Effect of a behavior change intervention on household food hygiene practices and complementary food contamination in rural Bangladesh

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Summary

An estimated 151 million children under 5 years worldwide suffer from chronic undernutrition. Key causes of undernutrition in children are an insufficient intake of nutritious food as well as poor sanitation and hygiene practices, leading to repeated enteric infection and illness. Complementary food in low-income settings often has a high burden of microbes, due to unhygienic preparation, storage, or feeding practices. Feeding of these foods puts the child at risk of ingesting pathogenic bacteria and to develop intestinal infection and diarrheal disease. Consistent adoption of handwashing and food hygiene practices can considerably reduce microbial food contamination and thereby diarrheal incidence. However, changing practice of these behaviors remains challenging. In Bangladesh, research shows that although knowledge about handwashing is widespread, handwashing at critical times is rarely practiced and not easily improved by large-scale WASH programs. Therefore, new strategies are needed to facilitate food hygiene behavior change in household and community settings. The FHEED study aimed to evaluate the impact of a relatively large-scale, less-intensive food hygiene behavior change intervention in Sylhet Division, Bangladesh on maternal food hygiene practices and the contamination of complementary foods.

This report is based on data from the Food and Agricultural Approaches to Reducing Malnutrition (FAARM) cluster-randomized controlled trial (ClinicalTrials.gov, ID: NCT02505711) and the Food Hygiene to reduce Environmental Enteric Dysfunction (FHEED) sub-study. Mixed-effects regression models were used to assess the effect of the intervention on food hygiene behaviors and complementary food contamination, as well as to identify the key food hygiene behaviors to reduce food contamination.

Exposure to the food hygiene intervention led to an increase in almost all promoted food hygiene behaviors. Besides an increase of maternal food hygiene practices in the intervention households compared to control households, overall practice of these key behaviors remained low. Even in the intervention group, most behaviors were reported to be practiced by less than 50% of women, and the actual observed behaviors were practiced even less frequently. Also, practice of multiple food hygiene behaviors simultaneously was rarely seen.

Accordingly, our findings provide no clear evidence that the food hygiene intervention was able to reduce complementary food contamination with *E. coli* in intervention compared to control households. However, when food hygiene behaviors were well practiced, there was evidence that this led to a reduction in complementary food contamination. Especially fresh preparation of food and handwashing at critical times had a strong effect on food contamination individually. Also, practice of multiple behaviors further decreased the probability of food contamination.

In summary, the evaluated intervention did not succeed to sufficiently and sustainably induce a change in food hygiene behavior in the women of the study population to a degree that could translate into a substantial reduction of bacterial food contamination in the household. A better understanding of barriers for behavior change might be needed to guide the design of future intervention packages, in order to achieve sustained behavior change and to enable an actual health impact. The findings from this study will be presented to national NGOs and Government bodies at the dissemination event of the FAARM trial in Dhaka, Bangladesh in November 2022.

Introduction

An estimated 20% of children under 5 worldwide (149 million) are chronically undernourished [1]. Particularly during the first 1000 days in life, undernutrition can have detrimental developmental consequences, like stunted physical growth ("stunting"), compromised immune function and impaired cognitive development, thereby preventing the children from reaching their full potential and productivity in adulthood[2]. Among the key causes of undernutrition in children are an insufficient intake of nutritious food as well as poor sanitation and hygiene practices, leading to repeated enteric infection and illness. Most interventions addressing the problem of undernutrition are tackling the pathway of nutrient intake, yet a systematic review assessing the effectiveness of nutrition-specific interventions showed that such interventions alone had only a limited effect on linear child growth [3,4].

In resource-poor settings, complementary foods fed to young children are often highly contaminated with pathogenic microbes. [5, 6, 7, 8] There is evidence that suboptimal household hygiene is associated with contamination of complementary foods.[9, 10] Hazard analyses have helped to identify critical control points in the food preparation chain that could lead to a potential introduction of contamination, such as 1) use of contaminated foods from field and markets, 2) inadequate handwashing practice (especially before food preparation and feeding), 3) cleaning of cooking and feeding utensils with contaminated water, 4) a long lag time between food preparation and actual feeding, combined with unsafe storing practices at high ambient temperature, and 5) inadequate reheating practice.[7, 11, 12, 13, 14, 15, 16] Therefore, good caregiver hygiene practices around food preparation and child feeding could be an important means to reduce complementary food contamination in the household setting.

However, changing practice of these behaviors remains challenging. In Bangladesh, research shows that although knowledge about handwashing is widespread, handwashing at critical times is rarely practiced and not easily improved by large-scale WASH programs. Therefore, new strategies are needed to facilitate food hygiene behavior change in household and community settings. Over the last decade, few trials have designed and evaluated interventions around caregivers' complementary food hygiene practices in low-income settings in south Asia and sub-Saharan Africa. [16 17, 18, 19] These interventions employed behavioral models to understand motivational drivers and focused on a wide range of behavior change techniques such as commitment, modification in the domestic environment, use of prompts and cues, and social rewards to promote multiple food hygiene behaviors among mothers and caregivers of young children. [16, 20, 21] However, whilst the success of these interventions in adopting the intended food hygiene behaviors and thereby reducing complementary food contamination was promising,[16, 22, 23] most of these evaluations come from small-scale studies implemented among small study populations over a short period [16, 17] and (or) with frequent intervention contacts.[16, 22] Evidence is also limited about their potential to maintain desirable behaviors over time.[23]

The FHEED study aimed to evaluate the impact of a relatively large-scale, less-intensive food hygiene behavior change intervention in Sylhet Division, Bangladesh on maternal food hygiene practices and the contamination of complementary foods.

Methods

Study setting and participants

This report is based on data from the Food and Agricultural Approaches to Reducing Malnutrition (FAARM) cluster-randomized controlled trial (ClinicalTrials.gov, ID: NCT02505711) and the Food Hygiene to reduce Environmental Enteric Dysfunction (FHEED) sub-study. Detailed information about the FAARM trial design, study setting and -population can be found in the study protocol [24]. In brief, the FAARM trial aimed to evaluate the impact of a Homestead Food Production (HFP) program by Helen Keller Intl. on child undernutrition in rural Habiganj district, Sylhet division, Bangladesh. The trial enrolled 2700 married women, age 30 or younger at enrolment, in 96 settlements (geographic clusters), which were randomly assigned to 48 intervention and 48 control clusters. The intervention package included trainings on year-round gardening, poultry rearing, and improved nutrition and hygiene practices [24]. An additional behavior change module was added in the third year of the intervention to strengthen household food hygiene practices, especially around food preparation and child feeding [25]. The four promoted behaviors covered: 1. Handwashing with soap and water before cooking, child feeding and/or eating, 2. Washing utensils with soap and water before preparing and serving food, 3. Safe storage of cooked food and drinking water, and 4. Cooking food fresh or thorough reheating of stored food before feeding/eating. Improved food hygiene practices should prevent or decrease complementary food contamination and thereby reduce the potential impact of intestinal infections and - disease on undernutrition.

The FHEED sub-study was designed to analyze the impact of the combined HFP and food hygiene intervention on household food hygiene practices, complementary food contamination, and intestinal infection and inflammation in children 0-18 months.

Data and sample collection

Data collection

For this report, we use data from three FAARM datasets: 1) background characteristics at the time of the FAARM baseline survey, 2) reported food hygiene behaviors collected as part of the FAARM's routine assessment surveillance, and 3) direct observation of behaviors and collection of food samples. The FAARM baseline survey was conducted in 2015 and collected data on household and woman characteristics, such as age, education, household wealth, and religion from all households. The FAARM surveillance system's routine assessment was conducted on a bimonthly basis from 2015 to 2019.[24] Data on reported food hygiene behavior were collected through a module added to the surveillance for two consecutive rounds from December 2018 to March 2019, after the conclusion of all food hygiene trainings. The food hygiene module targeted all households with a child under 24 months of age. Questionnaires were administered by trained data collection officers, conducting face-to-face interviews with the respondents.

During two separate cross-sectional surveys for FHEED (from July to September 2018 and from July to August 2019), we did household spot-checks around sanitation, kitchen, and food storage facilities, in all households with a child aged 6-18 months. Trained observers performed structured observations of household food hygiene behaviors over 3 hours, either in the morning or early afternoon. Observations focused especially on caretaker practices around complementary food preparation and child feeding, as well as handwashing behavior. To minimize bias, attendants were told that the observations were conducted to learn about daily household activities. All survey data were gathered using tablet-based

Open Data Kit (ODK) software.[26] Table 1 gives a summary of surveys and indicates which activities were supported by Fiat Panis.

Table 1: Summary of surveys included in this report

Survey	Data collected	Participants	Supported by Fiat Panis
FAARM baseline survey	Background characteristics of study households and participants	all 2700 FAARM participants [a]	
FAARM routine surveillance	Reported caregiver food hygiene practice	532 participants: households with a child age 6-23 m	
FHEED survey 2018 - observation	Observed caregiver food hygiene practice and environmental spot checks	366 participants: FHEED households with a child age 6-18 m	Partially supported by Fiat Panis
FHEED survey 2018 - food sampling	Complementary food sample for enumeration of *E. coli*	342 participants*: FHEED households with a child age 6-18 m	Supported by Fiat Panis
FHEED survey 2019 - observation	Observed caregiver food hygiene practice and environmental spot checks	205 participants: FHEED households with a child age 6-18 m (which were < 6m during the 2018 survey)	

[a] Background characteristics were provided by all FAARM study participants, this report shows only the background characteristics of those households involved in food hygiene data collection; * food was sampled from 342 participants during the observation in 2018, 24 participants were not able to provide a food sample during the survey. From the 366 participants in the observation in 2018, 348 also provided data on reported caregiver food hygiene practice (during FAARM routine surveillance).

Food sample collection

As part of the cross-sectional survey for FHEED in 2018, food samples were sampled just before child feeding or, if no feeding event was observed (in 19% of households), mothers were asked to prepare and serve food as if they would serve it to their 6-18 months old child. Prior to food collection, temperature of the prepared food was measured using a food thermometer (Manufacturer: SveBake, Model TP500). Mothers were asked to place the food sample into a sterile plastic bag which was then immediately stored in an ice-cooled bag and transported to the laboratory within 12 hours after collection, maintaining a cold chain (8-10 °C) at all times.

E.coli enumeration

Food contamination was assessed by counting colony-forming units (CFU) of Escherichia coli (*E. coli*), a WHO-recommended indicator organism for measuring fecal contamination.[27,28] For enumeration of *E. coli*, standard methodology was followed.[29] Briefly, an aliquot of 25 g solid or 25 mL liquid food sample was mixed well with 225 mL of 0.1% peptone water and homogenized in a Stomacher®400 circulator (Seward Co. Ltd., UK) at 230 rpm for 1 minute. One mL of the suspension was transferred to a tube containing 9 mL of sterile diluents and mixed thoroughly to get 10^{-2} dilution. Appearance of blue-green colonies on the TBX plate was indicative of the presence of *E. coli* and reported as CFU per gram of food (CFU/g). Samples negative for colonies on the initial dilution plate (10^{-1}) were reported as <10 CFU/g.

Outcomes

We specified the following outcomes of interest: Complementary food contamination, defined as binary variable (presence or absence of detectable E. coli in the food sample; limit of detection: 10 CFU/g food). Food contamination was also assessed as categorical variable, *E. coli* contamination absent/low (less than 10 CFU/g food), medium (10-100 CFU/g food), and high (more than 100 CFU/g food), given that 100 CFU/g is set as the safety threshold for ready-to-eat foods in microbiological food quality guidelines.[30] In addition, log-transformed *E. coli* counts were used as continuous outcome (log CFU/g food).

Using the surveillance data, we categorized caregiver's reported food hygiene practices as binary variables in line with key food hygiene behaviors: 1) handwashing with soap was reported for five critical time points: i) before food preparation, ii) before child feeding, iii) after defecation, iv) after cleaning the child, and v) after handling animal feces. In addition, reported handwashing at critical times was summarized into a handwashing score, ranging from 0 to 5; 2) using washed or clean child feeding utensils; 3) cooking food fresh or properly reheat stored food until steaming hot; and 4) storing food and water fully covered and elevated from the ground.

From household spot-checks and observations, we created variables on caregiver's observed food hygiene practices in line with the key food hygiene behaviors: 1) washing hands with soap or 1b) washing hands with soap or washing at least both hands with water; 2) using washed or clean utensils or 2b) washing utensils with soap before use; 3) cooking fresh or reheating foods before serving; and 4) storing cooked foods with lids and on a raised shelf/inside a cabinet. In addition, we assessed the cleanliness of the kitchen and food preparation area and the presence of a functional handwashing facility near the kitchen.

Statistical analysis

We performed all data analyses in Stata 14. We described outcome, exposure, and confounder variables using proportions or means and standard error. To estimate the intervention effect on reported food hygiene behaviors, we used mixed-effects logistic regression with a random effect for settlement-level clustering. Similarly, to estimate the intervention effect on observed food hygiene behaviors, we constructed mixed-effects logistic regression models with a random effect for settlement-level and woman-level clustering and a fixed effect for the observation round (2018 or 2019), baseline household wealth, and age of the index child. To assess the effect of the intervention on complementary food contamination, we used mixed-effects logistic regression with a random effect for settlement-level clustering for the binary outcome (contamination yes/no) and for the continuous outcome ($\log_{10}$ *E. coli* counts among *E. coli* positive samples) mixed-effects linear regression with a random effect for settlement-level clustering.

To explore the variations in simultaneous practices of multiple food hygiene behaviors (e.g. washing hands, using clean utensils, and cooking or reheating food) before food preparation and child feeding, we calculated the frequency (proportion) for all observed combinations of behaviors (e.g. followed all three together, in combination, one behavior alone, or none) over the total number of observed events.

To identify determinants of food contamination, we used mixed-effects logistic regression models including all reported or observed food hygiene behaviors, with a random effect for settlement-level clustering and adjusting for type of food, food storage time, temperature and humidity of the food storage area, intervention allocation, maternal literacy, and household wealth as potential confounders.

Results

Characteristics of the study population

This report includes data on reported food hygiene and handwashing behavior, collected from 532 households with a child 6-23 months of age during the FAARM routine surveillance surveys, as well as data on observed food hygiene behavior and complementary food contamination, collected from 571 households included in the FHEED sub-study. Background characteristics of the intervention and control settlements were largely similar regarding age and educational status of the mothers, household size, and religion (Table 2). However, we observed a small difference in household wealth between groups, about one third of intervention households belonged to the richest wealth tercile compared to one quarter of control households.

Table 2: Characteristics of women and households participated in the food hygiene survey during routine surveillance (left) and observation (right) in Habiganj District, Sylhet, Bangladesh

	Food hygiene survey		Food hygiene observation	
	Control (N= 263)	Intervention (N=269)	Control (N=279)	Intervention (N=292)
Women characteristics				
Age of woman, years	22.8 (3.8)	23.4 (3.6)	22.9 (3.9)	22.9 (3.7)
Education level				
None	34 (13%)	40 (15%)	34 (12%)	46 (16%)
Primary (1-5 years)	121 (46%)	119 (44%)	137 (49%)	129 (44%)
Secondary (≥ 6 years)	108 (41%)	110 (41%)	108 (39%)	117 (40%)
Household characteristics				
Religion, Muslim	198 (76%)	205 (77%)	206 (74%)	226 (77%)
Household members, average	6.9 (3.1)	7.2 (3.0)	6.8 (2.5)	7.1 (3.0)
Household wealth, tercile				
Poor	107 (41%)	95 (36%)	111 (40%)	102 (34%)
Middle	93 (35%)	92 (34%)	102 (36%)	95 (33%)
Rich	62 (24%)	80 (30%)	66 (24%)	95 (33%)

Total N (food hygiene survey during surveillance): 532 households, N (food hygiene observation): 571 households.

Reported food hygiene behaviors

Among the critical time points for washing hands, handwashing after defecation was reported most frequently (58% of households), followed by handwashing before eating and before food preparation (43% and 32% of households respectively, data not shown). From other food hygiene behaviors, fresh preparation or reheating of food was reported by 83% of households and usage of clean utensils by 55% of households, while a safe storage of food was only reported by 14% of households (data not shown). Mothers from intervention households reported higher handwashing before food preparation (OR: 4.0, 95% CI: 2.3 – 7.2), before eating (OR: 4.7, 95% CI: 2.7 – 8.3), before child feeding (OR: 3.2, 95% CI: 1.8 – 5.7) and after defecation (OR: 2.6, 95% CI: 1.5 – 4.7) as compared to control households. For both handwashing after cleaning the child and after contact with child feces, the intervention group reported a slightly higher practice compared to the control. Yet, the differences were not large and could be due to chance (Table 3). Intervention households also reported higher utilization of clean utensils for feeding (OR: 1.8, 95% CI: 1.1 – 2.9) and higher practice of reheating stored food or preparing food fresh (OR: 2.6, 95%

CI: 1.0 – 6.8) compared to households from control settlements, while there was no difference in reported safe food and water storage (Table 3).

Table 3: Effect of intervention on caregiver's reported food hygiene practices

	Control %	Intervention %	OR* (CI)	p value
Proportion of households who mentioned				
Washing hands (unprompted)				
Before food preparation	19	45	4.0 (2.3-7.2)	<0.001
Before eating	27	58	4.7 (2.7-8.3)	<0.001
Before child feeding	18	37	3.2 (1.8-5.7)	<0.001
After defecation	48	68	2.6 (1.5-4.7)	0.001
After cleaning the child's bottom	18	25	1.7 (0.9-3.3)	0.137
After disposing child's feces	28	33	1.5 (0.7-3.2)	0.302
Food hygiene behaviors				
Hands washed before food prep. and feeding	7.6	21	3.5 (1.7-7.2)	0.001
Feeding utensils cleaned	49	61	1.8 (1.1-2.9)	0.019
Food stored safely	12	15	1.1 (0.4-3.4)	0.828
Water stored safe	69	70	1.2 (0.6-2.7)	0.581
Food prepared fresh or reheated thoroughly	79	88	2.6 (1.0-6.8)	0.046

Total: N=541, for food hygiene behaviors: N=532, as nine children have not yet received complementary feeding; reported behavior was assessed in households with children 6-23 months of age; OR: odds ratio, CI: 95% confidence interval; * Estimated from mixed-effects regression models adjusting for settlement level random effects

Observed food hygiene behaviors

Food hygiene practices were analyzed from 507 observed complementary child feeding events (262 from intervention; 245 from control) and 817 food preparation events (420 from intervention; 397 from control), primarily performed by mothers. Comparable to reported food hygiene practices, the use of washed or clean utensils, as well as cooking food fresh or reheating of stored food were frequently observed. However, handwashing with soap before food preparation or child feeding was rarely seen (Table 4) and the actual practice was much lower than the reported behavior (compare table 3 and 4).

Overall, we noted positive effects of the intervention on food hygiene practices related to child feeding: using clean feeding utensils (OR: 3.3, 95% CI: 1.6 – 6.7), cooking fresh or reheating food (OR: 1.7, 95% CI: 1.1 – 2.8), and handwashing with soap (OR: 5.3, 95% CI: 2.0 – 14.0); as well as in the context of food preparation: using clean feeding utensils (OR: 2.2, 95% CI: 1.0 – 5.0) and handwashing with soap (OR: 6.6, 95% CI: 1.8 – 23.8). However, there was no difference in cooking fresh food or reheating food between intervention and control households, when serving it to another family member. We could also not observe any difference in safe food storage practices (Table 4).

Table 4: Effect of intervention on observed caregiver food hygiene practices

	Control	Intervention		
	Predicted probability (%) *		OR (CI)	p value
Child feeding				
Washed hands with soap	2.6	11.6	5.3 (2.0-14.0)	0.001
Washed hands (any) ‡	8.9	20.5	2.8 (1.5-5.4)	0.002
Used washed or clean utensils §	79.8	92.0	3.3 (1.6-6.7)	0.001
Washed utensils with soap before use	3.4	9.2	3.0 (1.1-8.2)	0.027
Cooked fresh or reheated stored food ¶	50.8	62.5	1.7 (1.1-2.8)	0.030
Food preparation and storage				
Washed hands with soap	0.8	4.7	6.6 (1.8-23.8)	0.004
Washed hands (any) ‡	14.1	22.1	2.0 (1.2-3.3)	0.008
Used washed or clean utensils §	71.9	80.2	2.2 (1.0-5.0)	0.055
Washed utensils with soap before use	2.2	5.2	4.1 (0.9-18.6)	0.067
Cooked fresh or reheated stored food ¶	69.8	72.7	1.2 (0.7-2.0)	0.469
Food covered and stored on elevated place ||	29.9	30.4	1.0 (0.6-1.7)	0.907

Number of observed events: Child feeding: N(handwashing and clean utensils): intervention= 262, control= 245, N(cooking and reheating): intervention= 229, control= 216; Food preparation and storage: N(handwashing and utensils cleaning): intervention= 420, control= 397; N(cooking and reheating): intervention= 364, control= 319; Number of observed households for food storage, N: intervention= 292, control= 279. *Estimated from mixed-effect logistic regression models using marginal standardization. All models included a random effect for settlement and fixed effects for observation year, child age in months and baseline values for household wealth; *OR: odds ratio, CI: 95% confidence interval;* ‡Any handwashing refers to either washing hands with soap and water or at least both hands with water before feeding the child or during food preparation. §All utensils were either at least washed with clean water (or soap and water) or taken from a clean place before use for serving or preparing food. ¶Cooking fresh or reheating all stored foods before feeding/serving a meal. ||Storing cooked foods with lids and on a raised shelf/inside a cabinet.

An exploratory analysis, performed to get a better understanding of behavior patterns prone to introducing contamination, revealed that simultaneous and consistent practice of behaviors varied. Figure 2 shows the variations in practices of multiple food hygiene behaviors during child feeding or serving a meal (Figure 1A or 1B, respectively). Only in 45 out of 445 child feeding events (overall 10%; intervention 16% vs control 4%), all three food hygiene behaviors were followed simultaneously, and in 28 events (~6%), no food hygiene behavior was practiced at all (Figure 1A). A similar pattern appears for serving a meal to another family member, all three food hygiene behaviors were followed simultaneously in 25 out of 361 serving events (overall 7%; intervention 10% vs control 3%), while no food hygiene behavior was practiced in 41 events (~11%, Figure 1B). Cooking or reheating foods and using clean utensils were the two behaviors that were most commonly practiced together: before feeding in 39% and before serving food to a family member in 31% of observations (Figure 1A & 1B).

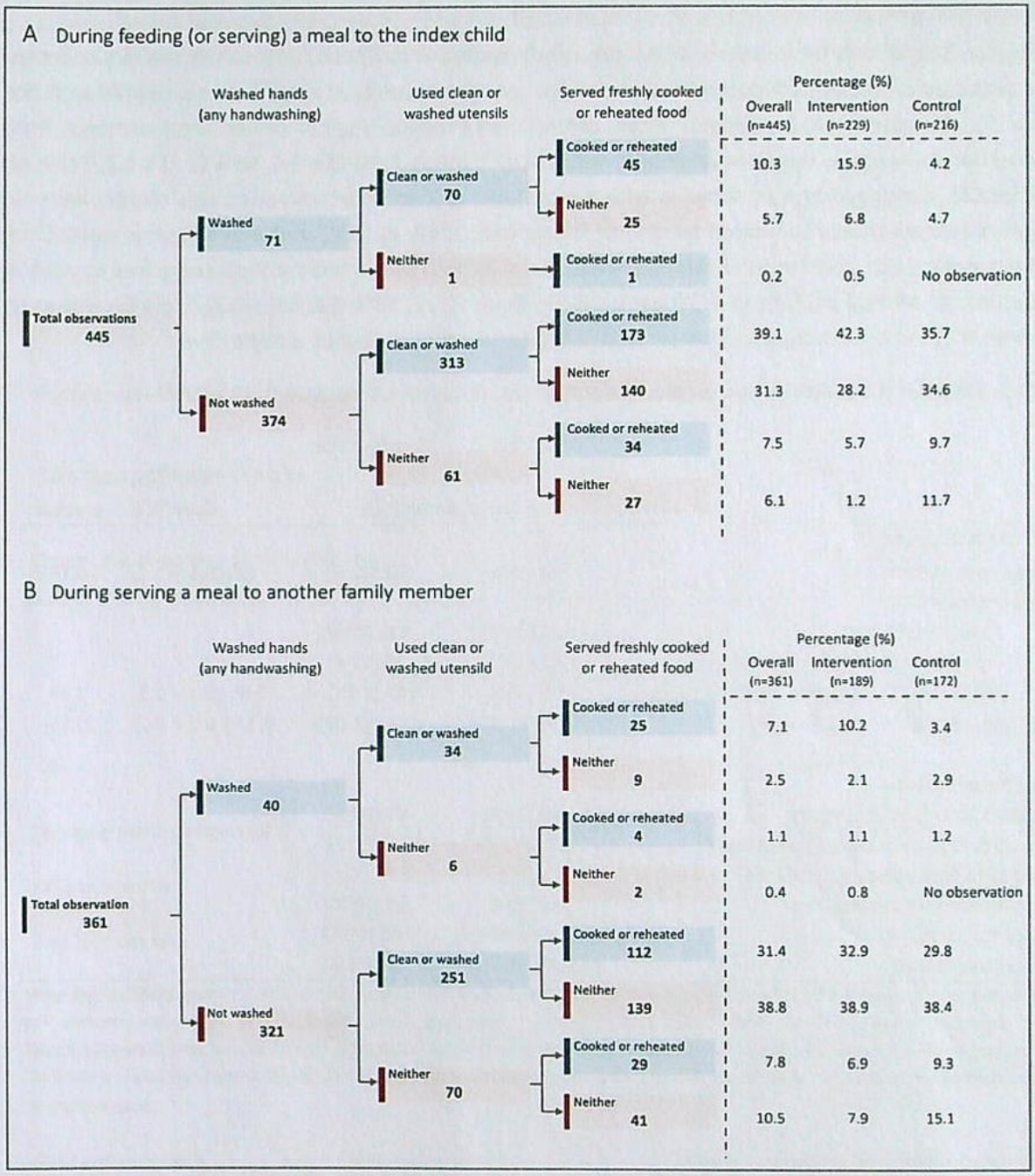

Figure 1: **Variations in practices of multiple food hygiene behaviors during feeding or serving a meal**
Figures show the practice of multiple food hygiene behaviors in combination during feeding (or serving) a meal to the index child (A), and during serving a meal to another family member (B), disaggregated by intervention group. A meal refers to a heavier and larger portion of food; in our context, this usually includes rice eaten with vegetables/lentils/fish/meat. Children also received khichuri (a soft one-pot dish usually prepared with rice, lentils, and vegetables) and porridge as meals. Index child refers to a child aged 6-18 months.

Food contamination

Among the 342 food samples tested, 46% were contaminated with *E. coli*. Most of the samples collected were prepared on the day of food collection and the most common food were dishes prepared with rice (Table 5). Compared to households from control settlements, slightly fewer food samples from intervention households were contaminated with *E. coli* (50% vs 42%, OR: 0.6, 95% CI: 0.3-1.2, Table 5). Additionally, the proportion of samples with a high level of *E.coli* contamination was slightly lower in intervention households compared to control households (24% vs 31%) and overall mean log10 E.coli counts among E.coli positive food samples were also slightly lower in intervention compared to control households (2.48 log10 CFU/g vs 2.37 log10 CFU/g, Coef: -0.11, 95% CI: -0.5 – 0.2, Table 5). However, evidence that these are actual differences and not observed due to chance is rather low.

Table 5: Effect of the intervention on microbial contamination of complementary food

	Control	Intervention		
	n (%) or *mean (SD)*		OR* (CI) *Coef[#](CI)*	p value
Food contamination				
Sample positive for *E.coli*	84 (50%)	72 (42%)	0.6 (0.3 – 1.2)	0.16
E.coli contamination:				
low (<10 CFU/g)	85 (50%)	101 (58%)		
medium (10-100 CFU/g)	32 (19%)	30 (17%)		
high (>100 CFU/g) (vs. medium or low)	52 (31%)	42 (24%)	0.69 (0.4 – 1.3)	0.28
Mean Log_{10} E.coli counts (CFU/g) [$]	*2.48 (1.18)*	*2.37 (1.07)*	*-0.11 (-0.5 – 0.2)*	*0.55*
Food characteristics				
Safe storage of food and water	40 (23%)	47 (27%)		
Temperature of food storage area (in °C)	*31.0 (1.8)*	*31.0 (1.9)*		
Humidity of food storage area (in %)	*83.6 (5.7)*	*83.7 (5.6)*		
Food prepared fresh/reheated	62 (37%)	88 (51%)		
Type of food: rice	124 (73%)	120 (69%)		
Food cooked today	145 (86%)	156 (90%)		

Total N=342; complementary food has been sampled from children age 6-18 months; SD: standard deviation; OR: odds ratio; Coef: regression coefficient; CI: 95% confidence interval; *estimated from mixed-effects regression models for binary/categorical outcomes adjusting for settlement level random effects; #estimated from mixed-effects linear regression model adjusting for settlement level random effects; $this model includes only log10 E.coli counts from E.coli positive samples.

Determinants of food contamination

To get a better understanding of the potential impact of improved food hygiene practices on complementary food contamination, we identified which of the promoted food hygiene behaviors were associated with a reduced E. coli contamination. In a multivariable model of reported food hygiene behaviors and E. coli contamination, we found that reported handwashing practice score was associated with reduced contamination of complementary food (OR: 0.8, CI: 0.6 – 0.9). So was reported safe storage of food and water, although evidence for this association was weak (OR: 0.4, CI: 0.1 – 1.0; Figure 2A). In a multivariable model of observed food hygiene behaviors and E. coli contamination, fresh preparation of food was strongly associated with lower odds of complementary food contamination (OR: 0.3, CI: 0.1 – 0.7). There was also an association between the cleanliness of feeding utensils and food contamination, although evidence for this association was weak (OR: 0.4, CI: 0.2 – 1.0). However, there was little evidence

for an association between the presence of a functional handwashing station or reheating of stored food with food contamination (OR (handwashing station): 0.7, CI: 0.4 – 1.4, and OR (reheating): 1.1, CI: 0.4 – 2.8, Figure 2B).

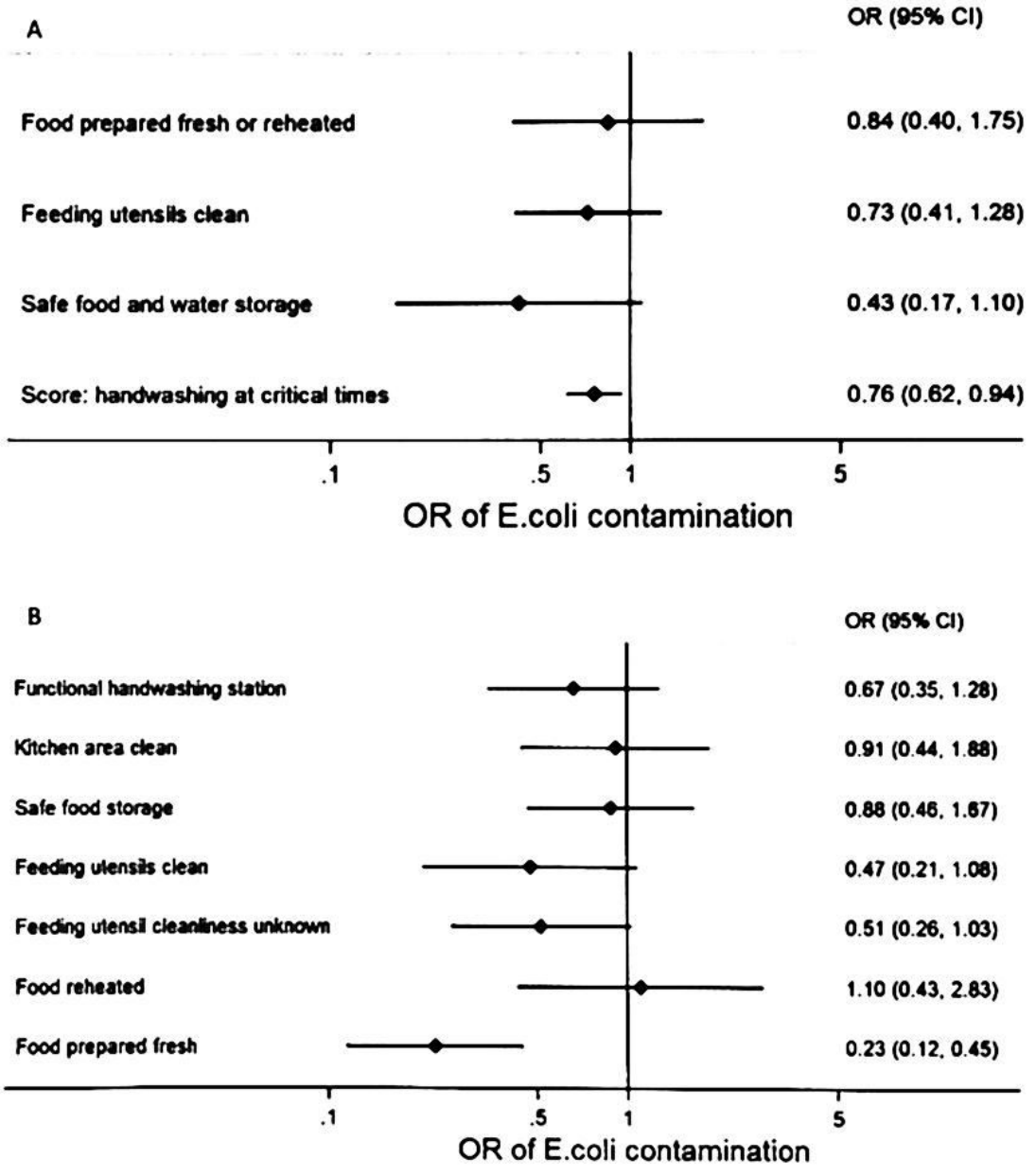

Figure 2. Association of maternal food hygiene behaviors and complementary food contamination in Sylhet, Bangladesh. Odds ratios (OR) of E. coli contamination in complementary food samples (N=342), with 95% confidence intervals from multilevel multivariable regression models with a) reported or b) observed maternal food hygiene behaviors and spot checks, adjusted for temperature and humidity of the food storage area, food type, day of food preparation, household wealth, maternal literacy and intervention allocation, with settlement random effects.

Conclusion and recommendations

This study addresses the potential of domestic food hygiene behavior change as a measure to reduce complementary food contamination in a low-income setting, in order to decrease the risk of foodborne infections and their long-term health impacts. The findings from this study provide evidence for the ability of a food hygiene behavior change intervention to increase maternal reported as well as observed food hygiene behavior in Sylhet, Bangladesh. Exposure to the food hygiene intervention led to an increase in almost all promoted food hygiene behaviors. Besides a clear increase of maternal food hygiene practices in the intervention group compared to control, overall practice of these key behaviors remained low. Even in the intervention arm, most behaviors were reported to be practiced by less than 50% of women, and the actual observed behavior were practiced even less frequently. Also, practice of multiple food hygiene behaviors simultaneously – which is needed in a process like the clean preparation of foods – was rarely seen, indicating that there might be remaining barriers that prevent a consistent change in behavior.

Accordingly, our findings provide no clear evidence that the food hygiene intervention was able to reduce complementary food contamination with *E. coli* in the intervention compared to the control households. However, when food hygiene behaviors were well practiced, there was evidence that this led to a clear reduction in complementary food contamination. Especially fresh preparation of food and handwashing at critical times had a strong effect on food contamination individually. Also, practice of multiple behaviors further decreased the probability of food contamination.

In conclusion, the evaluated intervention did not succeed to sufficiently and sustainably induce a change in food hygiene behavior in the women of the study population to a degree that could translate into a substantial reduction of bacterial food contamination in the household. We hope that this study can make a contribution to our understanding of the improvement of domestic food hygiene practice and the adaptation of future food hygiene interventions and programs. Based on the findings from this study, we want to give the following recommendations:

1. Food hygiene, if practiced well, is able to reduce food contamination and thereby likely to reduce the risk of infection and diarrhea. Integrating food hygiene messages into nutrition and WASH programs could further strengthen their impact by addressing the pathway from food contamination via infection to malnutrition.
2. Our findings suggest that a large-scale, low intensity food hygiene behavior change intervention alone might not be effective to induce a sustainable change in food hygiene behavior in a resource-poor setting. Future food hygiene interventions, therefore, need to consider integrating of important contextual, psychosocial and technological factors.
3. Future research (like a barrier analysis) should consider understanding complex interlinked factors, including social norms, attitudes, the perceived complexity of behaviors, and constraints in terms of cost, effort, and infrastructure that could explain behavioral maintenance in these contexts and design interventions that can potentially achieve the effect at large scale.

The findings from this study will be presented to national NGOs and Government bodies at the dissemination event of the FAARM trial in Dhaka, Bangladesh in November 2022. Scientific manuscripts based on the presented research will be published in open access journals.

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Appendix – overview manuscripts

1. Sobhan S, Mueller-Hauser AA, Huda TMN, Waid JL, Gautam OP, Gon G, Wendt AS, Gabrysch S, 2022. Design, delivery, and determinants of uptake: findings from a food hygiene behavior change intervention in rural Bangladesh. BMC Public Health 22: 887. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9066747/pdf/12889_2022_Article_13124.pdf

2. Mueller-Hauser AA, Sobhan S, Huda TMN, Waid JL, Wendt AS, Islam MA, Rahman M, Gabrysch S, 2022. Key Food Hygiene Behaviors to Reduce Microbial Contamination of Complementary Foods in Rural Bangladesh. Am J Trop Med Hyg., 107(3). https://www.ajtmh.org/downloadpdf/journals/tpmd/107/3/article-p709.pdf

3. Huda TMN, Mueller-Hauser AA, Sobhan S, Hossain MS, Sultana J, Rahman M, Islam MA, Gautam OP, Wendt AS, Waid JL, Gabrysch S. Food hygiene intervention to reduce contamination in complementary food in rural Bangladesh. *Manuscript in preparation.*

4. Sobhan S, Mueller-Hauser AA, Huda TMN, Gon G, Waid JL, Wendt AS, Rahman M, Gabrysch S. Effect of a behaviour change intervention on household food hygiene practices in rural Bangladesh: a cluster-randomized controlled trial. *Manuscript in preparation.*

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Key Food Hygiene Behaviors to Reduce Microbial Contamination of Complementary Foods in Rural Bangladesh

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Abstract. Microbial contamination of complementary foods puts young children at risk of developing intestinal infections and could be reduced by improved handwashing and food hygiene practices. We aimed to identify which promoted food hygiene practices are associated with reduced complementary food contamination in a rural population in Bangladesh. We collected cross-sectional data on reported and observed maternal food hygiene behaviors and measured *Escherichia coli* counts as an indicator of microbial contamination in complementary food samples from 342 children of women enrolled in the Food and Agricultural Approaches to Reducing Malnutrition trial in Sylhet, Bangladesh. We used multivariable logistic regression to examine associations of food hygiene behaviors with food contamination. Approximately 46% of complementary food samples had detectable levels of *Escherichia coli*. Handwashing with soap at critical times and fresh preparation of food before feeding were strongly associated with reduced odds of food sample contamination (odds ratio [OR]: 0.8, 95% confidence interval [CI]: 0.6–0.9 and OR: 0.3, 95% CI: 0.1–0.7, respectively); in contrast, there was no or only weak evidence that reheating of stored food, safe food storage, and cleanliness of feeding utensils reduced contamination. Reduction in food contamination could be more than halved only when several food hygiene behaviors were practiced in combination. In conclusion, single food hygiene practices showed limited potential and a combined practice of multiple food hygiene behaviors may be needed to achieve a substantial reduction of complementary food contamination.

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RESEARCH ARTICLE Open Access

Design, delivery, and determinants of uptake: findings from a food hygiene behavior change intervention in rural Bangladesh

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Abstract

Background: Microbial food contamination, although a known contributor to diarrheal disease and highly prevalent in low-income settings, has received relatively little attention in nutrition programs. Therefore, to address the critical pathway from food contamination to infection to child undernutrition, we adapted and integrated an innovative food hygiene intervention into a large-scale nutrition-sensitive agriculture trial in rural Bangladesh. In this article, we describe the intervention, analyze participation and uptake of the promoted food hygiene behaviors among intervention households, and examine the underlying determinants of behavior adoption.

Methods: The food hygiene intervention employed emotional drivers, engaging group activities, and household visits to improve six feeding and food hygiene behaviors. The program centered on an 'ideal family' competition. Households' attendance in each food hygiene session was documented. Uptake of promoted behaviors was assessed by project staff on seven 'ideal family' indicators using direct observations of practices and spot checks of household hygiene conditions during household visits. We used descriptive analysis and mixed-effect logistic regression to examine changes in household food hygiene practices and to identify determinants of uptake.

Results: Participation in the food hygiene intervention was high with more than 75% attendance at each session. Hygiene behavior practices increased from pre-intervention with success varying by behavior. Safe storage and fresh preparation or reheating of leftover foods were frequently practiced, while handwashing and cleaning of utensils was practiced by fewer participants. In total, 496 of 1275 participating households (39%) adopted at least 5 of 7 selected practices in all three assessment rounds and were awarded 'ideal family' titles at the end of the intervention. Being an 'ideal family' winner was associated with high participation in intervention activities [adjusted odds ratio (AOR): 11.4, 95% CI: 5.2–24.9], highest household wealth [AOR: 2.3, 95% CI: 1.4–3.6] and secondary education of participating women [AOR: 2.2, 95% CI: 1.4–3.4].

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