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Effectiveness of participatory trainings in improving nutrition knowledge and dietary diversity in rural Bangladesh

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Abstract

Background Despite improvements in recent decades, Bangladesh continues to face malnutrition rates that are among the highest in the world. Consuming a nutrient-rich diverse diet can mitigate the risk of malnutrition-induced health problems. However, consumers often lack knowledge about what constitutes a healthy diet, and often knowledge improvements do not necessarily translate to behavior change due to social norms and access constraints.

Objectives This study evaluates the effectiveness of participatory nutrition education in improving nutrition knowledge and dietary diversity among rural men and women in Bangladesh, investigates whether increased nutrition knowledge leads to changes in dietary behavior, and explores the factors limiting behavior change to aid in the development and implementation of nutrition-sensitive interventions.

Design Three-arm randomized control study. We randomize participants into two participatory workshop interventions or the control group of no training. The first intervention consisted of workshop activities related to selecting a balanced diet. The second intervention included the activities of the first intervention as well as activities related to gender and intrahousehold food allocation.

Participants 358 adult men and women in two districts of Bangladesh.

Results Using pre- and post-intervention survey data and lagged dependent variable regression analyses, we find an 8–11% increase ($p=0.010$) in the comprehensive nutrition knowledge score among workshop attendees, compared to the control. We find larger effects, up to a 30% increase ($p=0.002$), on targeted scores measuring knowledge around food groups and nutrients. Despite increases in knowledge, we find little to no evidence that the workshops impact dietary diversity or that nutrition knowledge translates to behavior change. Our survey responses reveal economic factors such as income and food access limit participants from putting their improved nutrition knowledge into action.

Conclusions Habits, social norms and economic factors such as income and access constraints can prevent participants from putting improved nutrition knowledge into action. Short-term, low-cost participatory workshops may be more effective when coupled with economic incentives, gifts-in-kind, or nutrition-sensitive agriculture.

Keywords Malnutrition, Participatory approaches, Nutrition education, Dietary diversity, Bangladesh

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Introduction

Malnutrition affects one in three people globally [1] and is linked to numerous health problems including predisposition to infection, incidence of overweight or underweight, risk of chronic diseases (e.g., diabetes and heart disease), and micronutrient deficiencies [2]. Despite improvements in recent decades, Bangladesh continues to face malnutrition rates that are among the highest in the world [3]. Anemia burdens 36.7% of Bangladeshi women of reproductive age, and 11.9% of adult men and 10.9% of adult women suffer from diabetes in Bangladesh [4]. Rates of malnutrition are largely driven by a lack of dietary diversity with consumption of rice accounting for approximately 60% of daily per capita calorie intake amongst rural households in 2016 (the year in which the current study was conducted) [5]. Women are particularly affected as they generally consume less protein than men, and traditional hierarchies influence the allocation of food items within the household [6].

Consuming a nutrient-rich diverse diet can mitigate the risk of malnutrition-induced health problems [7–9]. However, consumers often lack knowledge about what constitutes a healthy diet [10]. Spronk et al. (2014), Kullen et al. (2016), Wu et al. (2022), and Sheafer et al. (2023) find that a lower level of nutrition knowledge is related to poor eating habits and unbalanced dietary patterns [11–14]. Even when consumers are equipped with adequate knowledge, food environments, economic status, and social and cultural norms affecting access can impede healthy dietary behaviors [15, 16]. Globally, practitioners have recommended participatory training approaches that engage individuals in experiential learning and participatory discussion to improve nutrition [17–19]. Furthermore, there is a growing body of research that advocates for nutrition messaging and education to be integrated into ongoing agricultural extension and advisory services that address access constraints and reshaping social norms [20, 21].

An example of such programming is the U.S. Agency for International Development (USAID) funded Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES) project. INGENAES' aims included "assist partners in Feed the Future countries… to build more robust, gender-responsive, and nutrition-sensitive institutions, projects and programs…; disseminate gender-appropriate and nutrition-enhancing technologies and access to inputs to improve women's agricultural productivity and enhance household nutrition; identify, test efficacy, and scale proven mechanisms for delivering improved [extension and advisory services] EAS to women farmers; and apply effective, nutrition-sensitive, extension approaches and tools for engaging both men and women" [22]. The INGENEAS initiative partnered with various agencies to develop and deliver projects and programs in eight USAID feed the future countries: Bangladesh, Honduras, Liberia, Malawi, Nepal, Sierra Leone, Tajikistan, Uganda and Zambia. The initiative focused on developing nutrition-sensitive extension programs that addressed needs specific to women and issues of gender equity in these countries, since traditional cultural norms around gender can influence food consumption [22]. The program's aims were implemented through a variety of integrated activities including knowledge transfers through workshops and programming like homestead food production initiatives. In order to deliver "effective, nutrition-sensitive, extension," a rigorous assessment of INGENAES' nutrition programming is required. Thus, this study seeks to evaluate the effectiveness of the two participatory experiential learning activities pertaining to nutrition in the INGENAES participatory workshop guide (S1 File) [23]. A qualitative evaluation highlighting workshop participant testimonials in Nepal suggest INGENAES activities were successful at improving awareness about gendered norms [24]. This study seeks to quantitatively evaluate the efficacy of the nutrition-specific activities in improving nutrition knowledge and dietary diversity, examine whether individual dietary diversity improves among individuals who experience an increase in nutrition knowledge, and to understand the factors that may impede dietary behavior change following changes in knowledge. A better understanding of the factors impeding behavior change provides useful insights to INGENAES administrators designing programming and to extension and advisory services (EAS) implementing the INGENAES' programming and similar integrated programming.

Prior studies suggest that participatory trainings and nutrition-sensitive interventions can improve child and maternal dietary diversity in low-income settings [25–30]; however, few studies investigate the impacts on both adult men and women participants. Nutrition-sensitive interventions address the underlying causes of poor nutrition such as food security and food access, contrasting nutrition-specific interventions which address the immediate determinants of nutrition such as adequate caloric and nutrient intake [31]. Nutrition-sensitive interventions generally facilitate access to services or material inputs (e.g., cash transfers, livelihood programs, and income generating activities) [32]. A variety of participatory trainings and nutrition-sensitive interventions have been implemented across the globe. In Kenya, Boedecker et al. [26] find increases in child dietary diversity when community members engage in the design and implementation of nutrition and farm diversification interventions. Engaging mothers in a "learn by doing" training program [29] and improving women's nutrition

knowledge [30] positively affects child nutrition outcomes in Ethiopia. Participation in community self-help groups improves women and children's dietary diversity in Bihar [28]. Targeted participatory training [27] or intergenerational dialogue with participatory discussion [25] improves the diets of children in Malawi. A meta-analysis of nutrition-sensitive agricultural interventions finds that they have a significant positive impact on the diet diversity scores of children 6–60 months of age [33].

Given its high rate of malnutrition, several interventions have been implemented in Bangladesh. Waid et al. [34] examine the impact a homestead food production program implemented in conjunction with the Food and Agricultural Approaches to Reducing Malnutrition (FAARM) trial through the international nongovernmental organization (NGO) Helen Keller International in the Habiganj District of Bangladesh. During the intervention spanning from 2015 to 2018, groups of approximately 16 women participated in bimonthly courtyard meetings. The authors find that when considering the intervention and postintervention periods together, women receiving the intervention and their children's odds of consuming a minimally diverse diet nearly doubled; they also find that the improvements in dietary diversity persisted after the intervention ended, including during the beginning of the COVID 19 lockdown. In addition to improving dietary diversity, the intervention improved women's empowerment. Using survey data collected 4 months following the conclusion of the project from a subset of participants, Waid et al. [35] find that women who had received the intervention had more agency, had greater ownership of assets, and had more control of income. Baseline data from the same FAARM trail were analyzed to quantify possible pathways between empowerment and dietary diversity [36]; in addition to the direct effects of schooling on dietary diversity, women with post-primary schooling use their voice with their husbands be better able to negotiate better diets. Warren et al. [32] examining the Alive and Thrive initiative find expenditures on eggs and flesh foods increase among participants that receive intensive child and maternal nutrition interventions in the form of interpersonal counseling, community mobilization, and mass media campaigns implemented in Bangladesh; although these women did not receive material inputs, they shifted their time use to additional income generation activities or sold jewelry to purchase more nutritious food items [32]. A study by Harris-Fry et al. [18] aimed to reduce newborn mortality through monthly group meetings spanning 13 months focusing on women's health, nutrition, and family planning in Bangladesh and concludes that participatory methods have the potential to improve women's health and dietary diversity. Kramer [37] evaluates the effectiveness of a short-term nutrition education intervention where some participants also participate in a cooking contest in Bangladesh. The author finds standard classroom nutrition training improves knowledge but does not result in healthier household diets, and the participatory cooking contests generate no additional effects on knowledge or diets.

The current study contributes to the growing body of literature examining interventions designed to improve nutrition in Bangladesh. While the context of this study is similar to Harris-Fry et al. [18] and Kramer [37], we test a short-term nutrition education intervention designed by the INGENAES feed the future initiative that is unique in its use of participatory training methods, its target population of both women and men, and its nesting within integrated nutrition-sensitive programming. The current study also contributes to the literature by exploring the constraints that limit behavior change following changes in knowledge. The examined activities in the participatory workshop guide (S1 File) adhered to Kolb's (1984) cycle of experiential learning [38, 39]. Improving knowledge from educational activities is the first step to changing behavior [40], thus our primary aim of this study is to evaluate impacts of two nutrition-focused INGENEAS training activities on nutrition knowledge using household survey data from Bangladesh. However, as prior research suggests, learning does not necessarily lead to behavior change. "Learning without performance" [41] can occur, because external factors such as economic conditions and social norms impact the ability for individuals to change behavior [41, 42]. In fact, an assessment of the Bangladesh Integrated Nutrition Program (BINP) revealed that nutrition counseling and supplementary feeding improved knowledge but not behavior largely due to resource constraints [43]. Thus, we also examined whether changes in nutrition knowledge from the INGENEAS activities translated into changes in dietary behavior and the economic constraints that may have hindered changes in knowledge translating into changes in dietary behavior.

Methods

This study was approved by the Institutional Review Board (IRB) at the University of Florida, protocol #2016-U-0269 and the University of Delaware, protocol #1589464-1. Data collection was conducted in partnership with the Bangladesh Agricultural University (BAU). The Bureau of Socio-Economic Research and Training (BSERT) at BAU Ethical Standard Review Committee accepted IRB approval from the University of Floridaand waived the need for additional ethics approval. Per IRB approval, verbal consent was obtained from participants. The enumerator read an approved narrative describing

the study objectives, witnessed the verbal consent, and documented the consent in the survey.

The data for this study came from a larger study of nutrition interventions [44] where 1200 adult participants from two districts of Bangladesh were randomly selected from the membership rosters of the Bangladesh Agricultural University Extension Center (BAUEC) in Mymensingh and Shushilan, a local non-government organization, in Barisal. Both organizations provided agricultural extension services to their members. Neither organization had provided nutrition training to their members in our research locations prior to the study. The two organizations differed in the gender composition of their members; BAUEC membership was primarily male (54%), whereas Shushilan membership was primarily female (94%). This study utilized survey data from the sample of 358 participants who were randomly assigned to three arms of the larger study: each of the two participatory workshop interventions and the control group (receiving no interventions). Pre-intervention and post-intervention household survey data were collected for all participants approximately 2 months apart. The survey elicited pre- and post-intervention information about nutrition knowledge, food consumption, participant demographics, household characteristics, and farm characteristics. Data collection for the study spanned August 2016 through January 2017.

Participants assigned to the first intervention attended a 60-min participatory nutrition education workshop. Those assigned to the second intervention attended the same nutrition education workshop and also engaged in an additional 60-min participatory component on the gender dynamics around intra-household allocation of food for a total workshop length of 120 min. Participants assigned to the two intervention groups attended two identical workshops, 1 month apart. The workshop content, which varied by intervention, was repeated, because repetition is a key principle of numerous theories of learning [45] and the design of the larger study required participant attendance at two sessions. The workshops were held at the field offices of the partner agencies (BAUEC and Shushilan), and the facilitator remained the same throughout the study in each respective location. Participants assigned to the intervention groups attended the first workshop one or two business days after s/he completed the pre-intervention survey. The post-intervention survey was administered approximately 2 months after the initial survey for all participants (1 month following the second workshop if the participant was in an intervention group).

The workshops followed the participatory training methods described in the INGENAES workshop facilitator guide (S1 File) [23]. The INGENAES workshop facilitator guide presents a menu of participatory activities designed for use by extension and outreach practitioners in Feed the Future countries. The activities, which can stand alone or be presented in conjunction with one another, are low-cost, short-term interventions designed to be implemented using minimal resources. The trainings were piloted in project countries, one of which was Bangladesh. However, the efficacy of the nutrition activities in the training had not been examined prior to this study. Following Kolb's theory of experiential learning [38, 39] the INGENAES activities incorporated hands-on experience, reflective observation, and group discussion about how the skills could be put into practice in their home lives. The bulk of the INGENEAS activities focused on participatory behavior change communication around gender norms. This study evaluated two of the training activities from the workshop that focused specifically on nutrition. The participants in the first intervention group, hereafter the nutrition education intervention, participated in the "What's Goes on the Plate" activity and participants in second intervention, hereafter the nutrition education with gender component intervention, also participated in the "Who Gets What to Eat" activity in Henderson [24].

For the "What's Goes on the Plate" activity, the facilitator divided participants into small groups of four or five individuals and instructed each group to draw a circle to represent a plate. In a hands-on activity, the group members then drew food items inside the plate that constituted a healthy diet. A representative from each group described the illustration and the facilitator moderated reflective discussion among participants about national dietary recommendations and foods that constitute a healthy diet. Next, the groups engaged in a budgeting activity where they prepared a shopping list for a healthy meal within a given budget. Group members shared their grocery lists and responded to reflective questions. The session concluded with a presentation by the facilitator on national nutrition guidelines and a discussion about putting these skills into practice in their home lives. All participants assigned to either intervention group participated in these activities.

Participants assigned to the second intervention group also participated in the "Who Gets What to Eat" activity in Henderson [24] immediately following the "What's Goes on the Plate" activity. The activity incorporated an interactive role play scenario where each member of the group was assigned a different household member role. The person who played the role of wife distributed food items among the household members in accordance with social and cultural norms. The facilitator then led a discussion about intra-household allocation of food and the importance of gender equity in food allocation where

participants reflected on questions about household members accessing nutritious foods, nutrition requirements for different ages and genders and intra-household allocation of food.

Statistical analysis

Data were analyzed using Stata 15.1 software. Lagged dependent variable (LDV) regression analyses were used to estimate the treatment effects of the participatory workshops on six outcome variables described below: comprehensive nutrition knowledge score, four nutrition knowledge sub-scores, and individual dietary diversity score (IDDS). LDV regression analyses were also used to analyze the effect of changes in nutrition knowledge on dietary behavior.

Participants' pre-intervention and post-intervention nutrition knowledge scores were constructed from their responses to 16 pre-intervention and post-intervention survey questions from the general nutrition knowledge questionnaire (GNKQ) for adults [46]. We selected the GNKQ as a reliable questionnaire that had been adapted and validated for a number of adult populations including the UK [46], Australia [47], Turkey [48], China [49] and Romania [50]. Since the GNKQ had not been validated for use in Bangladesh at the time of the study, we consulted with local nutrition experts at Bangladesh Agricultural University and the Food and Agricultural Organization (FAO) to confirm that the tool was appropriate in the context of Bangladesh and reflected the dietary guidelines in Bangladesh. The GNKQ questions were translated from English to Bengali and then back translated to ensure accuracy of the translation. The questions can be found in the supporting information S2 File. Scoring followed Parmenter and Wardle [46], with one point awarded for each correct response. The comprehensive nutrition knowledge score was calculated as the total number of points received for all correct responses; some questions had multiple correct responses and thus could be awarded multiple points.

In addition to the comprehensive nutrition knowledge score, four sub-scores were constructed based on four question themes: (1) dietary recommendations, (2) food groups and nutrients, (3) diet-related diseases, and (4) child and maternal nutrition. The workshop activities focused primarily on identifying food groups and nutrients that constituted a healthy diet and disseminating information about national nutrition guidelines and dietary recommendations; hence, the workshops were expected to lead to improvements in knowledge in the areas of (1) and (2).

Individual dietary diversity score (IDDS), a validated measure of dietary behavior and nutrition adequacy, was constructed following the FAO guidelines for 24-h IDDS [51]. The proposed number of food groups in the FAO guidelines is 16; however, we followed the aggregation guidelines such that meat included both organ meat and flesh meat [51]. Hence, IDDS was the count of food groups consumed, out of the 15 FAO food groups, in the last 24 h.

We estimated the effects of the two interventions on the outcome variables using a LDV model:

$$y_{it} = \alpha_0 + \alpha_1 y_{i0} + \alpha_2 T_1 + \alpha_3 T_2 + \theta' X_{i0} \quad (1)$$

where y_{it} was the respective outcome variable (nutrition knowledge score, sub-score, or IDDS) of participant i constructed using the post-intervention survey data. y_{i0} was the lagged (pre-intervention) outcome measure (nutrition knowledge score, sub-score, or IDDS, respectively) of participant i constructed from the pre-intervention survey data. The LDV, y_{i0}, controlled for the participant's pre-intervention knowledge or dietary behavior, respectively, which was hypothesized to affect the post-intervention outcome. T_1 was an indicator variable equal to 1 if the participant was assigned to the first intervention group (nutrition education) and 0 otherwise, while T_2 was an indicator variable equal to 1 if the participant was assigned to the second intervention group (nutrition education with gender component) and 0 otherwise. X_{i0} was a vector of covariates measured pre-intervention: participant's district was an indicator equal to 1 if the participant lived in Mymensingh, gender was an indicator variable equal to 1 if the participant was female, age was a continuous variable, completed primary school was an indicator variable equal to 1 if the participant completed primary school, Muslim was an indicator variable equal to 1 if the participant identified as practicing the Muslim religion, the natural log of total land owned was a continuous variable, and low crop diversity was an indicator variable equal to 1 if the participant had low on-farm crop diversity (i.e., reported growing fewer than the sample median number of crops). Standard errors were clustered by workshop participant group (workshop session) for all regressions. Due to the small number of participant workshop groups in the sample (18), inferences were based on the wild cluster bootstrap [52, 53]. In Eq. (1), α_2 was the average treatment effect of participation in the nutrition education intervention on the respective outcome measure, and α_3 was the average treatment effect of participation in the nutrition education with the gender component.

We used a similar LDV model to estimate whether changes in nutrition knowledge were correlated with dietary diversity:

$$d_{it} = \gamma_0 + \gamma_1 d_{i0} + \gamma_2 \Delta knowledge_i + \rho' X_{i0} \quad (2)$$

where d_{it} was equal to IDDS of participant i constructed from post-intervention survey data. The lagged dependent variable d_{i0} was the participant's pre-intervention IDDS. $\Delta knowledge_i$ was a continuous variable equal to the change in participant nutrition knowledge score from pre-intervention to post-intervention. We conducted analyses using the change in comprehensive nutrition knowledge score as well as the change in food groups and nutrients sub-score. X_{i0} contained the covariates defined above.

Because the IDDS is a comprehensive score constructed from the count of food groups consumed, it may mask trade-offs and changes in consumption of specific food groups. Furthermore, analyzing consumption of individual food groups may provide insights about how intra-household food allocation was impacted—an aspect we were unable to directly measure. Thus, we also estimated Eqs. (1) and (2) for each food group; in theses analyses, the dependent variable was an indicator variable that took the value of 1 if the participant consumed that particular food group in the 24 h preceding the survey, and 0 otherwise. We omit cereals, spices, and sugars from this analysis due to the lack of variation; nearly all participants indicated consuming these food groups in both the pre- and post-intervention surveys. Thus, we present the results for the remaining 12 FAO food groups.

Our decision to use lagged dependent variable (LDV) regression analyses stems from a fast-growing literature documenting issues with more traditional difference-in-difference approaches [54, 55]. Specifically, the two-way fixed effects (TWFE) difference-in-difference model requires the parallel trends assumption to hold to obtain unbiased estimates. Alternative approaches, such a LDV regression analysis, provide more efficient and less biased estimates when the assumption does not hold and when there is heterogeneity in treatment effects across groups or time [56]. Several recent studies comparing the LDV to more traditional two-way fixed effect difference-in-difference approaches suggest that LDV are more appropriate in many cases [56–61].

Results

Descriptive statistics of covariates are presented in Table 1. Participants were predominately female, average age 37, with low education and identifying with the Muslim faith. Participants had small landholdings, and about 40% had low on-farm crop diversity, growing fewer than the median number of crops (3). Balance tests of the covariates across intervention groups are presented in Table 2. Participant covariates in the sample were balanced across the nutrition education interventions and control groups, with age being the only statistically significant difference across groups. This imbalance arose by chance, because we did not stratify on age. We controlled for age of the study participant as well as all other covariates in the regression used to estimate treatment effects. Table 3 presents the mean nutrition knowledge scores and IDDS by intervention group and study phase. The pre-intervention sub-scores for dietary recommendations, food group and nutrients, and child and maternal nutrition averaged 5–7 points where participants scored a maximum of 9, 16, and 11 points, respectively. Pre-intervention diet-related disease scores averaged 1.4 points (SD = 0.961), where the highest participant score was 4 points. The comprehensive pre-intervention nutrition knowledge score averaged 19.5 (SD = 5.715) on a scale of 1 to 32 points. The pre-intervention average IDDS of 7 (SD = 4.357) food groups align with other studies reporting national metrics of dietary diversity in rural areas at the time of this study and more recently [6, 62].

T tests

Table 4 presents the results of statistical t tests comparing nutrition knowledge scores and IDDS by intervention

Table 1 Pre-intervention summary statistics of covariates by intervention group

	All (1)		Control (2)		Nutrition Education (3)		Nutrition Education with Gender (4)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Mymensingh	0.55	0.498	0.57	1.332	0.58	1.393	0.51	1.369
Female	0.84	0.372	0.87	0.671	0.81	0.969	0.83	0.977
Age	36.88	12.106	38.53	17.359	34.88	10.162	37.28	15.438
Completed primary school	0.34	0.475	0.33	0.571	0.38	0.781	0.31	0.750
Muslim	0.94	0.240	0.96	0.461	0.93	0.595	0.93	0.707
Log of total land	4.04	1.431	4.00	2.277	3.93	2.766	4.19	2.336
Low on-farm crop diversity	0.43	0.496	0.43	0.715	0.44	0.847	0.42	0.773
Observations	358		117		120		121	

Table 2 Test for balance across covariates by intervention groups

	Control—nutrition education (2–3)		Control—nutrition education with gender (2–4)		Nutrition—nutrition education with gender (3–4)	
	Difference	***P*-value**	**Difference**	***P* value**	**Difference**	***P* value**
Mymensingh	− 0.04	0.971	0.93	0.353	0.97	0.331
Female	1.33	0.184	0.97	0.331	− 0.36	0.717
Age	**2.27**	**0.024**	0.77	0.443	− 1.67	0.096
Completed primary school	− 0.67	0.505	0.32	0.752	0.99	0.322
Muslim	1.05	0.294	0.79	0.430	− 0.27	0.789
Log of total land	0.39	0.700	− 1.03	0.305	− 1.43	0.154
Low on-farm crop diversity	− 0.22	0.825	0.09	0.928	0.32	0.753

Bold font indicates statistical significance at the 5% level

Table 3 Mean nutrition knowledge scores and individual dietary diversity by intervention group and intervention phase

	All (1)		Control (2)		Nutrition Education (3)		Nutrition education with gender (4)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Pre-intervention								
Dietary recommendations sub-score	5.10	1.806	4.97	2.646	5.02	3.035	5.31	2.274
Food groups and nutrients sub-score	6.99	4.357	6.93	5.859	7.15	7.075	6.89	5.927
Diet-related diseases sub-score	1.36	0.961	1.44	1.641	1.23	1.141	1.40	0.924
Child and maternal nutrition sub-score	6.09	2.322	6.21	3.214	6.17	3.388	5.89	3.225
Nutrition knowledge score	19.54	5.715	19.56	7.777	19.56	8.360	19.49	7.169
Individual dietary diversity score	7.24	2.092	7.28	4.450	7.17	4.101	7.26	3.555
Observations	358		117		120		121	
Post-intervention								
Dietary recommendations sub-score	5.07	1.620	5.03	0.151	4.93	0.145	5.27	0.155
Food groups and nutrients sub-score	10.00	4.670	8.45	0.468	11.31	0.377	10.21	0.415
Diet-related diseases sub-score	1.47	0.813	1.33	0.080	1.54	0.073	1.54	0.073
Child and maternal nutrition sub-score	6.91	2.022	7.13	0.200	6.88	0.190	6.74	0.175
Nutrition knowledge score	23.46	5.811	21.94	0.572	24.65	0.460	23.76	0.555
Individual dietary diversity score	7.79	3.110	7.92	0.319	7.68	0.289	7.78	0.262
Observations	347		113		114		120	

as well as differences in outcomes pre- and post-intervention. Participants across intervention and control groups had statistically similar levels of nutrition knowledge prior to the workshop. Post-intervention levels of nutrition knowledge were significantly higher for the those in the intervention groups than those in the control group, but no statistically significant difference existed in post-intervention nutrition knowledge between the two variations of the workshop. The results showed statistically significant post-intervention increases in nutrition knowledge score as well as the food groups and nutrients score and the child and maternal nutrition score for both intervention groups and the control group. Similar to nutrition knowledge, there were no statistically significant differences in pre-intervention IDDS across intervention groups or the control. No statistically significant differences appeared in post-intervention IDDS by intervention. Changes in pre- and post-intervention IDDS were only weakly significant for the control group. Paired *t* test results of differences in post-intervention mean change in nutrition knowledge score by intervention group can be found in S1 Table.

Regression results

Table 5 shows the regression results of Eq. (1). Results for model 1 show that workshop participation improved

Table 4 Differences in mean nutrition knowledge scores and individual dietary diversity by intervention group and study phase

	Comprehensive nutrition knowledge (1)		Dietary recommendations (2)		Food groups and nutrients (3)		Diet related disease (4)		Child and maternal nutrition (5)		Individual dietary diversity score (6)	
	Diff	***P* value**	**Diff**	***P* value**	**Diff**	***P* value**	**Diff**	***P* value**	**Diff**	***P* value**	**Diff**	***P* value**
Pre-intervention												
Nutrition—control	0.01	0.994	0.18	0.857	0.37	0.710	− 1.69	0.093	− 0.15	0.881	− 0.42	0.677
Nutrition with gender—control	− 0.11	0.914	1.41	0.160	− 0.07	0.944	− 0.39	0.701	− 1.11	0.267	− 0.10	0.925
Nutrition—nutrition with gender	0.096	0.924	− 1.25	0.212	0.46	0.644	− 1.45	0.148	0.92	0.360	− 0.34	0.736
Post-intervention												
Nutrition—control	**3.70**	**< 0.001**	− 0.46	0.644	**4.75**	**< 0.001**	1.92	0.056	− 0.93	0.355	− 0.55	0.584
Nutrition with gender—control	**2.29**	**0.023**	1.11	0.269	**2.81**	**0.005**	1.98	0.048	− 1.48	0.141	− 0.35	0.724
Nutrition—nutrition with gender	1.23	0.220	− 1.58	0.115	1.95	0.052	− 0.06	0.949	0.53	0.600	− 0.23	0.816
Pre-intervention vs. post-intervention (Post–Pre)												
Control	**3.04**	**0.003**	0.23	0.818	**2.44**	**0.015**	− 0.93	0.351	**3.12**	**0.002**	1.71	0.089
Nutrition	**6.93**	**< 0.001**	− 0.40	0.693	**7.36**	**< 0.001**	**2.70**	**0.008**	**2.38**	**0.018**	1.51	0.132
Nutrition with gender	**5.88**	**< 0.001**	− 0.17	0.862	**5.98**	**< 0.001**	1.35	0.179	**3.26**	**0.001**	1.62	0.107

Bold font indicates statistical significance at the 5% level

Table 5 Treatment effects on nutrition knowledge scores and individual dietary diversity ($n = 347$)

Variable	Comprehensive nutrition knowledge (1)	Dietary recommendations (2)	Food groups and nutrients (3)	Diet related disease (4)	Child and maternal nutrition (5)	Individual dietary diversity score (6)
Pre-intervention score	0.06 [− 0.092, 0.220]	0.02 [− 0.071, 0.095]	0.01 [− 0.118, 0.152]	0.12** [0.009, 0.235]	0.09* [− 0.006, 0.180]	0.01 [− 0.168, 0.204]
Nutrition education	2.59** [0.693, 4.563]	− 0.11 [− 0.491, 0.269]	2.63*** [1.007, 4.314]	0.21* [− 0.017, 0.456]	− 0.13 [− 0.640, 0.350]	− 0.17 [− 1.185, 0.744]
Nutrition education with gender	1.79* [− 0.277, 4.023]	0.07 [− 0.251, 0.404]	1.69* [− 0.002, 3.239]	0.20* [− 0.037, 0.430]	− 0.16 [− 0.623, 0.304]	0.09 [− 0.978, 1.085]
Mymensingh	− 2.48** [− 4.497, − 0.517]	− 2.40*** [− 2.818, − 1.974]	− 0.93 [− 2.442, 0.418]	− 0.54*** [− 0.767, − 0.333]	1.39*** [0.626, 2.297]	3.45*** [2.413, 4.654]
Female	2.31** [0.045, 4.707]	− 0.06 [− 0.575, 0.395]	0.54 [− 1.264, 2.332]	0.22* [− 0.114, 0.499]	1.53** [0.120, 3.014]	0.53 [− 0.929, 1.933]
Age	− 0.05* [− 0.116, − 0.007]	− 0.01 [− 0.023, 0.006]	− 0.05** [− 0.091, − 0.000]	− 0.01*** [− 0.013, − 0.004]	0.01 [− 0.010, 0.025]	0.01 [− 0.019, 0.039]
Primary school	2.92*** [1.334, 4.524]	0.05] [− 0.431, 0.553	1.90*** [0.832, 3.115]	0.25** [0.037, 0.462]	0.81** [0.135, 1.421]	0.24 [− 0.414, 0.961]
Muslim	− 1.10 [− 10.792, 4.865]	0.06 [− 1.516, 0.874]	− 1.24 [− 9.028, 4.584]	0.04 [− 0.585, 0.643]	0.01 [− 1.644, 1.861]	0.16 [− 1.769, 1.609]
Log of total land	0.48 [− 0.254, 1.231]	0.09 [− 0.057, 0.230]	0.20 [− 0.365, 0.781]	0.07* [− 0.010, 0.156]	0.13* [− 0.014, 0.280]	0.12 [− 0.050, 0.313]
Low on-farm crop diversity	− 0.95 [− 2.244, 0.327]	− 0.33* [− 0.690, 0.030]	− 0.58 [− 1.794, 0.529]	0.15 [− 0.100, 0.376]	− 0.17 [− 0.503, 0.151]	− 0.39 [− 1.366, 0.667]
Constant	20.70*** [13.752, 28.868]	6.35*** [4.985, 7.856]	10.20*** [5.034, 16.268]	1.14*** [0.424, 1.974]	3.40** [1.081, 5.456]	4.53** [1.002, 7.734]
R-squared	0.17	0.48	0.14	0.17	− 0.1324	− 0.17

Estimated coefficients are reported with wild bootstrap 95% confidence intervals in brackets; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

participants' comprehensive nutrition knowledge by 2.6 points (95% CI 0.693, 4.563) (an 11.8% increase on the mean) for the nutrition education intervention and 1.8 points (95% CI − 0.277, 4.023) (an 8.2% increase on the mean) for the nutrition education with gender component intervention. As anticipated, the significance

and magnitude of the effects of the interventions varied by nutrition knowledge sub-score (models 2–5). The impacts of workshop participation on knowledge about dietary recommendations or child and maternal nutrition were not significant. However, among workshop participants there was a statistically significant improvement in knowledge about food groups and nutrients (model 3). Participant scores on food groups and nutrient knowledge increased by 2.63 points (95% CI 1.007, 4.314) (a 31% increase on the mean) as a result of the nutrition education intervention and 1.69 points (95% CI − 0.002, 3.239) (a 20% increase on the mean) for individuals who participated in the nutrition education with gender component intervention. There was also modest evidence that diet-related disease knowledge scores increased among participants in both workshop interventions. Model 6 in Table 5 showed no statistical evidence that participants' dietary diversity improved as a result of the participatory trainings. However, supplementary analyses on the individual food groups showed statistically significant increases in the consumption of other vegetables (95% CI 0.016, 0.200) and fat/oils (95% CI 0.002, 0.060) resulting from participating in the gender and nutrition training (S2 Table); specifically, participants that received the nutrition education with gender training were 11% more likely to consume other vegetables within the past 24h compared to the control group of no training.

In addition to measuring the effects of the training on nutrition knowledge and dietary diversity, we evaluated whether a change in nutrition knowledge impacted dietary diversity (Eq. 2). The results in Table 6 showed marginally significant evidence of an improvement in dietary diversity among those individuals that increased their comprehensive nutrition knowledge score (95% CI − 0.004, 0.083) (model 1). Further analysis of individual food groups shows that this increase in dietary diversity was driven by an increase in fruit consumption among those individuals whose nutrition knowledge score increased; each additional point increase in the knowledge score increased the likelihood of consuming vegetable in the past 24 h by 1% (95% CI 0.002, 0.012) (S3 Table). We then further investigated whether dietary behavior changed among those individuals whose knowledge of food groups and nutrients—the primary focus of the training—increased (model 2, Table 6 and S4 Table). There was no statistical evidence that increased knowledge of food groups and nutrients translated to dietary behavior change. Further analysis of post-intervention survey data revealed that dietary behavior changes were constrained by income. Nearly all (99%) of post-intervention survey respondents, of whom 65% are the primary decision maker of food purchasing and preparation, stated they would spend more money on food if they had a higher income. When asked about variety of food, 81% stated a desire to purchase different types of food if more income was available. In particular, a majority of respondents reported a willingness to purchase higher value, higher nutrient products such as meat, fish, dairy and fruit under a relaxed budget constraint.

Table 6 Impact of changes in nutrition knowledge on adult dietary diversity

Variable	Comprehensive nutrition knowledge score (1)	Food groups and nutrients score (2)
Pre-intervention score	0.02 [− 0.150, 0.202]	0.02 [− 0.152, 0.205]
Change in nutrition knowledge	0.04* [− 0.004, 0.083]	0.01 [− 0.022, 0.052]
Mymensingh	3.59*** [2.585, 4.645]	3.45*** [2.413, 4.560]
Female	0.50 [− 0.898, 1.818]	0.54 [− 0.897, 1.875]
Age	0.01 [− 0.017, 0.037]	0.01 [− 0.018, 0.042]
Completed primary school	0.23 [− 0.446, 0.950]	0.24 [− 0.429, 0.919]
Muslim	0.17 [− 2.237, 3.427]	0.19 [− 1.980, 2.357]
Log of total land	0.12 [− 0.061, 0.325]	0.13 [− 0.049, 0.325]
Low on-farm crop diversity	− 0.38 [− 1.379, 0.632]	− 0.39 [− 1.327, 0.634]
Constant	4.24 [1.162, 6.840]	4.32 [1.416, 6.881]
Observations	347	347
R-squared	0.38	0.37

Estimated coefficients are reported with wild bootstrap 95% confidence intervals in brackets; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Discussion

Our analysis indicates INGENEAS participatory nutrition workshop activities increased nutrition knowledge among men and women who engaged in these activities. Workshop activities related to food groups and dietary recommendations led to improvements in comprehensive nutrition knowledge score and sub-scores pertaining to knowledge about food groups and nutrients as well as diet-related diseases. The effects of the trainings persisted, albeit in lower magnitude, when these nutrition education activities were coupled with an additional role-playing activity on the intrahousehold allocation of food. However, we found no evidence that participation in the INGENEAS participatory nutrition workshops led to improvements in dietary diversity as measured by IDDS. Furthermore, we found improvements in nutrition knowledge led to only marginally statistically significant

impacts on dietary diversity and increased consumption of fruits and fats and oils.

The findings of prior studies that evaluate the effectiveness of participatory nutrition education interventions on nutrition knowledge and dietary behaviors in low-income countries are mixed. While several studies find that participatory trainings improve both knowledge and diets [18, 25–30, 32], other studies find improvements in knowledge only [43, 63–65]. Contradictory findings between this study and these prior studies that find improvements in diet might be due to difference in target populations, methods of analysis, or duration of the interventions. Previous studies that evaluated participatory methods for nutrition education and behavior change in low-income countries have tended to focus on child and maternal nutrition outcomes and relied on quasi-experimental or qualitative approaches [25, 26, 32, 39]. The current study expanded the literature by implementing a randomized control study to measure changes in participant nutrition knowledge and dietary diversity when adult men and women engaged in participatory training activities using a rigorous empirical approach. Our findings suggest that short-term interventions are effective at increasing knowledge; however, changes in knowledge do not necessarily translate into changes in behavior. Our findings align with several prior studies that found nutrition interventions improved knowledge but did not generate shifts toward healthier diets [43, 63–65].

The mixed findings of the aforementioned studies are likely driven by the complexity of human behaviors. Behaviors and the successfulness of efforts to elicit behavior change are influenced not only by knowledge but also by other factors including economic conditions constraining resources, social norms, self-efficacy, structural constraints, and habits [42]. Several behavioral psychology theories, including the theory of reason action, theory of planned behavior, and transtheoretical model, attempt to explain and predict behaviors; these theories postulate that attitudes and beliefs about the benefit or consequences of a behavior interact with beliefs about social norms and external constraints to influence behavior [66]. The nutrition education activities in the studied intervention aimed to change attitudes toward the importance of consuming a healthy diet, while the additional gender component that participants in the second intervention group engaged in sought to change beliefs about social norms. However, these activities did not impact the participants' resource constraints, habits, or environmental factors. Warren et al. [32] suggest that even if an intervention does not offer material inputs, improvements in dietary diversity may still be achieved through shifting time toward income generating activities or liquidating savings (in the form of selling jewelry) to be able to afford more diverse food, or reallocating expenditures toward healthier foods; while we do not find an improvement in dietary diversity, we do find some evidence in shifts in consumption across food groups.

Because many nutrition behaviors are habitual it may be necessary to combine knowledge transfers with behavioral interventions and practical activities that encourage new skills and habits to encourage behavior change [42]. For example, educational sessions with hands-on activities such as identifying healthful foods, shopping, cooking, and gardening increased participants' nutrition knowledge and improved dietary behaviors among low-income women in the U.S. [19]. Even if knowledge is increased and new skills are developed through participatory workshops, the ability to act on knowledge and employ these skills is influenced by other external factors [16, 42]. Particularly in the context of a low-income country, the translation of nutrition knowledge to improved dietary diversity may depend on access to markets and the availability and affordability of healthy foods [67]. Dizon et al. [68] estimated that 53% of the population in Bangladesh spent less on food per household than the cost of dietary recommendations, which indicates that households simply cannot afford nutrient-dense foods. Our survey results suggest that income constraints played an important role in the disconnect between improvements in knowledge and practice. In the larger study from which our data were taken, the researchers [44] removed income and access constraints and found individuals who engaged in the same participatory workshop activities analyzed in the current study consumed more diverse meals at a buffet immediately following the trainings relative to study participants assigned to the control of no interventions. Their positive findings of the effects of the workshops suggest that knowledge can translate to behavior change when access constraints are removed. However, even realized short-term behavior changes such as those observed by Davidson et al. [44] may not be predictive of longer-term behavior as habits are difficult to change.

One approach to alleviate budget constraints in food purchasing decisions is to provide economic assistance through microcredit or cash transfers. In rural China, access to formal microcredit improved child health status and weight [69]. Cash transfer programs increased expenditures on food, calorie consumption and/or food diversity in a number of countries, particularly in Latin America [70]. For example, the conditional cash transfer Programa de Educación, Salud y Alimentación (PROGRESA) improved the acquisition of calories from vegetables and animal products among the rural poor in Mexico [71], and household and community cash

transfers in Indonesia led to increases in children's consumption of protein-rich items like milk and fish [72]. In Bangladesh, cash transfers and food transfers had positive effects on calories consumed and food expenditures [73].

The aforementioned cash transfer programs were standalone transfers that did not include nutrition education. A better practice may be to couple education programs with economic incentives, access to credit, or gifts in-kind that support nutrition messages. For example, in the United States, Supplemental Nutrition Assistance Program (SNAP)-eligible participants consumed 0.5 cups more fruits and vegetables per day after attending interactive nutrition and cooking classes paired with vouchers for use at the farmers market [74]. In Bangladesh, cash transfers combined with nutrition messaging increased the intake of animal source foods which led to improvements in child nutritional outcomes [75].

Furthermore, participatory nutrition trainings could be combined with other initiatives focusing on nutrition-sensitive agriculture such as the promotion of the cultivation of nutritious foods (e.g., homestead food production) to improve access and nutrition [76–81]. However, the evidence is mixed whether increasing farm production diversity improves smallholder diets and nutrition [76, 77]. Sibhatu and Qaim [76] conduct a meta-analysis and find, collectively, a positive but small effect of production diversity on dietary diversity with heterogeneity across interventions and subsamples of participants. As previously discussed, the FAARM trial indicated that the gender-responsive, nutrition-sensitive programming improved both women's diets and empowerment. Iannotti, Cunningham, and Ruel [78] indicate the nearly 20-year-old homestead food production program implemented in Bangladesh by Helen Keller International improved food security for nearly 5 million people. Ahmend et al. [79] examine the impacts of agriculture training alone, nutrition behavior communication change (BCC) alone, combined agriculture training and nutrition BCC, and agriculture training and nutrition BCC combined with gender sensitization on production diversity and diet diversity and quality in rural Bangladesh. The largest improvement in diet occurred when nutrition and agriculture trainings were combined. Similar to our findings, the authors found no significant impact of adding gender sensitization. A cluster randomized controlled trial conducted in Cambodia suggests homestead food production and aquaculture initiative increases consumption of key vitamins and minerals, reducing deficiencies [80]. Also evaluating data from rural Cambodia, Dragojlovic et al. [81] suggest that homestead food production programs are cost-effective; in addition to improving diets, homestead programs may also have a societal monetary benefit due to increased agricultural production. The INGENEAS initiative included both homestead food production and aquacultural programming [22]; examining the effectiveness these programs when coupled with the workshops evaluated in current study is an area for further research.

While this study contributes to the growing body of literature pertaining to the effectiveness of participatory nutrition education by implementing a randomized control study, it is not without limitations. To our knowledge, at the time of this study, no validated nutrition knowledge instrument existed for use with Bangladeshi populations. Thus, we choose the GNKQ due to its validity and reliability in other populations. In addition, we could not directly measure changes in household allocation of food. The impacts of gender-sensitive nutrition education on intrahousehold food allocation is a direction for future research. Furthermore, the lower magnitude of the effects of our combined training may signal that too much information diluted participant retention. Further research should investigate the effectiveness of alternative strategies such as delivering session content across multiple days. Furthermore, our measure of dietary behavior relied on 24-h recall data. In addition to potential issues with recall, using only 1 day of pretreatment and 1 day of posttreatment information could have biased our estimated treatment effects if the participant's consumption on the days surveyed did not adequately represent their typical consumption. To minimize the potential biases, we avoided collecting food consumption data in close proximity to holidays. Furthermore, we followed the FAO guidelines for data collection and calculation of the IDDS [51]. These methods have been validated and are widely used in nutrition studies within similar contexts. Finally, our sample is limited to two districts of Bangladesh as this study targeted impacts on the rural poor. Further research should explore whether nutrition knowledge translates to behavior change for the general population where financial constraints are less severe.

Conclusion

Bangladesh faces malnutrition rates that are among the highest in the world [3] and participatory trainings on nutrition could help alleviate this burden. In this study, we evaluated the impacts of a short-term, low-cost participatory training intervention on nutrition knowledge and dietary diversity. The results confirmed findings of prior studies that participatory nutrition trainings are effective mechanisms to disseminate information and improve nutrition knowledge. Workshop participation increased comprehensive nutrition knowledge by 8–11% and increased knowledge about food groups and nutrients by up to 30%. However, changes in knowledge

did translate into behavior change. We found little to no statistical evidence that dietary diversity changed as a result of the participatory trainings. Habits, social norms and economic factors such as income and access constraints can prevent participants from putting improved nutrition knowledge into action. Our survey data indicated that after attending the trainings, participants had the desire to improve their diets but faced budget constraints in purchasing decisions or lacked access to markets. Future research should seek to evaluate the effectiveness of these workshops and other short-term, low-cost participatory nutrition education interventions when coupled with economic incentives, gifts-in-kind, or nutrition-sensitive agriculture.

Supplementary Information

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Additional file 1.

Additional file 2.

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Author contributions
KD and JK formulated the research question, designed the study, collected data, analyzed the data, and wrote the article. WR managed the data collection and contributed to writing the article.

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Availability of data and materials
The data sets generated and analyzed during the current study are available in the Open Science Framework (OSF) repository, https://osf.io/4ef9m/?view_only=7d528ea1853a4e1a947cb2b8899c0228.

Declarations

Ethics approval and consent to participate
This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the University of Florida Institutional Review Board (protocol #2016-U-0269). Data collection was conducted in partnership with the Bangladesh Agricultural University (BAU). The Bureau of Socio-Economic Research and Training (BSERT) at BAU Ethical Standard Review Committee accepted IRB approval from the University of Florida Institutional Review Board, and waived the need for additional ethics approval. Verbal informed consent was obtained from all subjects. Verbal consent was witnessed and formally recorded.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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