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Effect of a behaviour change intervention on household food hygiene practices in rural Bangladesh: a cluster-randomised controlled trial

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ABSTRACT

Introduction: Behavioural interventions could improve caregivers' food hygiene practices in low-resource settings. So far, evidence is limited to small-scale and short-term studies, and few have evaluated the long-term maintenance of promoted behaviours. We evaluated the effect of a relatively large-scale behaviour change intervention on medium and long-term maintenance of household food hygiene practices in Bangladesh.

Methods: We analyse a secondary outcome of the Food and Agricultural Approaches to Reducing Malnutrition (FAARM) cluster-randomised trial and its sub-study Food Hygiene to reduce Environmental Enteric Dysfunction (FHEED), conducted in Habiganj district, Sylhet division, Bangladesh. The FAARM trial used a 1:1 parallel arm design and included 2,705 women in 96 settlements: 48 intervention and 48 control. Women in the intervention settlements received training in homestead gardening, poultry rearing and nutrition over three years (2015-2018), complemented by an eight-month (mid-2017 to early-2018) behaviour change component on food hygiene using motivational drivers. Nested within the FAARM trial, the FHEED sub-study evaluated several outcomes along the hygiene pathway. For this article, we evaluated household food hygiene behaviours by analysing structured observation data collected in two cross-sectional surveys, four and 16 months after the food hygiene promotion ended, from two independent subsamples of FAARM women with children aged 6-18 months. We assessed intervention effects on food hygiene practices using mixed-effects logistic regression, accounting for clustering. In exploratory analyses, we further assessed behaviour patterns – how often critical food hygiene behaviours were performed individually, in combination and consistently across events.

Results: Based on the analysis of 524 complementary feeding and 800 food preparation events in households from 571 participant women, we found that intervention households practised better food hygiene than controls four months post-intervention, with somewhat smaller differences after 16 months. Overall, the intervention positively affected food hygiene, particularly around child feeding: using soap for handwashing (odds ratio 5·8, 95% CI 2·2-15·2), cleaning feeding utensils (3·8, 1·9-7·7), and cooking fresh/reheating food (1·8, 1·1-2·8). However, the simultaneous practice of several behaviours was rare, occurring in only 10% of feeding events (intervention: 15%; control: 4%), and the practice of safe food hygiene behaviours was inconsistent between events.

Conclusion: Our findings suggest that a motivational behaviour change intervention encouraged caregivers to maintain certain safe food hygiene practices in a rural setting. However, substantial physical changes in the household environment are likely needed to make these behaviours habitual.

Trial registration number NCT02505711

Keywords Behavioural maintenance, Structured observation, Handwashing, Complementary feeding, Nutrition-sensitive intervention.

1 **1. Introduction**

2 Hygiene during food preparation, feeding, and storage is as essential for young children's growth and
3 nutrition as an adequate and diverse diet (Dewey and Adu-Afarwuah, 2008). Intestinal infections and
4 diarrhoeal disease in children caused by pathogens transmitted in food is a global public health concern,
5 particularly in low-and middle-income countries (LMICs) (Kirk et al., 2017). In economically
6 disadvantaged communities in LMICs, most food contamination and recurrent foodborne infections
7 originate at the household level, primarily from exposure to faecal pathogens in the domestic
8 environment and caregivers' poor food hygiene practices (Curtis et al., 2000). Interventions that aim to
9 interrupt the transmission of pathogens to children in these settings focus largely on reducing direct
10 human contact with faecal pathogens, with particular attention to safe human faeces disposal and
11 handwashing with soap after defecation (Ejemot-Nwadiaro et al., 2021; Humphrey et al., 2019; Luby
12 et al., 2018; Null et al., 2018; Wolf et al., 2022). Even though unwashed hands before handling food,
13 use of unclean feeding utensils, and inadequate reheating of leftovers with poor storage practice remain
14 critical entry points for children's intake of (re)contaminated food in a contaminated environment (Islam
15 et al., 2013; Motarjemi et al., 1993; Parvez et al., 2017), improving caregivers' food hygiene behaviours
16 has only recently received attention in water, sanitation and hygiene (WaSH) and nutrition literature
17 (Curtis et al., 2011).

18 Over the last decade, a few intervention trials have attempted to improve caregivers' food hygiene
19 practices around complementary child feeding in low-income settings of South Asia and sub-Saharan
20 Africa (Gautam et al., 2017; Manjang et al., 2018; Morse et al., 2020; Mumma et al., 2019). They
21 employed behavioural models to understand motivational drivers, and the interventions focused on a
22 wide range of behaviour change techniques such as commitment, modification in the domestic
23 environment, use of prompts and cues, and social rewards to encourage the adoption of safe food
24 hygiene behaviours among mothers and caregivers of young children (Gautam et al., 2017; Manjang et
25 al., 2018; Morse et al., 2019; Simiyu et al., 2020). While the success of these trials in improving targeted
26 behaviours was promising (Chidziwisano et al., 2020a; Gautam et al., 2017; Manaseki-Holland et al.,
27 2021), most of the interventions were of limited scale and short duration (Gautam et al., 2017; Manjang

28 et al., 2018) and implemented with frequent contacts with participants (Gautam et al., 2017; Morse et
29 al., 2020). Evidence about long-term behavioural maintenance in response to such interventions is also
30 limited, to our knowledge, reported only in one food hygiene study in The Gambia (Manaseki-Holland
31 et al., 2021).

32 Concurrent with other food hygiene studies, we designed a less intensive behavioural intervention to
33 promote food hygiene as part of a larger nutrition-sensitive agriculture trial in Bangladesh. During
34 follow-up visits during the implementation phase, we noted a substantial increase in all promoted food
35 hygiene behaviours compared to the pre-intervention period (Sobhan et al., 2022). Nevertheless, it
36 remained to be seen whether these behaviours could be maintained long-term. Furthermore, safe food
37 preparation, consumption and feeding children are complex processes involving several critical points
38 (Islam et al., 2013) and practising multiple food hygiene behaviours together might be required to
39 substantially minimise the risk of food contamination (Müller-Hauser et al., 2022). Also, these
40 behaviours need to be practised repeatedly during every preparation and feeding event to achieve
41 optimal impact on child health. However, how often multiple food hygiene behaviours are practised
42 simultaneously and consistently remains an open question.

43 In this article, therefore, we primarily aimed to evaluate the effect of this relatively large-scale, less
44 intensive behavioural intervention on the maintenance of household food hygiene practices at four and
45 sixteen months after the intervention. In exploratory analyses, we also assessed the behavioural patterns
46 to expand our understanding about (a) variations in the practice of several food hygiene behaviours
47 during food preparation and child feeding and (b) consistency in food hygiene practices across multiple
48 observed events.

49 2. Materials and methods

50 2.1. Study design and participants

51 This analysis was conducted to evaluate a pre-specified secondary outcome of the Food and Agricultural
52 Approaches to Reducing Malnutrition (FAARM) cluster-randomised controlled trial
53 (ClinicalTrials.gov, ID: NCT02505711) and its sub-study: Food Hygiene to reduce Environmental
54 Enteric Dysfunction (FHEED). Details of the FAARM trial design, setting, participants and information
55 about the FHEED sub-study can be found in the published protocol (Wendt et al., 2019). In summary,
56 the FAARM trial (2015-2019) was set up to evaluate the impact of a homestead food production (HFP)
57 program on child undernutrition and growth in two rural sub-districts of Habiganj district, Sylhet
58 division, Bangladesh. It enrolled 2,705 married women aged 30 years or younger in 96 settlements
59 (geographic clusters of 10-65 women living close to each other) who expressed interest in homestead
60 gardening and had access to at least 40m² of land. Settlements were then randomised (1:1) using
61 covariate-constrained randomisation, with 48 clusters assigned to receive a three-year HFP intervention
62 and 48 to controls. The HFP intervention, implemented by Helen Keller International from mid-2015
63 to late-2018, promoted the consumption of diverse and nutrient-rich foods, especially among women
64 and children, through vegetable gardening, poultry rearing and nutrition counselling. In its third year,
65 an additional behaviour change component promoting good food hygiene was introduced and
66 implemented over eight months (mid-2017 to early-2018) with an aim to complement the benefits of
67 nutrient-rich and diverse diets in improving child nutrition with reduced food contamination and
68 intestinal infections. Consequently, in 2018, the FHEED sub-study was added to the FAARM trial to
69 specifically collect and analyse data on multiple outcomes along the hygiene-infection-nutrition
70 pathway more elaborately, from adoption of household food hygiene behaviours to complementary food
71 contamination, enteric infection, and inflammation in children. This article evaluated the intervention
72 effect on the maintenance of household food hygiene behaviours among women with (index) children
73 aged 6-18 months.

74 2.2. Food hygiene component: content and delivery

75 Adapting a food hygiene intervention package implemented in Nepal, we designed a behaviour change
76 component within the FAARM intervention to promote four food hygiene behaviours: 1) handwashing
77 with soap and water; 2) washing utensils with soap and water; 3) cooking food fresh or thoroughly
78 reheating stored food; and 4) safe storage of cooked food and drinking water. We focussed on emotional
79 drivers of hygiene behaviours (e.g. nurture, disgust, affiliation, and pride) and adopted several
80 behaviour change techniques to address knowledge, instrumental and experiential beliefs, personal
81 agency, and social norms drivers of the intended behaviours. The package contained fun and
82 participatory activities in four group sessions and four household visits, implemented over eight months.
83 An overview of the design, implementation and content of the FAARM food hygiene component has
84 been published previously (Sobhan et al., 2022) and is summarised in Table S1.

85 2.3. Data collection procedure

86 We evaluated the post-intervention maintenance of promoted food hygiene behaviours in two cross-
87 sectional structured observations from two independent sub-samples of FAARM women with children
88 aged 6-18 months. The first structured observation took place in July-September 2018, approximately
89 four months after the food hygiene promotion ended, and all women with a child born between January
90 and December 2017 were eligible to participate. The second structured observation took place exactly
91 one year later, in July-August 2019, approximately 16 months post-intervention, and all women with a
92 child born between April and December 2018 were eligible to participate. However, women who had
93 already participated in the 4-month structured observation for an older child were excluded from the
94 16-month observation.

95 A trained female observer conducted a 3-hour direct observation in each woman's household in the
96 morning or early afternoon. During an observation session, she focussed mainly on two critical events:
97 (i) child feeding – observing the mother (FAARM women) or another adult family member feeding the
98 (index) child a meal or a snack; (ii) food preparation and serving - observing the mother or another adult
99 family member cooking family meals (e.g. rice, lentils, vegetables, curry) or preparing a special meal
100 for the child or serving meals and snacks to family members. The food hygiene practices around child

101 feeding and food preparation were recorded on a structured paper form. If more than one feeding,
102 cooking, or serving event occurred during the observation, each event was recorded separately. At the
103 end of each observation day, all collected information was transferred to a tablet-based Open Data Kit
104 questionnaire (Hartung et al., 2010).

105 The socio-demographic characteristics of the participating women and their households were extracted
106 from trial data: women's age, education, religion, and households' wealth and WaSH-related
107 characteristics from the FAARM baseline survey conducted in March-May 2015; (index) children's age
108 and sex from the FAARM surveillance records collected shortly after each child's birth; and the current
109 number of household members from the information as reported by the women during structured
110 observation. Women's education was categorised based on completed school years: no formal
111 education, primary (1-5 years of schooling), or secondary education (6+ years of schooling). Household
112 wealth was calculated based on each household's asset information collected during the FAARM
113 baseline survey to determine their position within the national wealth quintile of the Bangladesh
114 Demographic and Health Survey 2014, using EquityTool (www.equitytool.org). Access to an improved
115 water source (e.g. tube well, public tap), sanitation facilities (e.g. pit latrine, flush or pour-flush flush
116 latrine) and handwashing facilities were defined following the WHO/UNICEF Joint Monitoring
117 Programme for Water Supply, Sanitation and Hygiene (JMP) classifications (World Health
118 Organization (WHO) and the United Nations Children's Fund (UNICEF), 2017).

119 *2.4. Sample size*

120 The sample size for structured observation was determined solely based on the expected number of
121 women with children aged 6-18 months at both points. Based on the FAARM routine assessment
122 conducted every two months, we estimated that around 400 women with a child in this age group would
123 be eligible to participate in the 4-month structured observation, with 200 women in each group. We
124 calculated that with this sample size, we could detect a 15% absolute difference in the proportion of
125 mothers (25% in the intervention vs 10% in control) performing all food hygiene behaviours with 90%
126 power and a design effect of 1.5. However, due to time and resource limitations, we only included
127 women with children aged 6-15 months for 16-month structured observation. Consequently, the
128 estimated sample size is smaller, with approximately 130 women in each group.

129 2.5. *Blinding*

130 Given the nature of the intervention, it was impossible to keep the implementation team and women in
131 the intervention group blinded to the intervention activities. However, a minimum distance of 400m
132 was maintained between two neighbouring settlements to limit any spillover to control settlements. An
133 independent team, not involved in the implementation process or aware of the settlement allocation,
134 carried out the structured observations at both time points. To minimise reactivity bias during structured
135 observation, the observers informed participants that they would record household activities without
136 disclosing their interest in food hygiene behaviours.

137 2.6. *Outcomes*

138 We specified four primary outcomes for this analysis: 1) handwashing with soap before handling food;
139 2) washing utensils with cleaning agent before use; 3) cooking fresh or reheating foods before serving;
140 4) storing cooked foods with lids and on a raised shelf/inside a cabinet (see Table 1 for definitions).
141 Besides, we also evaluated two composite measures as secondary outcomes: *any handwashing* and
142 *using clean utensils*. Any handwashing involves adhering to at least one of the two actions: (a) washing
143 one hand with soap and clean water or (b) washing both hands using only clean water. We included
144 washing both hands with clean water as this could also substantially reduce bacterial contamination of
145 hands compared to not washing them at all (Burton et al., 2011; Luby et al., 2011). Using clean utensils
146 entails adhering to at least one of the three utensil cleanliness measures: (a) washing utensils with a
147 cleaning agent right before use, (b) using visibly clean utensils after rinsing them thoroughly with clean
148 water or (c) using pre-washed utensils from a clean, elevated place. We included washing utensils with
149 clean water and using pre-washed utensils from a clean place, as similar measurements for clean utensils
150 were assessed in other food hygiene studies. (Chidziwisano et al., 2020a; Islam et al., 2013; Manaseki-
151 Holland et al., 2021; Touré et al., 2013). Other secondary outcomes we measured were the overall
152 cleanliness of the kitchen and food preparation area and the presence of a functional handwashing
153 facility near the kitchen (Table 1).

154 2.7. Statistical Analysis

155 We first analysed and compared the socio-demographic characteristics of the participants between
156 intervention and control groups at baseline, using proportions for categorical variables and means and
157 standard deviations for continuous variables. Next, we compared the observed food hygiene practices
158 between the two groups and the two observation time points. We summarised the findings using
159 proportions and absolute percentage point differences accounting for settlement-level clustering. The
160 effects of the food hygiene component on individual food hygiene behaviours were evaluated using
161 mixed-effects logistic regression models with repeat measures. However, the smaller sample size and
162 infrequent occurrence of certain behaviours during the 16-month observation made it challenging to fit
163 these outcomes into a regression model and evaluate the intervention effect as a stand-alone evaluation.
164 Therefore, we combined the 4-month and 16-month structured observations into a single dataset to
165 increase the frequency of individual outcomes and improve the statistical power for measuring the
166 effect. We fitted mixed-effects logistic regression models with a random effect for settlement-level
167 clustering and fixed effects for temporal variations (4-month or 16-month) for each outcome. We
168 calculated predicted probabilities using marginal standardisation and effect estimates as odds ratios with
169 corresponding 95% confidence intervals (CIs). Analyses were stratified by child feeding and food
170 preparation events to determine variations in food hygiene practices by occasion. Analyses were
171 intention-to-treat.

172 In sensitivity checks, we conducted the following analyses: 1) We replicated the models adjusting for
173 (slight) imbalance in wealth quintiles at baseline and child age measured in completed months. 2) We
174 ran the models separately for 4-month structured observation only (first only with a random effect for
175 settlement and then again adjusted for baseline wealth quintiles and child age) to assess any differences
176 in the effect estimates that could arise from combining two distinct observations that occur place at
177 different time points.

178 Finally, to evaluate behaviour patterns, we focused on two aspects. First, we assessed the simultaneous
179 practice of three critical food hygiene behaviours (i.e. washing hands, using clean utensils, and
180 cooking/reheating food) during a child feeding or serving event. We grouped the combinations as ‘all
181 three behaviours performed together’, ‘any two performed together’, ‘one performed alone’, or ‘none’.

182 Next, we evaluated the consistency in food hygiene practices only among women for whom we recorded
183 two serving events. Observing their food hygiene practices in both events, we assessed the frequency
184 of each behaviour on a scale of ‘never’, ‘either one time’, or ‘repeated both times’. For both analyses,
185 we combined 4-month and 16-month structured observations to increase the sample size and only
186 included feeding and serving meal events (excluding snacking events). All analyses were conducted in
187 Stata version 17.

188 *2.8. Ethical considerations*

189 The FAARM trial protocol was positively reviewed by Heidelberg University in Germany (Ref.: S-
190 121/2014) and the James P. Grant School of Public Health, BRAC University in Bangladesh (Ref.:
191 37A). The FHEED study protocol was positively reviewed by Heidelberg University (Ref.: S-606/2017)
192 and icddr,b in Bangladesh (Ref.: PR-17126). All participants provided informed written consent when
193 they enrolled in the trial and additional verbal consent before data collection.

194 3. Results

195 Overall, we present results from 571 FAARM women and their households (intervention: 292, control:
196 279) who participated in one of the two cross-sectional structured observations, representing 86% of
197 668 eligible women with children aged 6-18 months. Fig. 1 illustrates the flowchart of participants,
198 including reasons for exclusion from structured observations and analysis at each time point.

199 Table 2 describes the socio-demographic characteristics of the sample at baseline in 2015, disaggregated
200 by intervention and control groups and structured observation time points. Both groups were broadly
201 similar regarding baseline women's age, educational attainment, religion, and household size. The mean
202 age of women was 23 years, and about half had completed some years of primary education. About
203 three-quarters of households were Muslim, and the remaining were Hindu. On average, seven people
204 lived in one household. There was a slight difference in baseline wealth between groups, as around 38%
205 of intervention households were in the top two wealth quintiles compared to only 30% in the control
206 group. This imbalance could be traced to small differences in household assets and amenities, such as
207 higher ownership of agricultural land and marginally better house construction in intervention
208 households (Table S2). Regardless, in terms of water, sanitation and hygiene infrastructure and
209 facilities, the difference between the two groups was very minimal: in both groups, about one-third of
210 households had access to an improved water source on their premises, two-fifths had an improved
211 latrine, and less than one-tenth had a functional handwashing facility near the kitchen. At baseline,
212 reported handwashing with soap varied from ~30% before child feeding to ~40% before food
213 preparation. The mean age of the (index) children, extracted from the FAARM birth surveillance record,
214 was 13 months in the 4-month structured observation and 11 months in the 16-month observation.

215 *3.1. A comparative analysis of food hygiene practices between groups and observation time points*

216 We analysed food hygiene practices from 524 child feeding (intervention: 270; control: 254) and 800
217 food preparation and serving events (intervention: 412; control: 388), primarily performed by the
218 mother (89% and 86%, Table S3). Table 3 presents descriptive statistics of food hygiene outcomes for
219 intervention and control households, separately by 4-month and 16-month structured observation.
220 During the 4-month structured observation, intervention households had better food hygiene practices

221 than controls; they used clean utensils in 91% of child feeding events (71% in control) and cooked fresh
222 or reheated stored food before serving in 58% of events (45% in control). Handwashing with soap was
223 also higher in the intervention group, with the frequency being low overall (intervention: 12%; control:
224 3%). Even when both hands rinsed only with water were counted alongside washing hands with soap,
225 the observed frequency of handwashing before child feeding was below 25%. Around one-quarter of
226 intervention households had a functional handwashing facility near the kitchen compared to 16% in
227 controls. We observed a similar pattern of food hygiene practice during food preparation events as
228 during child feeding. Among the four primary outcomes, only storing cooked food with a cover and on
229 a raised shelf was less prevalent among households in the intervention group (29%) compared to
230 controls (38%); however, the evidence is relatively weak, and the difference could be due to chance.
231 During the 16-month structured observation, the observed practice of most food hygiene behaviours in
232 intervention households remained largely the same as during the 4-month round, whilst some practices
233 had also increased in controls (Table 3). At the 4-month observation, the frequency of using clean
234 utensils for food preparation was higher in intervention households (71%) than in controls (57%), while
235 at 16 months, it was higher and similar in both groups (intervention: 94%; control: 95%). Likewise,
236 serving fresh or reheated food to a family member was similar between groups at 16 months, while
237 serving fresh or reheated food to children was still slightly higher in intervention (72%) than in control
238 (64%) (Table 3). Table S4 details the frequency of food hygiene practices, kitchen, and WaSH-related
239 characteristics.

240 *3.2. Effect of the intervention on household food hygiene practices*

241 Table 4 shows the predicted probabilities and overall intervention effects estimated from 4-month and
242 16-month structured observations combined. We found positive effects of the intervention on several
243 food hygiene practices related to child feeding: handwashing with soap (odds ratio (OR) 5·8, 95%
244 confidence interval (CI) 2·2-15·2), washing feeding utensils with soap (OR 3·4, CI 1·3 -8·8), and
245 cooking fresh or reheating stored food (OR 1·8, CI 1·1-2·8). We also observed similar effects in the
246 context of food preparation.

247 Given the slight imbalance in baseline household wealth between intervention and control groups, as
248 sensitivity analysis, we assessed the overall effects on each behaviour, adjusting for baseline wealth and

249 child age and found no substantive changes in the effect estimates compared to the primary models.
250 Similarly, we assessed the intervention effects on each outcome exclusively for the 4-month structured
251 observation to evaluate any differences in the effect estimates that could arise from combining
252 observations from two different time points. Again, we found no noteworthy differences in the effect
253 estimates (Table S5).

254 *3.3. Behaviour patterns in observed food hygiene practices: exploratory analyses*

255 Our exploratory analyses to understand behaviour patterns highlighted that simultaneous practice of
256 multiple food hygiene behaviours during a child feeding or food preparation event was uncommon, and
257 safe behaviours were not consistently or repeatedly followed across different events. Out of 462 child
258 feeding events, in only 45 occasions (overall 10%; intervention: 15%; control: 4%), all three critical
259 behaviours (i.e. washing hands, using clean utensils, and serving fresh/reheated food) were carried out
260 together whereas in 31 events (~7%), none of the behaviours were observed. Cooking fresh or reheating
261 foods and using clean utensils were more commonly practised together than any other combination:
262 occurred before 39% of child feeding events and 31% of serving events (Fig. 2A & 2B). Fig. 3
263 demonstrates the consistency in food hygiene practices for 99 women (intervention group only) whose
264 food hygiene behaviours were observed two times on two occasions. Even though more than three-
265 fourths of them used clean utensils at both events, few consistently washed their hands before feeding
266 or serving food: only 5% washed their hands at both times and 25% at least in one of two observed
267 events (see Table S6 and Table S7 for a detailed breakdown of the frequency and proportion by
268 intervention group).

269 4. Discussion

270 This trial is one of few to investigate the impact of a behaviour change intervention on medium and
271 long-term maintenance of multiple food hygiene practices around complementary child feeding. We
272 conducted two cross-sectional structured observations one year apart, approximately four months and
273 16 months after implementation. The observed frequency of several recommended food hygiene
274 behaviours was substantially greater in intervention households after four months, and most behaviours
275 remained higher than in controls after 16 months. Overall, the intervention showed positive effects on
276 three of the four recommended behaviours: washing hands with soap, using clean feeding utensils, and
277 cooking fresh or reheating stored food, especially before feeding to young children. However,
278 handwashing with or without soap before handling food was very low overall, and practice of several
279 food hygiene behaviours at once was rare.

280 So far, results from three randomised controlled trials evaluating food hygiene interventions in three
281 developing countries have been published. The three-month behaviour change intervention in Nepal
282 found that the practice of all five promoted food hygiene behaviours was more common among mothers
283 in the intervention group (43%) than controls (2%) 45 days after the study ended (Gautam et al., 2017).
284 The trial in The Gambia assessed the impact in two long-term post-intervention evaluations and found
285 that adherence to all targeted behaviours was substantially better in intervention villages (65%) than in
286 controls (15%) six months post-intervention. However, the difference between the two groups
287 decreased after 32 months (47% vs 40%) (Manaseki-Holland et al., 2021). A concurrent behaviour
288 change intervention in Malawi also showed immediate improvement in three of the four promoted food
289 hygiene behaviours following nine months of intervention (Chidziwisano et al., 2020a).

290 Similar to the other three trials, our study found mothers and family members in intervention households
291 were more than three times as likely to use clean utensils and twice as likely to cook fresh or reheat
292 stored food, especially before feeding young children, compared to the control households.
293 Handwashing with soap before food preparation and child feeding was also substantially more frequent
294 in the intervention households (OR: 5.8) but was rarely and inconsistently practised: it was observed in
295 around 12% of child feeding (controls 3%) and only 5% of food preparation events (controls: 1%). Even

296 handwashing without soap was rare, practised in less than a quarter of observations. This frequency is
297 much smaller than what has been seen for handwashing with soap in Nepal (intervention: 67%; control:
298 5%) (Gautam et al., 2017), The Gambia (intervention: 46-64%; control: 4-19%) (Manaseki-Holland et
299 al., 2021) and Malawi (intervention: 43-47%; control: 0-0.6%) (Chidziwisano et al., 2020a). To
300 alleviate concerns that the slight imbalance in wealth between the two groups biased our findings in
301 favour of better food hygiene practices in intervention households, we undertook a sensitivity analysis
302 which adjusted for baseline wealth quintile and found no substantial change in the effect estimates.

303 In our study, despite overall household wealth not being a determining factor in practising safe food
304 hygiene behaviours, the absence of direct water connection and soap in most households' kitchens was
305 likely the primary reason for low hand washing. During our post-intervention evaluation, we did
306 observe some improvement in the availability of functional handwashing facilities near the kitchen in
307 intervention households: it increased from 6% at baseline to 21% after food hygiene promotion,
308 nevertheless, it remained much lower than reported in other food hygiene studies in The Gambia and
309 Malawi. In The Gambia, about 90% of intervention households had soap in their kitchens during the
310 post-intervention evaluation (Manaseki-Holland et al., 2021), and in Malawi, more than half of
311 intervention households had a handwashing facility with soap and water conveniently located close to
312 the kitchen (Chidziwisano et al., 2020b). On the other hand, in the Nepal study, more than 50% of study
313 households had access to piped water on compounds, and 40% had tap water inside the house (Gautam
314 et al., 2017). Even though more than 80% of our study households had access to a tube well (hand
315 pump), with ~60% located on-premises, most were set at some distance from the kitchen and living
316 unit. Therefore, it is not surprising that the effort of walking to the tube wells to wash hands or constantly
317 refilling the handwashing bucket several times a day may have made handwashing, even simply rinsing
318 hands under water, too cumbersome for the mothers or household members – as this behaviour needs
319 to be performed dozens of times a day, after every instance of recontamination. On the same note,
320 washing feeding utensils with clean water, which only needs to be done a few times a day, was more
321 frequently practised than handwashing with water (~60% vs ~13% of child feeding events). This
322 contrast between the two behaviours suggests that the proximity of the water source to the kitchen was

323 not the only obstacle to handwashing; frequency may also have played a role in determining their
324 enactment. Research showed that when a behaviour is viewed as too challenging due to a difficult
325 context, people may lack the motivation to perform it repeatedly (Ouellette and Wood, 1998).
326 Interaction with water while rinsing utensils may also have altered caregivers' intention to wash their
327 hands properly by giving them the satisfaction of cleaning hands at the same time, as reported in a
328 previous study in Bangladesh (Nizame et al., 2016).

329 Safe food storage (cooked food fully covered with lids and stored on a raised shelf) was the only
330 behaviour that showed no overall difference between the intervention and control groups. However, at
331 least part of the message had been taken up more in intervention households than in the controls: more
332 intervention households stored food on an elevated shelf (69% vs 59% in control), but pots were often
333 uncovered or only partially covered (54% vs 51% in control). More freshly cooked and reheated food
334 was left uncovered than previously cooked food – probably due to the typical practice of allowing food
335 to cool before storing it and lack of covered shelves or mesh food covers – suggesting that more frequent
336 fresh preparation and reheating of leftovers in intervention households than controls could have offset
337 better safe food storage behaviour in our setting.

338 Even though most food hygiene behaviours in intervention households remained unchanged between
339 the 4-month and the 16-month observation, the differences between the two groups reduced and hence
340 diminished the intervention effects as several practices (especially using clean utensils and serving fresh
341 food/reheating leftovers) had also increased in control households at 16 months. The food hygiene study
342 in The Gambia reported similar fade-out effects on certain food hygiene practices by 32 months post-
343 intervention, apparently due to cross-contamination from intervention villages (Manaseki-Holland et
344 al., 2021). In our study, some control households may have received food hygiene information from
345 families or relatives who participated in the FAARM intervention. However, to our knowledge, such
346 family connections between participants of the two groups were not common. Besides, due to limited
347 mobility, visiting friends and relatives was also not a frequent social activity for these women (Waid et
348 al., 2022). Therefore, exchanging information during family visits may have partly influenced better
349 practices among the control group but likely does not fully explain the marked increase. Seasonality

350 cannot explain this increase either, as both observations took place at the same time of year. Although
351 the smaller sample size and fewer observed events during the 16-month observations led to less power
352 to detect differences between the two groups, explaining the improvement in some food hygiene
353 practices among control households remains difficult.

354 Our exploratory analyses revealed that the simultaneous and consistent practice of multiple food
355 hygiene behaviours was rare. Several factors could lead to such suboptimal behaviour patterns. First, in
356 a rural Bangladeshi household, cooking, washing hands and utensils, and food storage happen in
357 different places – some inside and some outside the kitchen and living unit. The distance between the
358 cooking/dining area and the water source with poorly equipped kitchens can make it difficult for
359 mothers to perform all behaviours simultaneously. Inadequate support within the household could also
360 have overwhelmed them with different household chores and caring for children and the elderly and
361 limited their ability to adopt, practice and continue the behaviours simultaneously and consistently
362 across the day. Finally, preparing meals or feeding a child and following multiple food hygiene
363 behaviours is itself a complex process involving many sub-actions. In resource-poor settings, this means
364 more effort, time and deliberate attention for mothers and caregivers to ensure that each activity is
365 performed at the right time(s). This continuous thinking of when to act may have led them to struggle
366 with holding their positive intentions, properly completing the safe practices, and, more importantly,
367 carrying those out repeatedly. While we noted an effect of the intervention in the expected direction,
368 with intervention households exhibiting better food hygiene practices than controls, the fact that most
369 of these behaviours were only practised infrequently or inconsistently offers more clarity on why these
370 improvements may have been insufficient to reduce food contamination (Huda et al., to be published)
371 and, therefore, likely had no impact on diarrhoea and EED, as noted in our separate analyses in two
372 recently published articles (Lambrecht et al., 2023; Müller-Hauser et al., 2023).

373 Our study had several strengths. We directly observed mothers' and other household members' food
374 hygiene practices, which is more objective and reliable than self-reported practice, as socially desirable
375 behaviours like food hygiene are commonly over-reported (Chidziwisano et al., 2020b). To our
376 knowledge, this is the second randomised controlled trial evaluating medium and long-term intervention
377 effects on household food hygiene behaviours. Our rich household observation data also allowed us to

378 better describe the patterns of food hygiene behaviours, including how they were adopted
379 independently, in combination, and maintained over time.

380 A few limitations should be mentioned as well. A single 3-hour observation in each household limited
381 the feeding events observed and may have prevented us from recording less common food hygiene
382 practices in some households. However, as the frequency of observed events was similar in the
383 intervention and control groups, this should hardly bias our impact estimates. Despite our best efforts
384 to conduct the observations in a natural setting, the presence of an observer might have led to reactivity
385 bias (Gittelsohn et al., 1997). Given the low observed handwashing frequency, such bias also seems
386 unlikely. Finally, we conducted this study in only two rural sub-districts in north-eastern Bangladesh.
387 Nevertheless, the poor household conditions and suboptimal food hygiene practices resemble numerous
388 rural villages in Bangladesh and other similar settings in South Asia and sub-Saharan Africa, supporting
389 the generalisability of our findings.

390 **5. Conclusions**

391 Behaviour change strategies in a low-intensity intervention can motivate caregivers to improve food
392 hygiene around complementary child feeding. However, the still low handwashing frequency and
393 suboptimal pattern of food hygiene behaviours suggest that without a substantial change in the physical
394 environment (e.g. piped water inside the kitchen), these interventions may not enable caregivers to
395 practice these behaviours consistently. Much remains to be done for a better understanding of complex
396 interlinked factors, including the influence of social networks and norms, the perceived complexity of
397 behaviours, and constraints in terms of cost, effort, and infrastructure, as well as the effectiveness of
398 different intervention approaches that could promote the maintenance of multiple food hygiene
399 behaviours in a resource-poor setting.

Authors' contributions

SG is the principal investigator of the FAARM trial and FHEED study. SG, AAM, and TNH conceived and designed the FHEED study and acquired funding. SS, AAM, and TNH developed all data collection tools with guidance from GG, ASW, and other members of the study team. SS and TNH managed the FHEED field team in Bangladesh and supervised data collection. JLW led the data management of the entire FAARM trial, including the FHEED data, and prepared the initial datasets for this study. SS analysed the data, prepared, and interpreted the results, and wrote the first and subsequent drafts of this article. AAM and GG provided guidance on data analysis and interpretation of results. MR provided general supervisory and management support to the FHEED team in Bangladesh. All authors critically reviewed the manuscript in several steps and approved the final version.

Declaration of interests

We have no competing interests.

Data sharing

A deidentified dataset with the individual participant data that underlie the results reported in this article is available to interested researchers who provide a methodologically sound proposal for use of the data. Data requests with a proposal should be directed to the corresponding author (SS; shafinaz.sobhan@charite.de) and the principal investigator (SG; sabine.gabrysch@charite.de). A data access agreement will need to be signed to gain access to the data. The FAARM trial protocol is available online.

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Tables

Table 1

Definitions of outcome measures.

Primary outcomes

Handwashing with soap

Mother/an adult family members washing at least one hand with soap (including bar soap, liquid soap, powder detergent, and soapy water) and clean water before preparing food and feeding child.

Washing utensils with a cleaning agent

Washing all utensils with cleaning agent (including dishwashing bar, dishwashing liquid, detergent powder) and clean water right before use for food preparation and serving.

Cooking fresh or reheating foods

Cooking family meals (e.g. rice, lentils, vegetables, curry) or a special meal for the child (e.g. khichuri*, porridge) and reheating all stored food before feeding the child or serving it to a family member.

Covering food and store elevated

Storing cooked foods with lids and on a raised shelf/inside a cabinet to protect from flies, insects, and domestic animals.

Secondary outcomes

Any handwashing

Mother/an adult family members was compliant if she adhered to at least one of the two handwashing actions before preparing food and feeding child: (a) washing hands with soap and clean water or (b) washing both hands using only clean water.

Using clean utensils

Mother/an adult family members adhered to at least one of the three utensil cleanliness measures before using them for food preparation and serving: (a) washing utensils with a cleaning agent right before use, (b) using visibly clean utensils after rinsing them thoroughly with clean water or (c) using visibly clean utensils that were stored in a clean, elevated place.

Cleanliness of the kitchen and food preparation area

Kitchen and food preparation area is visibly clean from flies, insects, and animal faeces during observation.

Functional handwashing facility near kitchen †

A fixed or mobile handwashing facility‡ with water and soap (including bar soap, liquid soap, powder detergent, and soapy water) is available inside or near kitchen/food preparation area.

*Khichuri is a soft one-pot dish usually made with rice, lentils, and vegetables and often prepared as complementary food for young children. †Functional handwashing facility was defined following the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) classifications. ‡In our context, a handwashing facility usually refers to tube wells (hand pumps), sinks with tap water, drums or buckets with taps, tippy-taps, jugs, and buckets/containers with mugs or pouring cups.

Table 2

Characteristics of women and households participating in the food hygiene observations in Habiganj District, Sylhet, Bangladesh

	4-month		16-month	
	Intervention (n=185)	Control (n=181)	Intervention (n=107)	Control (n=98)
Women and children's characteristics				
Age of woman, years	23.2 (±3.8)	22.9 (±4.0)	22.5 (±3.5)	22.7 (±3.7)
Education level				
None	29 (16%)	19 (11%)	17 (16%)	15 (15%)
Primary (Grade 1-5)	82 (44%)	91 (50%)	47 (44%)	46 (47%)
Secondary (≥ Grade 6)	74 (40%)	71 (39%)	43 (40%)	37 (38%)
Age of (index) child, months	12.6 (±3.8)	13.3 (±3.6)	10.9 (±2.8)	10.8 (±2.8)
Sex of (index) child, female	85 (46%)	76 (42%)	54 (50%)	45 (46%)
Household characteristics				
Religion, Muslim	146 (79%)	138 (76%)	80 (75%)	68 (69%)
Household members, average	7.2 (±3.1)	6.4 (±2.1)	6.9 (±2.8)	7.6 (±2.9)
Household wealth, quintile *				
Poorest	14 (8%)	29 (16%)	13 (12%)	11 (11%)
Lower	55 (30%)	57 (32%)	24 (23%)	34 (35%)
Middle	46 (25%)	42 (23%)	28 (26%)	23 (23%)
Upper	58 (31%)	46 (25%)	33 (31%)	24 (25%)
Wealthiest	12 (6%)	7 (4%)	9 (8%)	5 (5%)
Household WaSH characteristics				
Improved water source on premises †	94 (51%)	91 (50%)	52 (49%)	43 (44%)
Access to an improved sanitation facility ‡	71 (38%)	74 (41%)	48 (45%)	32 (33%)
Functional handwashing facility near kitchen §	10 (5%)	9 (5%)	8 (7%)	9 (9%)
Reported handwashing with soap				
Before food preparation	70 (38%)	70 (39%)	36 (34%)	42 (43%)
Before child feeding	74 (40%)	54 (30%)	28 (26%)	29 (30%)

Data are frequency (proportion) or mean (±SD). Data on women, household and WASH characteristics were collected during the FAARM baseline survey in 2015. (Index) child's age and sex were obtained from the FAARM birth surveillance record collected within 72 hours of a child's birth. Information on current household members was collected at the time of observation. *An estimation of the national wealth quintile compared to the Bangladesh Demographic and Health Survey 2014 constructed using www.equitytool.org. †Improved water sources include household piped connections, public standpipes, protected tube wells with a platform, protected dug wells or springs and rainwater collection. ‡An improved sanitation facility refers to flush/pour-flush latrines connected to piped sewer systems, septic tank pit latrines, ventilated-improved pit latrines, pit latrines with a slab and composting toilets which are not shared with other households. §Availability of a fixed or mobile facility with water and soap (including bar soap, liquid soap, powder detergent, and soapy water). Access to an improved water source, sanitation and handwashing facilities were defined following the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) classifications. Abbreviations: WaSH: Water, sanitation, and hygiene.

Table 3

Comparative analysis of food hygiene practices between intervention groups, by observation round

	4-month			16-month		
	Intervention	Control	Percentage point difference (95% CI)	Intervention	Control	Percentage point difference (95% CI)
Child feeding						
Number of events observed	191	189	..	79	65	..
Washed hands with soap	23 (12%)	5 (3%)	9.4 (4.2-14.5)	9 (11%)	1 (2%)	9.9 (2.2-17.5)
Washed hands (any) *	44 (23%)	16 (8%)	14.6 (7.4-21.7)	11 (14%)	5 (8%)	6.2 (-3.8-16.2)
Washed utensils with soap	19 (10%)	7 (4%)	6.2 (1.2-11.3)	6 (8%)	2 (3%)	4.5 (-2.7-11.7)
Used clean utensils †	174 (91%)	134 (71%)	20.2 (12.6-27.8)	74 (94%)	63 (97%)	-3.3 (-10.1-3.6)
Preparing food before feeding ‡	183	178	..	54	47	..
Cooked fresh or reheated	107 (58%)	80 (45%)	13.5 (3.3-23.7)	39 (72%)	30 (64%)	8.4 (-9.8-26.6)
Food preparation						
Number of events observed	251	231	..	161	157	..
Washed hands with soap	10 (4%)	2 (1%)	3.1 (0.4-5.8)	10 (6%)	1 (1%)	5.6 (1.6-9.5)
Washed hands (any) *	57 (23%)	29 (13%)	10.2 (3.4-16.9)	39 (24%)	25 (16%)	8.3 (-0.4-17.0)
Washed utensils with soap	14 (6%)	5 (2%)	3.4 (0.0-6.8)	10 (6%)	3 (2%)	4.3 (0.0-8.6)
Used clean utensils †	178 (71%)	132 (57%)	13.8 (5.3-22.3)	151 (94%)	149 (95%)	-1.1 (-6.2-4.0)
Preparing food before serving ‡	227	192	..	129	119	..
Cooked fresh or reheated	175 (77%)	127 (66%)	10.9 (2.3-19.6)	93 (72%)	92 (77%)	-5.2 (-16.0-5.6)
Food storage and kitchen environment						
Number of households observed	185	181	..	107	98	..
Food covered and stored elevated	53 (29%)	69 (38%)	-9.5 (-19.1-0.1)	37 (35%)	15 (15%)	19.3 (7.8-30.8)
No insects or animals around storage	70 (38%)	61 (34%)	4.1 (-5.7-13.9)	33 (31%)	18 (18%)	12.5 (0.8-24.1)
Clean kitchen and food preparation area	37 (20%)	35 (19%)	0.7 (-7.5-8.8)	20 (19%)	9 (9%)	9.5 (0.2-18.8)
Functional handwashing facility §	43 (23%)	29 (16%)	7.2 (-0.9-15.3)	17 (16%)	7 (7%)	8.7 (0.1-17.3)

Data are frequency (proportion) of observed food hygiene practices. *A mother/an adult family member adhered to at least one of the two handwashing actions: (a) washed one hand with soap and clean water or (b) washed both hands using only clean water. †A mother/an adult family member adhered to at least one of the three utensil cleanliness measures: (a) washed utensils with a cleaning agent right before use, (b) used visibly clean utensils after rinsing them thoroughly with clean water or (c) used visibly clean utensils stored in a clean, elevated place. ‡Denominators are smaller as they excluded snacking events. §Availability of a handwashing facility with water and soap inside/near kitchen. Abbreviations: CI: Confidence Interval.

Table 4

Intervention effect on food hygiene practices (4-month and 16-month observations combined)

	Predicted probability (%) *		Odds ratio (95% CI)	p value
	Intervention	Control		
Child feeding †	270	254
Washed hands with soap	11.7	2.4	5.8 (2.2-15.2)	<0.001
Washed hands (any) ‡	20.9	8.4	3.1 (1.6-6.0)	0.001
Washed utensils with soap	9.6	3.2	3.4 (1.3-8.8)	0.013
Used clean utensils §	92.1	77.8	3.8 (1.9-7.7)	<0.001
Cooked fresh or reheated stored food ¶	61.7	48.7	1.8 (1.1-2.8)	0.013
Food preparation and serving †	412	388
Washed hands with soap	4.9	0.8	6.8 (1.9-24.1)	0.003
Washed hands (any) ‡	23.2	13.9	1.9 (1.2-2.9)	0.003
Washed utensils with soap	6.5	2.0	4.2 (1.1-16.1)	0.036
Used clean utensils §	80.6	72.6	1.8 (1.0-3.5)	0.061
Cooked fresh or reheated stored food ¶	75.3	70.6	1.3 (0.8-2.0)	0.241
Food storage †	292	279
Food covered and stored on elevated place	30.3	30.0	1.0 (0.6-1.6)	0.958

*Estimated from mixed-effect logistic regression models using marginal standardisation. All models included a random effect for settlement-level clustering and a fixed effects for observation year. †Total observations (n) in the model. ‡A mother/an adult family member adhered to at least one of the two handwashing actions: (a) washed one hand with soap and clean water or (b) washed both hands using only clean water. §A mother/an adult family member adhered to at least one of the three utensil cleanliness measures: (a) washed utensils with a cleaning agent right before use, (b) used visibly clean utensils after rinsing them thoroughly with clean water, or (c) used visibly clean utensils stored in a clean, elevated place. ¶Observations excluded snacking events (for child feeding, total n: intervention 237, control 225); (for food preparation and serving, total n: intervention 356, control 311). Abbreviations: CI: Confidence Interval.

Figures

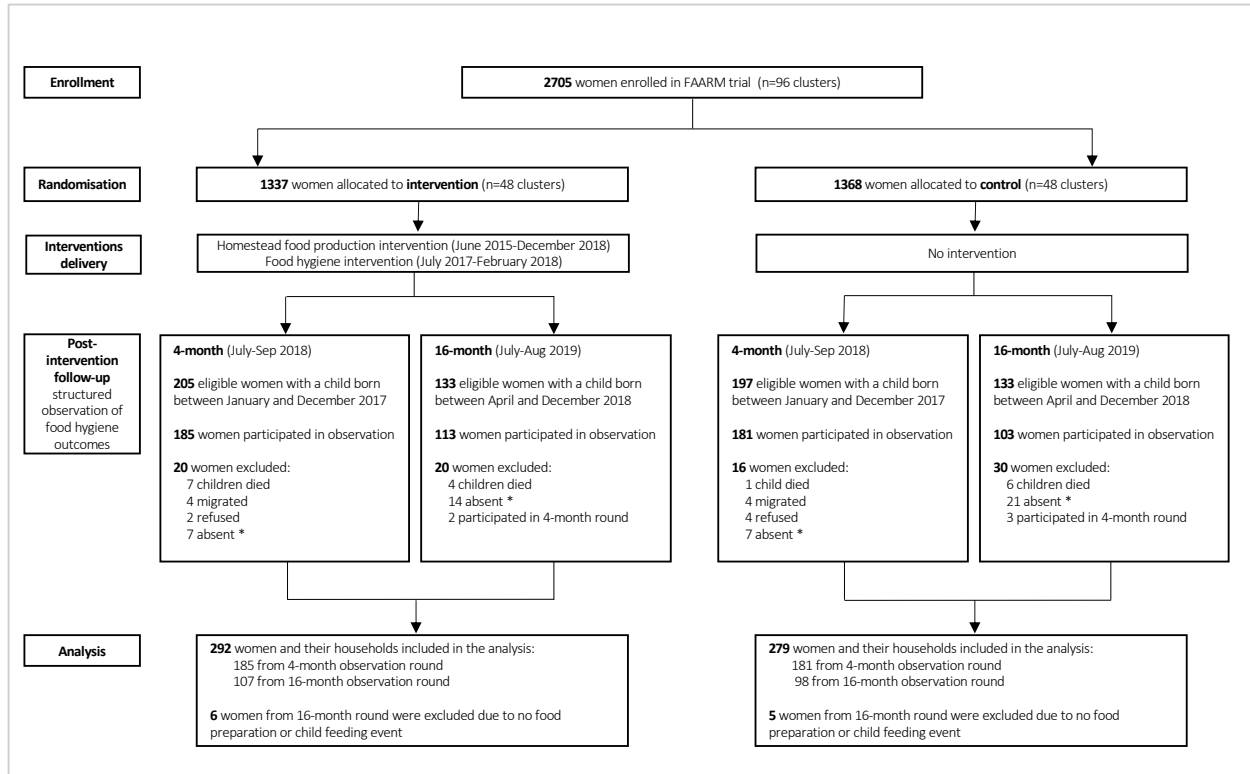


Fig. 1. Study flow diagram. FAARM=Food and Agricultural Approaches to Reducing Malnutrition. * Absent is defined as being unavailable on three visits during the observation round.

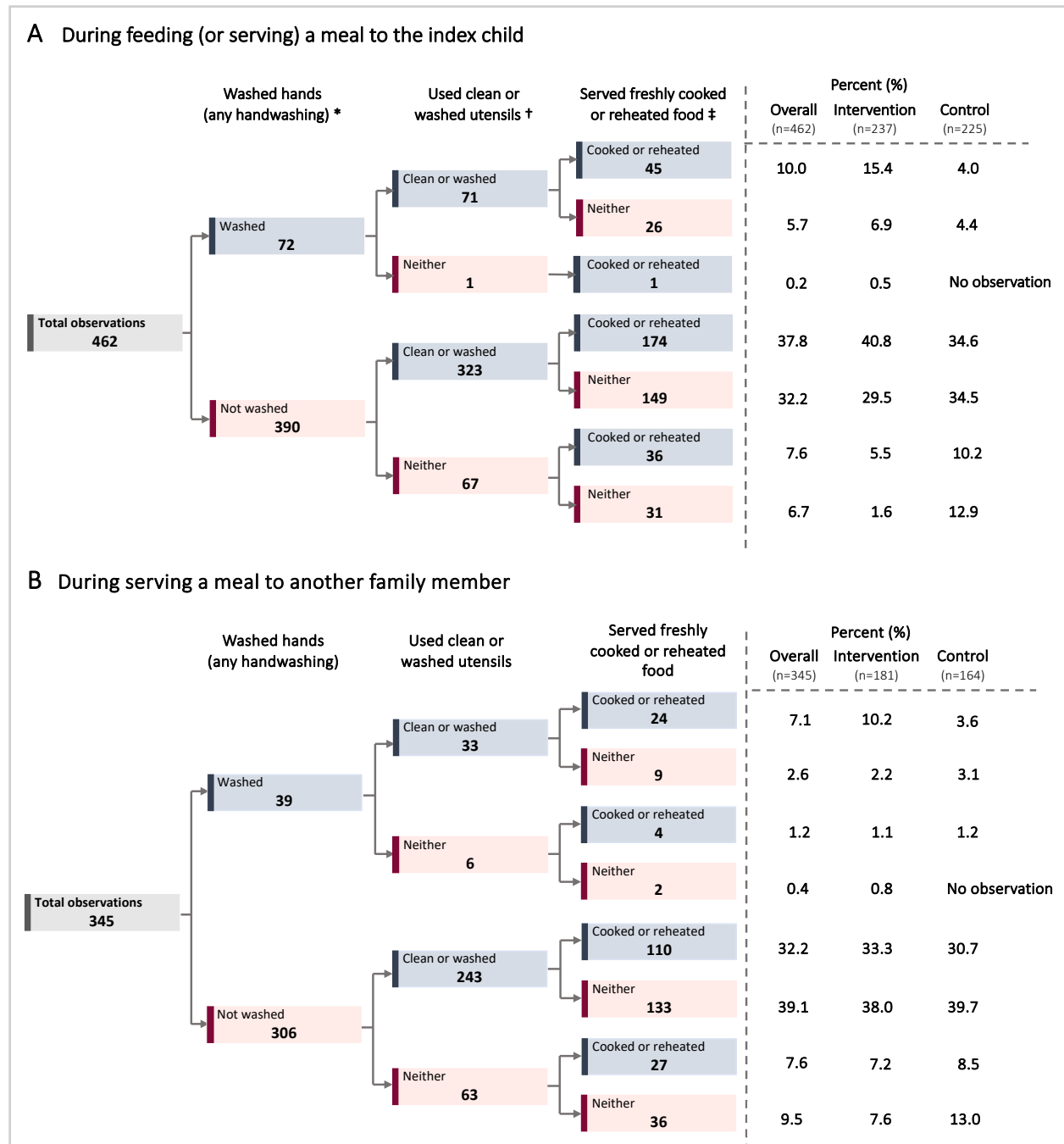


Fig. 2. Practice of multiple food hygiene behaviours during feeding and serving a meal. The panels show the simultaneous practice of multiple food hygiene behaviours during feeding (or serving) a meal to the (index) child aged 6-18 months (A), and during serving a meal to another family member (B), with percentages disaggregated by intervention group. This analysis only includes observations of feeding and serving meals (no snacking events). See Table S6 for the frequency of each combination 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. Mothers also give young children khichuri (a soft one-pot dish usually made with rice, lentils, and vegetables) and porridge as complementary food. *A mother/an adult family member performed at least one of the two handwashing actions: (a) washed one hand with soap and clean water or (b) washed both hands using only clean water. †A mother/an adult family member performed at least one of the three utensil cleanliness measures: (a) washed utensils with a cleaning agent right before use, (b) used visibly clean utensils after rinsing them thoroughly with clean water, or (c) used visibly clean utensils from a clean, elevated place. ‡ A mother/an adult family member adhered to at least one of the two activities before feeding or serving food to family members: (a) served freshly cooked food or (b) reheated all stored food.

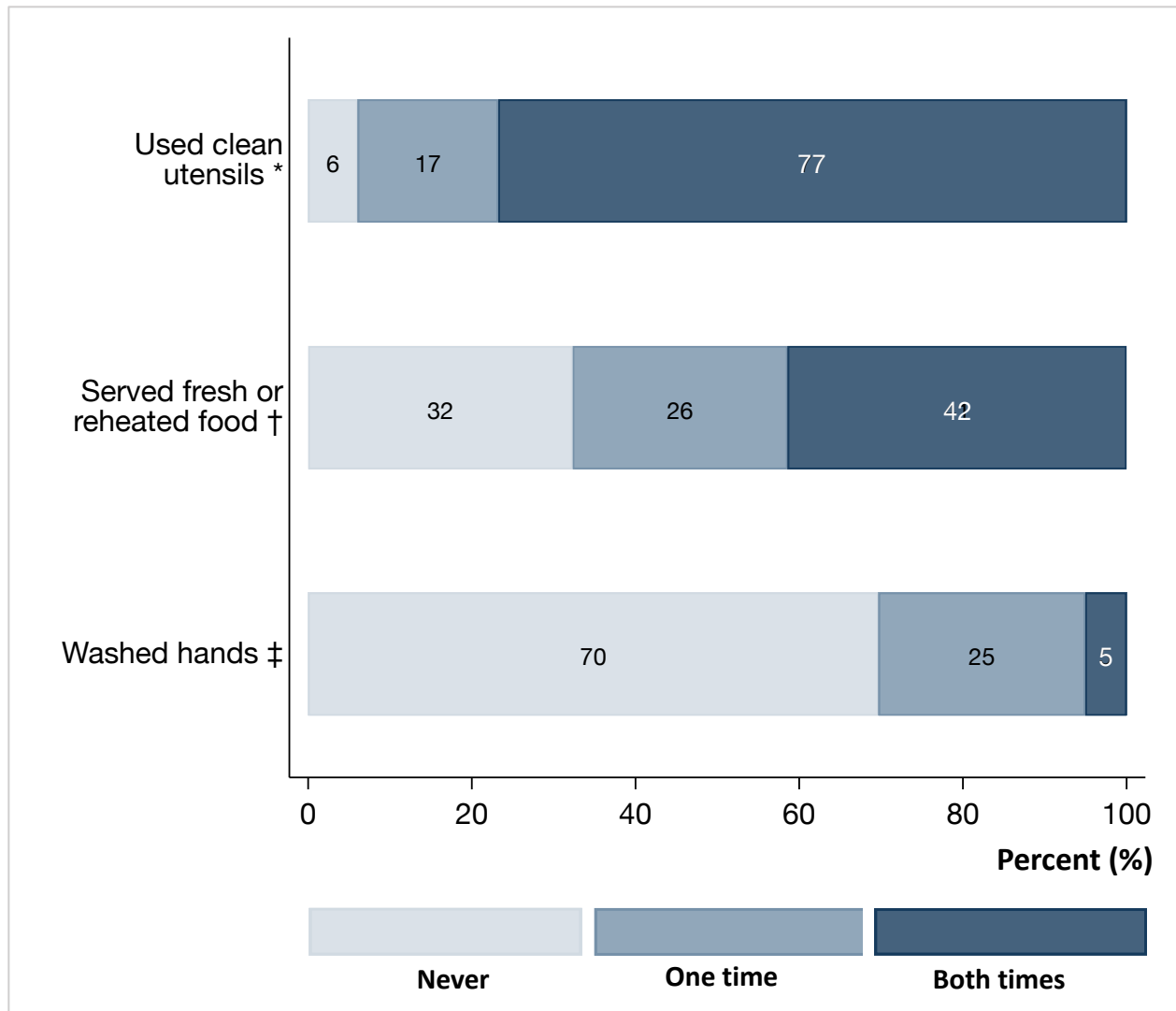


Fig. 3. Consistency in food hygiene practices among mothers in the intervention group. The graph shows the consistency in food hygiene practices among mothers in the intervention group (total n=99) for whom we observed two meal serving events: one for the (index) child aged 6-18 months and one for another family member. A meal refers to a heavier and larger portion of food; in our context, this usually includes rice eaten with vegetables/lentils/fish/meat. Mothers also often give young children khichuri (a soft one-pot dish usually made with rice, lentils, and vegetables) and porridge as complementary food. *Performed at least one of the three utensil cleanliness measures: (a) washed utensils with a cleaning agent right before use, (b) used visibly clean utensils after rinsing them thoroughly with clean water or (c) used visibly clean utensils from a clean, elevated place. †Adhered to at least one of the two activities before feeding or serving food to family members: (a) served freshly cooked food or (b) reheated all stored food. ‡Performed at least one of the two handwashing actions: (a) washed one hand with soap and clean water or (b) washed both hands using only clean water. See Table S7 for the frequency and proportion by intervention group.