until she arrives, and re-explain purpose).* Could you please spare some time (around 45 minutes) for the interview? The information you give will be confidential and will only be used to prepare a report of general findings – but will not include any names. You will not get any additional entitlements because of the interview. At any time during the survey, you are free to stop the survey, or not choose not to provide an answer to any question. If you are willing to participate in this survey, please indicate your oral consent by saying "yes" or "no".

Enumerators: *indicating oral consent:*

_____ YES _____ NO

Enumerators– *If the respondent is not willing, do not ask any of the questions and move to the next household. If the household contains children under the age of 5, but the mother is not present, ask when it is a good time to return, and return at a later time. We only want to interview mothers of children under the age of 5.*

I. General Information

Instruction: please refer the list of woredas and kebeles/village from the list to be provided by CRS and the

Supervisor must give the name of the village to enumerators before departing.

No.	Item	Name		
101	Woreda Name			
102	Kebele Name			
103	Village Name			
104	Household ID			
105	Date of interview	DD	MM	YY

Data Processing Checks		**Name**	**Signature**
105	Enumerator Name		
106	Supervisor Name		

II: Household Demographic Characteristics

201. Age of respondent	Enter age in year ☐	
202. Respondent relationship to head of household (HHH)	1 = Head of household 2 = Wife of the HHH 3 = Daughter of the HHH 4 = Daughter in law of HHH 5 = Granddaughter of HHH	
203. Gender of head of household	1= Male 2 = Female	
204. Marital Status of head of household.	1. Married (Monogamous) 2. Married (polygamous) 3. Single	4. Divorced or separated 5. Widowed 6. No answer
205. What is the highest grade level completed by the respondent**?**	1 = No Education 2 = Can read or write (informal education only) 3 = Grade 1-4 (Primary School) 4 = Grade5-8 (Primary School)	5 = Grade 9-10 (secondary school) 6 = Grade 11-12 (Preparatory) 7= Above grade 12 (College)
206. What is the highest grade level completed by the head of household (if someone other than respondent)**?**	1 = No Education 2 = Can read or write (informal education only) 3 = Grade 1-4 (Primary School) 4 = Grade5-8 (Primary School)	5 = Grade 9-10 (secondary school) 6 = Grade 11-12 (Preparatory) 7= Above grade 12 (College)

207. What is the total number of people who have been living in this HH over the past 6 months (including non–family members)?

< 5 Years		**5-18 Years**		**19-60 Years**		**> 60 Years**		**Total**	
M	F	M	F	M	F	M	F	M	F

208. ***Enumerators:*** **From the children under the age of 5, randomly select one. Record its exact age in months. Ask for the name, to be used in conversation throughout the rest of the interview.**	Child Age in Months: _____ Months	Child Gender: M F

III. Household Access to PSNP/DFAP

301	"Has this household ever received Safety Net Support?"	1. Yes 2. No 3. Don't know **If no, skip to 304**
302	*If yes to 301:* "Have you or a family member received a food transfer at any time in the past 12 months (one year)?"	1. Yes 2. No
302a	*If yes to 302:* "How many separate times did you receive a food transfer in the past 12 months?"	_____ times
303	*If yes to 301:* "Have you or a member of your family received cash transfers from the government at any time during the past 12 months (one year)?"	1. Yes 2. No
303a	*If yes to 303:* "How many separate times did you receive a cash transfer?"	_____times
304	"Have you received vegetable seeds?"	1. Yes 2. No
305	"Do you currently produce vegetables in your backyard?"	1. Yes 2. No
306	"Do you know about keyhole gardens?" *Define if need be.*	1. Yes 2. No
306a	*If yes to 306,* "Does your community have an established demonstration keyhole garden?"	1. Yes 2. No
307	"What messages have you received from the health extension workers and health workers?"	***Enumerators:*** *Do not read off answer choices. May indirectly probe for options. Circle all that apply* 1. Food preservation 2. Food preparation 3. Food choices from market 4. Backyard gardening 5. Breastfeeding techniques 6. Complimentary feeding of children 7. Handwashing techniques 8. Latrine use 9. Proper care for sick child 10. Other:
308	*If yes to 305:* **Observation question for Enumerators:** Enumerators ask to see the backyard vegetable garden. Observe the presence and abundance of the vegetables in the backyard garden.	***Enumerators:*** *Circle one answer* 1. Garden plot with vegetables observed 2. Garden plot observed, but with no or few vegetables 3. No garden plot observed

		4. Could not observe
309	*If yes to 306:* **Observation question for Enumerators:** Ask to see the demonstration keyhole vegetable garden. Observe the presence and abundance of the vegetables in the keyhole garden. *If far from home, can answer this question at end of survey.*	***Enumerators:*** *Circle one answer* 1. Garden plot with vegetables observed 2. Garden plot observed, but with no or few vegetables 3. No garden plot observed 4. Could not observe

IV. Dietary Intake

401	"Of the following food types listed, which food types have you (mother) consumed within the past 24 hours?"	***Enumerators:*** *Read all lists of food types one by one and select all that apply.* 1. Injera, bread, rice, pasta, or any other foods made from grains, such as, teff, oats, maize, barley, wheat, sorghum, millet, or other grains 2. White potatoes, white sweet potatoes, bulla, kocho, maniac, cassava, beetroot or any other foods made from roots 3. Foods made from beans, peas, lentils or nuts 4. Milk, cheese, yogurt, or any other milk products 5. Liver, kidney, heart or other organ meats 6. Any meat such as beef, pork, chicken, lamb, goat, duck or fish 7. Eggs 8. Dark green, leafy vegetables like gomen, or amaranth leaves 9. Banana, mangos, papaya, pumpkin, carrot, orange (red) sweet potatoes, or any other fruits and vegetables that are orange or yellow inside
402a	*If selected child was between 0 and 5 months:* "Has (CHILD'S NAME) ever been breastfed?"	**1.** Yes **2.** No **3.** I don't know
402b	*If yes to 402a:* "Was (CHILD's NAME) breastfed yesterday, either during the day or the night?"	**1.** Yes **2.** No **3.** I don't know
402c	"Did (CHILD'S NAME) have any liquid other than breast milk, such as water, canned, powdered or fresh animal milk, juice, or thin porridge, yesterday?"	**1.** Yes **2.** No **3.** I don't know
402d	"Did (CHILD'S NAME) eat any solid, semi-solid or soft foods (such as thick porridge, fruits, bread, meat, eggs, vegetables) yesterday?"	**1.** Yes **2.** No **3.** I don't know
403a	*If family had children 6-23 months:*	**1.** Yes **2.** No **3.** I don't know

	"Has (CHILD'S NAME) ever been breastfed?"	
403b	*If yes to 403a:* "Was (CHILD's NAME) breastfed yesterday, either during the day or the night?"	**1.** Yes **2.** No **3.** I don't know

404A	*For children between the ages of 6 months and 59 months:* "Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Injera, bread, rice, pasta, porridge or any other foods made from grains, such as, teff, oats, maize, barley, wheat, sorghum, millet, or other grains?"	_____ times (*Enter 0 if did not eat).*
404B	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: White potatoes, white sweet potatoes, bulla, kocho, maniac, beetroots, cassava or any other foods made from roots or tubers"	_____ times
404C	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Foods made from beans, peas, lentils or nuts"	_____ times
404D	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Milk, cheese, yogurt, or any other milk products"	_____ times
404E	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Any meat such as beef, pork, chicken, lamb, goat, duck or fish"	_____ times
404F	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Eggs."	_____ times
404G	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Foods rich in vitamin A. Any foods that are orange or yellow inside, such as banana, mangos, papaya, pumpkin, carrot, orange (red) sweet potatoes; or any dark green, leafy vegetables like gomen, or amaranth leaves"	_____ times
404H	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods: Any other fruits and vegetables."	_____ times
404I	"Yesterday, during the day or night, how many times did you feed (CHILD'S NAME) any of the following foods:	_____ times

	Any commercially fortified baby food, such as Fafa, Hilina, Cerilak, Cerifam or Mother's Choice".	
405	"When is the best time to start breastfeeding a child?"	***Enumerators:*** *read off all answer choices and circle the best one* 1. Within the first hour after giving birth 2. Within the first six hours after giving birth 3. Within the first twelve hours after giving birth 4. Within one day after giving birth 5. I don't know

V. Food Security

501a	"During which seasons did you have enough food from all sources?"	***Enumerators:*** *Read each season one by one and select all that apply.* 1. Belg (March, April, May) 2. Bega (December, January, February) 3. Tseday (Septembter, Octover, November) 4. Kiremt (June, July, August)
501b	"During which seasons did you have not have enough food from all sources?"	***Enumerators:*** *Read each season one by one and select all that apply.* 1. Belg (March, April, May) 2. Bega (December, January, February) 3. Tseday (Septembter, Octover, November) 4. Kiremt (June, July, August)
502a	"How often do you resort to the following behaviors in order to meet your needs during a food shortage period?" "During a food shortage period, how often to you resort to EATING LESS PREFERRED FOODS to meet your needs?"	***Enumerators:*** *Select one answer.* 1. At least once a week 2. Only once a week 3. 2-3 days a week 4. 4-6 days a week 5. Daily 6. Never
502b	"During a food shortage period, how often to you resort to BORROWING FOOD/MONEY FROM FRIENDS OR RELATIVES to meet your needs?"	***Enumerators:*** *Select one answer.* 1. At least once a week 2. Only once a week 3. 2-3 days a week 4. 4-6 days a week 5. Daily 6. Never
502c	"During a food shortage period, how often to you resort to LIMITING PORTIONS AT MEALTIMES to meet your needs?"	***Enumerators:*** *Select one answer.* 1. At least once a week 2. Only once a week 3. 2-3 days a week 4. 4-6 days a week 5. Daily 6. Never
502d	"During a food shortage period, how often to you resort to LIMITING ADULT INTAKE to meet your needs?"	***Enumerators:*** *Select one answer.* 1. At least once a week 2. Only once a week 3. 2-3 days a week 4. 4-6 days a week 5. Daily 6. Never
502e	"During a food shortage period, how often to you resort to REDUCING NUMBER OF MEALS PER DAY to meet your needs?"	***Enumerators:*** *Select one answer.* 1. At least once a week 2. Only once a week 3. 2-3 days a week 4. 4-6 days a week 5. Daily 6. Never

VI. Disease and Malnutrition

601	*For all children 0-59 months:* "Did (CHILD'S NAME) have diarrhea in the past two weeks, where diarrhea is defined as three or more loose stools or one loose, bloody stool within a 24 hour period?" **If no, skip to 603**	**1.** Yes **2.** No **3.** I don't know
602a	*If yes to 601:* "Now I would like to know how much (CHILD'S NAME) was given to drink, including breast milk, during the diarrhea" "Was he/she given less than usual to drink, about the same amount, or more than usual to drink?" *If less, probe:* "Was he/she given much less than usual to drink or somewhat less?"	1. Much less 2. Somewhat less 3. About the same 4. More 5. Nothing to drink **6.** I don't know
602b	*If yes to 601:* "When (NAME) had diarrhea, was he/she given less than usual to eat, about the same amount, or more than usual to eat?" *If less, probe:* "Was he/she given much less than usual to eat or somewhat less?"	1. Much less 2. Somewhat less 3. About the same 4. More 5. Nothing to eat 6. I don't know
603	"Has (CHILD'S NAME) been ill with a fever any time in the past two weeks?"	1. Yes 2. No 3. I don't know
604	"Has (CHILD'S NAME) had an illness with a cough at any time in the last two weeks?"	1. Yes 2. No 3. I don't know
604a	*If yes to 604:* "When (NAME) was sick with a cough, did he/she breathe faster than normal with short, rapid breaths or have difficulty breathing?'	1. Yes 2. No 3. I don't know
604b	*If yes to 604a:* "Was the fast or difficult breathing due to a problem in the chest or to a blocked or runny nose?"	1. Chest only 2. Nose only 3. Both 4. I don't know
605	"At any time during the past two weeks, did you (*mother)* have diarrhea?"	1. Yes 2. No 3. Don't know
606	"At any time during the past two weeks, have you (*mother)* been ill with a fever?"	1. Yes 2. No 3. Don't know

607	*If yes to 601, 603, 604, 605, or 606:* "When (YOU or CHILD'S NAME) was sick, did you seek advice or treatment from any source?"	1. Yes 2. No **3.** I don't know
607a	*If yes to 607:* "From where did you seek advice or treatment?"	***Enumerators:*** *Read off all and circle all that apply?* 1. Health center or post 2. Other clinic or hospital 3. Pharmacy or drug store 4. Traditional healer or spiritual counseling 5. Home treatment 6. Other
608	"Has (CHILD's NAME) ever been screened for malnutrition?"	1. Yes 2. No 3. I don't know
609	"Has (CHILD'S NAME) ever received plumpy nut at the health post or center?"	1. Yes 2. No 3. I don't know
610	"Now we would like to measure (CHILD'S) height and weight. Do we have your permission to measure the height and weight of your child?" **If the selected child is not at home, come back later. If the child refuses, do not chose another child.**	1. Accepted 2. Refused **If refused, skip to 701.**
610a	**Measure the height of the child**	***Enter height, in cm*** _____ ***cm***
610b	**Take the weight of the child**	***Enter weight, in kg*** _____ ***kg***
611	*For the measured child,* **Observe presence of BCG Scar**	1. Present 2. Absent

VII. Care

701	"Do you have access to a health post in your vicinity or kebele?"	1. Yes 2. No 3. Yes, but outside my kebele
702	"How far is the nearest active health post from your residential place?"	_____km
703	"How long does it take for an adult to reach the nearest active health post from your residential place (one way distance)?"	____hours and _____ minutes
704	*If the family has children 9-59 months:* "Did (CHILD'S NAME) receive a shot in the arm at age of 9 months or older, to prevent him/her from getting measles? Can you show us his/her vaccination card?"	1. Yes, on card, 2. Yes, from recall 3. No 4. Don't know
705	*If the family has children 6-59 months:* "Within the last six months, has (CHILD'S NAME) received a vitamin A dose like this?" *SHOW CAPSULES*	1. Yes 2. No 3. I don't know
706	*If the family has children 24-59 months:* "Within the last six months, was (CHILD'S NAME) given any drugs for intestinal worms?"	1. Yes 2. No 3. I don't know
707	*Ask mother of child:* "Did you visit any health facility for antenatal care during your most recent pregnancy?"	1. Yes 2. No 3. Don't know
707a	*If yes to 707,* "How many times did you receive antenatal care during your most recent pregnancy?"	*Insert number into box:* ☐
708	*Ask mother of child:* "During your most recent pregnancy, were you given or did you buy any iron tablets?" *SHOW CAPSULES*	1. Yes 2. No 3. Don't know
709	*Ask mother of child:* "Within 45 days after giving birth, did you receive a vitamin A dose like this?" *SHOW CAPSULES*	1. Yes 2. No 3. Don't know

VIII. Environmental (Water, Sanitation and Hygiene)

801	"What is the **main** source of water that members of your household use for drinking?" *NOTE: one answer only!!*	***Enumerators****: please circle one answer. If unknown, ask to be shown water source.* 1. Piped into home. 2. Piped into compound. 3. Public tap. 4. Protected spring 5. Protected well in compound 6. Protected public well. 7. Borehole with handpump 8. Rainwater collected from roof 9. Open well in compound 10. Open public well. 11. Unprotected spring 12. Surface water (river, lake, dam, stream, pond, etc) 13. Tanker truck 14. Don't know / no answer
802	"How many months do you have access to this source during the year (12 months)?"	_____months
803	"How long does it take you to travel one way to collect water from the source?"	***Enumerators:*** *If source is at household, write 0 minutes* _____minutes
804	"During the past week, for how many days was the water **not** available from your main source?"	***Enumerators:*** *enter "0" if the water was available for all days within the past week* _____days of past week
805	"What is an alternative source of water that you most commonly use if water at your main source is unavailable?"	***Enumerators****: please read off choices and select one answer* 1. Piped into home. 2. Piped into compound. 3. Public tap. 4. Protected spring 5. Protected well in compound 6. Protected public well. 7. Borehole with handpump 8. Rainwater collected from roof 9. Open well in compound 10. Open public well. 11. Unprotected spring 12. Surface water (river, lake, dam, stream, pond, etc) 13. Tanker truck 14. No secondary source

		15. No answer
806	"What do you use to store your drinking water?"	***Enumerators****: please circle one answer* 1. Jerry can with cap 2. Bucket with lid and tap 3. Bucket with large, removable lid (such that pitcher is dipped in for removal)/large plastic container 4. Clay pot 5. Other: _____
806a	**Observation Question for Enumerators:** ask to observe where they store their water.	***Enumerators****: please circle one answer* 1. Jerry can with cap 2. Bucket with lid and tap 3. Bucket with large, removable lid (such that pitcher is dipped in for removal)/large plastic container 4. Clay pot 5. Other ***6.*** Could not observe
807	**Observation Question for Enumerators:** ask to observe where they store their food. Note if food is uncovered or covered.	***Enumerators****: please circle one answer* 1. All food covered 2. Some food covered 3. All food uncovered 4. No food observed 5. Could not observe
808	"Do you do anything to treat or improve the quality of your drinking water at home?"	1. Yes **2.** No **If no, skip to 810**
809	*If yes to 808,* "What do you use to treat your water?"	***Enumerators****: please circle all that apply:* 1. Filter 2. Boiling 3. Chlorine tablet, such as aqua tabs 4. Bleach or waterguard 5. Other
809a	*If yes to 808,* **Observation Question for Enumerators:** ask to see what they use to treat their water	***Enumerators****: please circle all that apply:* 1. Filter 2. Boiling 3. Chlorine tablet, such as aqua tabs 4. Bleach or waterguard 5. Other 6. Nothing present ***7.*** Could not observe
810	"Have you noticed a change in the quality of your drinking water at the source in the past four years?" *If yes, prompt for the better or for the worse.*	1. Yes, for the better 2. Yes, for the worse 3. No

		4. Don't know
811	"Have you noticed a change in the quantity of your drinking water in the past four years?" *If yes, prompt for the better or for the worse.*	1. Yes, for the better 2. Yes, for the worse 3. No 4. Don't know
812	"What kind of facility does this household primarily use for defecation?"	***Enumerators****: please read off all answers and circle one answer. If unknown, will observe defecation facility later in the survey and can record then.* 1. Latrine with flush or pour/flush facilities 2. Piped sewer system 3. Pit latrine with cleanable slab 4. Pit latrine without cleanable slab 5. Pit latrine with cleanable slab and hole cover 6. Composting toilets 7. Ventilated improved pit latrines 8. Open defecation
813	*If "open defecation" answered in question 812:* "Which of the following are reasons that you have not constructed a latrine in your compound or do not use the latrine?" *(choose 1)*	***Enumerators****: please circle all that apply* 1. We don't need a latrine 2. We don't like latrines 3. It is costly to construct a latrine 4. It is not suitable for children 5. Don't know how to use 6. We rent/do not own our property 7. Others
814	"Which of the following does (CHILD'S NAME) primarily use for defecation?"	**1.** Latrine listed in **812** **2.** Diaper/ cloth **3.** Open area **4.** Plastic bag **5.** Potty (po-po) **6.** Other
815	"Where do you most often dispose of the child's feces?"	***Enumerators****: please circle one answer* 1. Latrine 2. Trash can/waste disposal pit 3. Open area/forest 4. Stream or waterway 5. Other
816	"When are critical times for handwashing?"	***Enumerators****: let the respondent answer herself. Circle all that are mentioned* 1. After defecation 2. Before eating 3. Before food preparation

		4. Before feeding a child 5. After cleaning a child 6. Other
817	"What do you primarily use for hand washing?" *(choose 1)*	***Enumerators**: please circle one answer* 1. Soap and water 2. Ash and water 3. Only Water 4. Other detergents
818	"Do you have access to a designated place for handwashing?	1. Yes **2.** No
818a	*If yes to 818* **Observation question for Enumerators:** Ask to observe their hand washing place and note if the HH have water and soap or ash or locally available cleansing agent in hand washing place.	***Enumerators**: please circle one answer* 1. Soap and water 2. Ash and water 3. Only Water 4. Other cleaning agent 5. No water and cleaning agent 6. Could not observe
819	**Observation question for Enumerators:** Indicate whether a designated place for the following animals is observed, where the animals are kept separate from the people:	***Enumerators:** select one answer*
819a	Chickens	1. Animals kept separate 2. Animals not kept separate 3. Animal not observed
819b	Sheep/Goats	1. Animals kept separate 2. Animals not kept separate 3. Animal not observed
819c	Cows	1. Animals kept separate 2. Animals not kept separate 3. Animal not observed
819d	Camels	1. Animals kept separate 2. Animals not kept separate 3. Animal not observed
820	**Observation question for Enumerators:** Walk around the home and note presence/absence of feces (human or animal) seen on the ground	1. No feces seen 2. Some feces seen, but are not near homes 3. Lots of feces seen or feces seen in close proximity to homes
821	**Observation question for Enumerators:** Ask to walk inside the indicated latrine and observe the following indicators of use:	***Enumerators**: select one*
821a	Water for flushing	1. Available 2. Not available 3. Not relevant (not a pour/flush latrine) 4. Could not observe
821b	Presence of feces inside latrine, around hole	1. Absent 2. Present 3. Could not observe

821c	Feces inside latrine hole appears wet	1. Absent 2. Present 3. Impossible to tell 4. Could not observe
821d	Worn path from the home to the latrine	1. Path visible 2. Path not visible 3. Could not observe

"This is the end of the interview. Thank you for your patience and cooperation!"

Appendix B: Z-Curves from WHO Anthro:

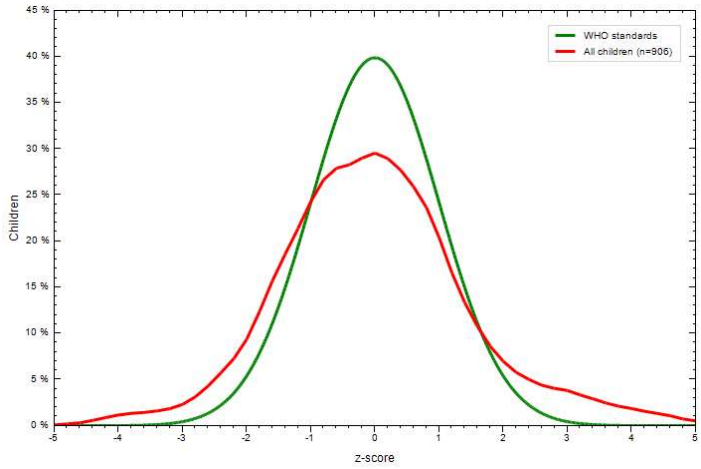

Figure 5. Weight for length/height Z-score. Mean: 0.05, SD: 1.74

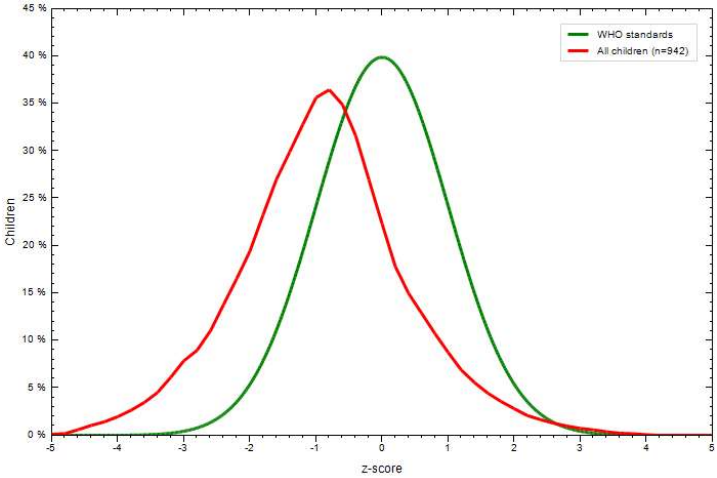

Figure 6. Weight-for-age Z-score, Mean: -0.92, SD: 1.31

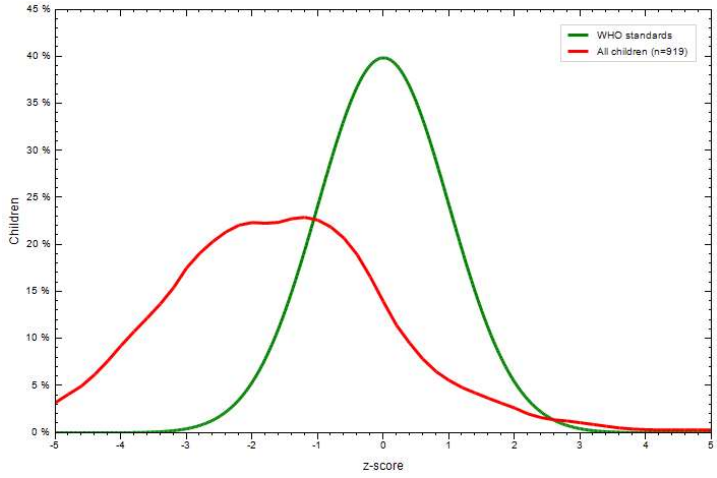

Figure 7. Height-for-Age Z-score, Mean: -1.67, SD: 2.07

Appendix C: Inter-Enumerator Reliability Reports

Table 5. ANOVA test for height-for-age Z-score by enumerator

Enumerator	N	HAZ		Bonferroni Group
		Mean	Std Dev	
1	92	-1.363	1.984	A
2	90	-1.767	2.002	A
3	91	-1.982	1.294	A
4	96	-2.188	2.903	A
5	79	-1.529	2.044	A
6	88	-1.424	2.256	A
7	93	-1.765	1.941	A
8	91	-1.797	1.991	A
9	86	-1.459	2.045	A
10	94	-1.700	2.056	A
11	87	-1.396	1.739	A

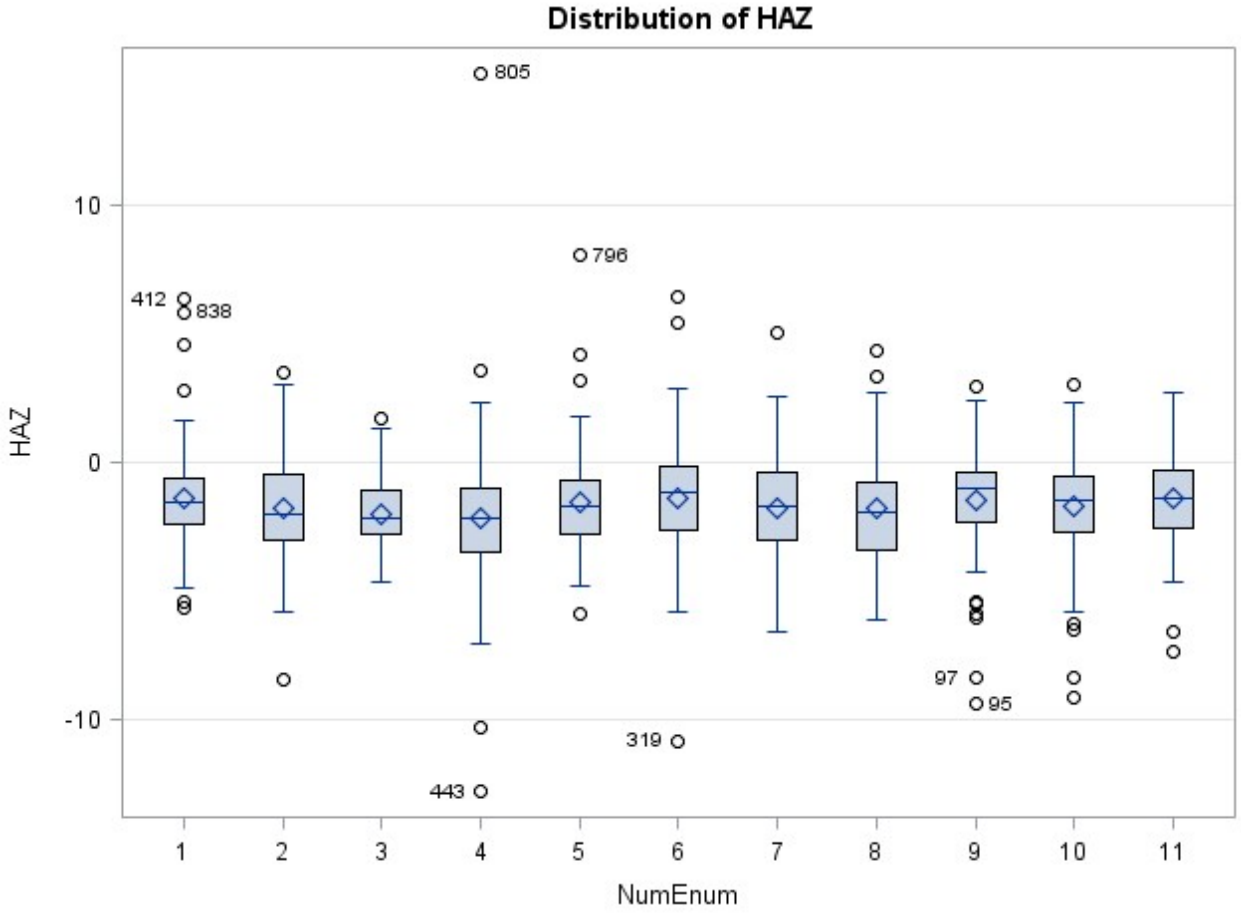

Figure 8. Comparison of mean and spread of height-for-age Z-score by enumerator

Table 6. ANOVA test for weight-for-age Z-score by enumerator

Enumerator	N	WAZ		Bonferroni Group	
		Mean	Std Dev		
1	93	-0.810	1.280	A	B
2	92	-1.040	1.231	A	B
3	91	-1.087	1.023	A	B
4	97	-1.331	1.491		B
5	82	-0.649	1.128	A	
6	87	-0.872	1.501	A	B
7	93	-0.862	1.345	A	B
8	91	-1.179	1.412	A	B
9	83	-0.760	1.271	A	B
10	94	-0.614	1.306	A	
11	87	-0.922	1.278	A	B

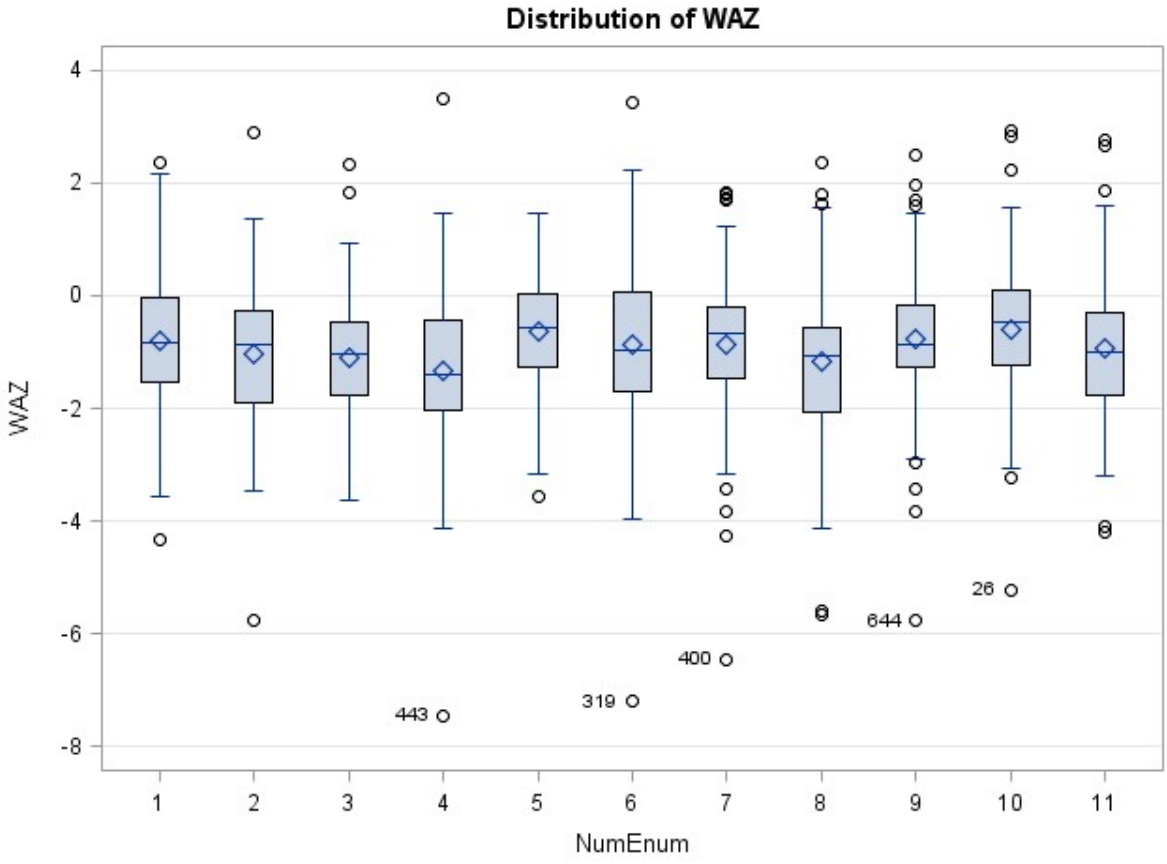

Figure 9. Comparison of mean and spread of weight-for-age Z-scores by enumerator

Table 7. ANOVA test for weight-for-height Z-score by enumerator

Enumerator	N	WHZ		Bonferroni Group
		Mean	Std Dev	
1	89	0.092	1.497	A
2	88	0.008	1.784	A
3	89	0.066	1.287	A
4	95	0.060	2.493	A
5	79	0.378	1.480	A
6	86	-0.213	1.327	A
7	93	0.226	2.167	A
8	91	-0.217	1.924	A
9	83	0.188	1.552	A
10	91	0.359	1.543	A
11	87	-0.230	1.527	A

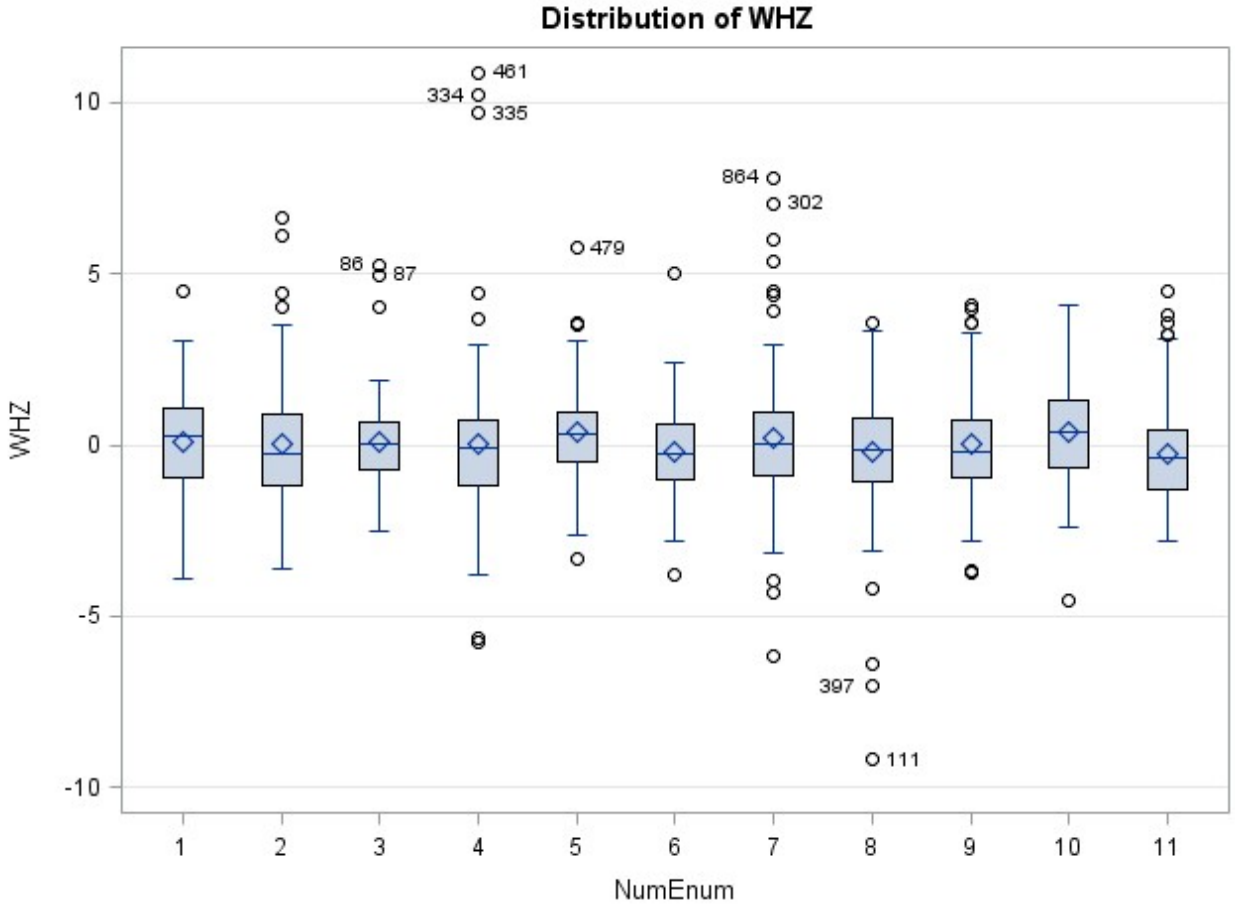

Figure 10. Comparison of mean and spread of weight-for-height Z-score by enumerator

Table 8. Effect of enumerator #4 on adjusted measures of association

	Proportion stunted (HAZ < -2) OR (95% CI)[1]		Proportion underweight (WAZ < -2) OR (95% CI)		Proportion wasted (WHZ < -2) OR (95% CI)	
	All Enumerators	Excluding #4	All Enumerators	Excluding #4	All Enumerators	Excluding #4
Intervention Type[2]	0.50 (0.26, 0.97)*	0.50 (0.25, 0.98)*	0.62 (0.30, 1.27)	0.61 (0.29, 1.32)	0.81 (0.40, 1.63)	0.80 (0.42, 1.52)
Dietary Conditions						
Dietary Diversity Score[3]	0.87 (0.71, 1.07)	0.90 (0.71, 1.13)	0.81 (0.60, 1.09)	0.81 (0.61, 1.09)	0.78 (0.62, 0.98)*	0.79 (0.61, 1.03)
Coping Strategy Index[4]	1.02 (1.01, 1.03)*	1.02 (1.00, 1.03)*	1.01 (0.99, 1.03)	1.01 (0.99, 1.02)	1.00 (0.98, 1.02)	1.00 (0.98, 1.08)
WASH and Environmental Conditions						
Access to improved sanitation facility	0.54 (0.36, 0.80)*	0.53 (0.35, 0.80)*	0.55 (0.31, 0.99)*	0.57 (0.31, 1.04)	1.38 (0.76, 2.49)	1.60 (0.83, 2.73)
Access to improved water source for at least 4 days in past week	--	--	--	--	0.59 (0.33, 1.07)	0.59 (0.31, 1.11)
Access to improved water source for at least 6 months of the year	0.80 (0.39, 1.61)	0.77 (0.42, 1.44)	0.75 (0.39, 1.44)	0.70 (0.38, 1.29)	--	--
Caretaker knowledge of critical hand washing times[5]	1.14 (1.00, 1.30)*	1.11 (0.96, 1.28)	0.89 (0.73, 1.09)	1.05 (0.31, 3.60)	1.14 (0.81, 1.62)	0.59 (0.31, 1.11)
Existence of designated hand washing location w/ cleaning agent	0.85 (0.31, 2.30)	0.92 (0.38, 2.21)	1.13 (0.38, 3.38)	1.05 (0.31, 3.60)	2.11 (0.78, 5.73)	1.91 (0.60, 6.02)
Existence of separate enclosure for domestic farm animals[6]	0.97 (0.61, 1.53)	1.00 (0.62, 1.59)	0.83 (0.44, 1.56)	0.83 (0.43, 1.61)	0.97 (0.64, 1.48)	1.00 (0.70, 1.41)
Observed presence of feces around compound	0.97 (0.60, 1.56)	1.01 (0.66, 1.55)	1.15 (0.66, 1.98)	1.14 (0.72, 1.82)	0.75 (0.45, 1.26)	0.81 (0.48, 1.38)

CI = confidence interval; OR = odds ratio; HAZ = height/length-for-age z-score; WAZ = weight-for-age z-score; WHZ = Weight-for-height/length z-score

[1]Adjusted for age in month, sex, education level of mother and head of household and family size; [2]Health and nutrition only used as the reference group; [3]Compares the odds of outcome for a child who consumed one more food group in the past 24 hours to a child who consumed one less food group; [4]Compares the odds of outcome for a child living in a household with a CSI score 1 point higher than a child living in a household with a CSI score 1 point lower. CSI is calculated by a weighted average of times per week a family must resort to a pre-defined coping strategy to meet their food needs [55]. Higher numbers indicate lower food security; [5]Compares the odds of outcome for a child whose mother reported one additional of the five critical hand washing times; [6]Domestic farm animals considered were chicken, sheep and goats.

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

Appendix D: Additional Analysis – Associations between disease history and undernutrition

Children with a positive two-week history caretaker-report of diarrhea or fever had higher odds of underweight, stunting and wasting compared to children with no history of illness (Table 5). Similarly, children with reported history of ARI had higher odds of underweight or wasting. Only the relationship between diarrhea and underweight was significant at the 95% confidence level. Children with recent diarrhea had 83% higher odds of being underweight than children with no recent history (OR: 1.83, 95% CI: 1.00, 3.34). The consequence of fever on weight-for-height was found to be significantly more serious at low levels of dietary diversity. Interactions between household food security and diarrhea with respect to nutritional status similar to the interaction found in this study between dietary diversity and fever were reported by Haddad et al., in a study on nutritional status of preschoolers from Ethiopia, Pakistan and Philippines [69].

Table 5. Association between two-week caretaker report of disease and anthropometric measurements in children 0-59 months

Two-week self-report	**Proportion HAZ < -2**		**Proportion WAZ<-2**		**Proportion WHZ<-2**	
	N	**OR[1] (95% CI)**	**N**	**OR (95% CI)**	**N**	**OR (95% CI)**
Diarrhea	983	1.34 (0.85, 2.11)	985	1.83 (1.00, 3.34)*	977	1.86 (0.73, 4.53)
Fever	986	1.01 (0.67, 1.52)	989	1.67 (0.75, 3.71)	--	--
Among children who consumed one more food group	--	--	--	--	913	1.00 (0.46, 2.16)
Among children who consumed the same no. food groups	--	--	--	--		1.32 (0.53, 3.31)
ARI	987	0.91 (0.48, 1.73)	990	1.40 (0.93, 2.11)	979	1.01 (0.51, 2.02)

ARI = acute respiratory infection; CI = confidence interval; OR = odds ratio;

[1]Adjusted for age in month, age squared, sex, education level of mother and family size. Reference group is no history of disease.

*P-value<0.05 by Wald-F test