Public Health Nutrition: 24(16), 5514–5523 doi:10.1017/S1368980021003189

Age differences in the impact of a Positive Deviance/Hearth programme on the nutritional status of children in rural Bangladesh

Yunjeong Kim[1], Jaganmay Prajesh Biswas[2], Md. Iqbal Hossain[2], Diane Baik[3], Kathryn Reinsma[3], Shinhye Min[4] and Yunhee Kang[1,*]
[1]Johns Hopkins School of Public Health, 615 N. Wolfe Street, Baltimore, MD 21205, USA: [2]World Vision Bangladesh, Banani, Dhaka, Bangladesh: [3]World Vision International, Monrovia, CA, USA: [4]World Vision Korea, Yeongdeungpo-gu, Seoul, South Korea

Submitted 5 June 2020: Final revision received 6 July 2021: Accepted 2 August 2021: First published online 5 August 2021

Abstract
Objective: To examine the difference in the rehabilitation rate from underweight by child age at enrolment in the Positive Deviance (PD)/Hearth programme.
Design: This secondary data analysis used programme monitoring records of underweight children aged 6–60 months attending a 2-week PD/Hearth session and followed up for 6 months from September 2018 to March 2019. Data were analysed using multilevel mixed-effect regression and Poisson regression with robust variance.
Setting: Rajshahi Division, Bangladesh.
Participants: A total of 5227 underweight (weight-for-age *Z*-score (WAZ) <-2) children attended the PD/Hearth sessions.
Results: From enrolment to 6 months follow-up, the mean WAZ improved from −2·80 to −2·09, and the percentage of underweight children decreased to 54·5 %. Compared to the enrolment age of 6–11 months, the estimated monthly change in WAZ at 6 months of follow-up were 0·05 lower for 12–23 months, 0·06 lower for 24–35 months, and 0·09 lower for 36–60 months of the enrolment age (all $P < 0{\cdot}001$). The probability of rehabilitation at 6 months of follow-up were lower by 16·7 % for 12–23 months (RR = 0·83; 95 % CI 0·77, 0·91), 15·5 % for 24–35 months (RR = 0·84; 95 % CI 0·78, 0·92), and 34·9 % for 36–60 months of the enrolment age (RR = 0·65; 95 % CI 0·59, 0·72), compared to the enrolment age of 6–11 months.
Conclusions: Enrolment in the PD/Hearth programme at a younger age had the advantage of greater rehabilitation from underweight than older age. Our findings provide a better understanding of the successes and failures of the PD/Hearth programme to achieve more sustainable and cost-effective impacts.

Keywords
Positive Deviance/Hearth
Underweight
Bangladesh
Social behaviour change

About 45 % of deaths in children under 5 years of age are attributable to undernutrition in the world[1]. In low- and middle-income countries, undernutrition remains one of the most significant causes of mortality and morbidity amongst children under 5 years of age, contributing to 13 million deaths amongst infants and children every year[2]. Early childhood undernutrition adversely impacts the life courses of children at a physical, psychological, and social level including cognitive development, academic performance, and low productivity[3–6].

The first 1000 d of life – from conception to 2 years of age – is critical to prevent long-term undernutrition[7]. Since the first 2 years of life require a high nutrient intake for physical growth and cognitive development[8], poor nutrition in this period can result in long-term negative consequences in health status, educational performance, and economic achievement[9,10]. Many studies have explored behavioural determinants of child undernutrition in low- and middle-income countries and have found that promoting appropriate complementary feeding practices

*Corresponding author: Email ykang12@jhu.edu

is essential to prevent early childhood undernutrition[11–16]. Handwashing and sanitation are also recognised as key drivers in reducing child undernutrition in developing countries[17].

Positive Deviance/Hearth (PD/Hearth) is a programme involving 2-week group nutrition sessions to improve child nutritional status and caregivers' behaviours on appropriate child feeding and hygiene practices, using locally available low-cost resources[18]. Conventionally, a PD/Hearth programme is comprised of in-depth formative research to identify the major contributing factors to undernutrition and community-based solutions that are used to design contextualised messages. The positive deviance approaches were already discussed in the 1960s when they mentioned the need to pay more attention to the individuals who have better health status than others in the same environments[19]. The concept of 'Hearth', where mothers gather ingredients, cook meals, and feed children, was integrated to develop a community-based nutrition training model[20]. The PD/Hearth programme was later implemented in the early 1990s in Vietnam, where its effectiveness in reducing child undernutrition started to be recognised[21,22]. Most of the previous studies on PD/Hearth programme effectiveness have found a significant reduction in child undernutrition[23–25].

In Bangladesh, 22 % of children under 5 years old are underweight (weight-for-age *Z*-score (WAZ) <-2), 31 % are stunted (length/height-for-age *Z*-score (LAZ/HAZ) <-2), and 8 % are wasted (weight-for-length/height *Z*-score (WHZ/WLZ) <-2)[26]. World Vision Bangladesh (WVB) has implemented large-scale PD/Hearth programmes in the country for more than a decade and enrolled a total of 10 095 children of 6–60 months of age to the PD/Hearth programme (March 2018–December 2020). This large-scale PD/Hearth programme enables revisiting the determining factors related to programme effect, such as enrolment age. Until now, only a few small-scale studies have examined the association between child age and growth in the context of child nutritional programmes and demonstrated the better effect of earlier interventions on growth and overall development[27–30].

Our study provides PD/Hearth programme-specific evidence by leveraging a 6-month weight-based large-scale monitoring data of children who attended the Hearth sessions. We hypothesise that younger age at enrolment in the PD/Hearth programme is associated with greater rehabilitation from underweight status. Thus, this study compared the monthly changes in WAZ and the rehabilitation rates of the child groups of different ages at enrolment for 6 months after the 2-week Hearth sessions.

Methods

Data sources

This secondary data analysis used the monitoring records of a PD/Hearth programme implemented in rural Bangladesh as the primary data source of this study. The PD/Hearth programme was conducted in the three rural Upazillas (subunits of districts in Bangladesh) of Joypurhat, Panchbibi, and Dhamoirhat in the Rajshahi division. These areas are poor, rural Bangladesh communities, with most residents engaged in agriculture practices[31]. According to a household survey in 2018, the prevalence of stunting, underweight, and wasting amongst children 0–59 months of age was 36·2 %, 31·0 %, and 18·2 % in these three areas[32]. Data of a total of 10 095 children who participated in the Hearth sessions from October 2018 to October 2020 were available. For implementation of ease and quality assurance, the Hearth sessions were administered in five cohorts during five different time periods. This study used the data of 5227 children from the first 3 time periods who were underweight at enrolment into the Hearth sessions. The first cohort of the Hearth sessions started in September 2018, the second cohort in November 2018, and the third cohort in March 2019.

PD/Hearth programme

The PD/Hearth programme was implemented as one of the main components of a 2-year Bangladesh Rajshahi Division Maternal and Child Nutrition (BRDMCN) programme (March 2018–December 2020) by WVB and World Vision Korea (WVK) and was funded by Korea International Cooperation Agency (KOICA)[33]. The PD/Hearth programme attempted to rehabilitate underweight children and promote appropriate nutrition and hygiene behaviours amongst caregivers based on WV's PD/Hearth programme implementation manual[34]. The BRDMCN programme team preferentially screened underweight children (WAZ < -2·0) at the ages of 6–36 months living in socio-economically poor households. Due to the absence of interventions that address the nutritional needs of older children, the PD/Hearth programme in the study area enrolled children 37–60 months of age as well to accommodate the demand in the communities.

The PD/Hearth team conducted a situational analysis to identify the children with healthy nutritional status from poor resource households, known as 'Positive Deviant Inquiry (PDI)'. The PDI process was initiated with formative research using activities including focus group discussions, community mapping, household wealth ranking, nutrition screening, and market survey to identify the positive-deviant (PD) households, the major challenges contributing to undernutrition at the community level, and the availability of the community's local food resources. Next, the PD households were asked how they fed their child during the past 24 h and were observed for their child caring and feeding practices[34,35]. During the process, the programme team ascertained how the PD households were overcoming the identified major challenges in terms of their feeding, hygiene, child caring and health-seeking behaviours, and the specific foods used for their children.

The identified foods were further investigated in terms of their market price, nutrient information, availability in the markets, and seasonality in each district.

As a result, the PD foods promoted in the PD/Hearth programme were rice, lentils, seeds of jackfruit, red amaranth, papayas, string beans, seeds of country bean, potatoes, Indian spinach, eggs, soybean oil, green leaf of drumstick, and pumpkins. The menu for children's meals in Hearth sessions was designed to suggest the recommended amount of intake and expected cost for each food (see online Supplemental Table 1). Also, the key PD behaviours included messages around continued breastfeeding, maintaining safe water sources and disposal systems, treating children with acute respiratory infections and diarrhoea at health centres, and knowledge of optimal physical and cognitive development of children.

During the Hearth sessions, caregivers prepared a meal using the identified locally available, low-cost, and micronutrient-dense foods to feed their children. Each caregiver contributed towards the meal by bringing food ingredients, utensils, firewood, and other materials. The caregiver participants were encouraged to continue to practice at home what they learned from the Hearth sessions. Sixty days of multiple micronutrient powder sachets were provided to all child participants on the first day of the sessions to enhance the dietary quality of child participants (see online Supplemental Table 2).

PD/Hearth monitoring system

A monitoring system of the PD/Hearth programme was established by WVB to identify the children who have not gained appropriate weight during and after Hearth sessions[33]. A total of 285 community facilitators oversaw monitoring the nutritional status of the programme children. As PD/Hearth programmes were initially designed to address being underweight and to track weight status as a major programme outcome, measuring other anthropometric indicators (e.g., height or mid-upper arm circumference) was not included[35]. At enrolment, a structured monitoring form was used to record child age, weight, date of birth, sex, immunisations, vitamin A intake in the past 6 months, and deworming. Community facilitators also extracted relevant data from the child's immunisation card. Child weights were measured using weighing scales (model PS240, Beurer/Germany; model GWL-GBWM-003, GETWELL/Bangladesh). First, caregivers were weighed holding their child, and then caregivers were weighed alone. The weight of the caregiver was subtracted from the weight of both the caregiver and child. Child weights were measured during the first day of the Hearth sessions. Next, the child weights were remeasured at 12 d, 1 month, 3 months, and 6 months after the first day of Hearth sessions. For the data at enrolment and 12-d follow-up, weight data were collected in the place of each Hearth session on the first day and last day. For the subsequent follow-ups, the community facilitators visited the participants' households to measure the weight of child participants in their affiliated villages. The monitoring forms were delivered to community facilitator supervisors, project officers, and a WVB Monitoring and Evaluation (M&E) officer. The data were entered and managed using a 2016 version Excel-based PD/Hearth database.

Available variables

In the secondary data from the PD/Hearth programme monitoring, weight in kg and age in months were exported to the Emergency Nutrition Assessment (ENA) for SMART software (version 2011) to calculate the WAZ[36]. The WAZ was used to categorise a child's underweight status based on the WHO Child Growth and Nutrition guidelines[37]. Child participants were classified into four underweight statuses, which were normal (WAZ $\geq$ -1), mild (-2 $\leq$ WAZ < -1), moderately (-3 $\leq$ WAZ < -2), and severely (WAZ < -3) underweight. To generate a binary variable for underweight status, we recategorised the normal weight and mild underweight as non-underweight and moderately and severely underweight as underweight. Child age at enrolment was categorised into four groups: 6–11 months, 12–23 months, 24–35 months, and 36–60 months of age.

Study design and outcomes

Based on the repeatedly assessed weight data, the present study constructed longitudinal cohort data and analysed the changes in outcomes of interest at 6 months. The analysis outcomes were the estimated differences in a monthly change of WAZ at 1 month, 3 months, and 6 months of follow-up, compared to WAZ at enrolment; and the rehabilitation ratio, measured by the probability of rehabilitation to being non-underweight (WAZ $\geq$ -2) from underweight status. For both outcomes, the comparisons were made between the youngest children and the other three groups of older children, using the youngest children as a reference group. All the power estimations were made based on the Type 1 error (α) of 5 % and the actual sample sizes for each age group, which was 654 for 6–11 months of age, 1742 for 12–23 months, 1505 for 24–35 months, and 1326 for 36–60 months. Using the youngest age group as a reference group, amongst any of the comparison age groups, we had a power larger than 0·80 to identify a 0·10 difference in WAZ and 7 % difference in the probability of becoming non-underweight for each of the three older age groups.

Statistical analysis

The data quality was checked using box plots and the quantile function of normal distributions. Values of WAZ < -6 or WAZ > 6 were treated as missing values (n 3 at enrolment, n 3 at 12 d, n 3 at 1 month of follow-up,

https://doi.org/10.1017/S1368980021003189 Published online by Cambridge University Press

n 3 at 3 months of follow-up, and n 2 at 6 months of follow-up). Accordingly, the corresponding underweight status for each missing WAZ was also treated as missing values. The values at the other follow-up times of the children with missing values were retained for further statistical analyses.

A total of 310 children participated in more than one Hearth session. This multiple participation was accounted for in the regression models. For children who participated in multiple sessions, only follow-up data for their first-round attendance were used in the analysis to avoid introducing bias caused by the effects of preceding attendance to the same PD/Hearth programme.

Analysis of variance (ANOVA) and χ^2 tests were conducted to compare nutritional status at enrolment, 12 d, 1 month, 3 months, and 6 months of follow-up between different age groups of child participants. The child characteristics at enrolment, such as age, sex, living location (Dhamoirhat, Joypurhat, and Panchbibi district), vitamin A supplementation, having been immunisation (fully or partially), deworming, and the time of their PD/Hearth participation (first, second, and third cohorts), were explored by the different child age groups.

The changes in the nutritional status of child participants over 6 months were explored using graphical analysis. For continuous outcomes, the changes in mean and distribution of WAZ over time were presented by boxplots. Fractional polynomial prediction plots were used to estimate changes in WAZ over 6 months, stratified by child ages at the enrolment. For dichotomous outcomes, the change in the proportion of children underweight over follow-up time in each age group was examined by bar plots.

For the continuous outcome of WAZ, the multilevel mixed-effects linear regression model was employed to conduct the longitudinal analysis of change in WAZ over time. Three levels were applied to account for the homogeneity between repeated measures within each level. The dataset of repeated measures was set in the hierarchical form, with the repeated anthropometric measures (level 1) nested within child participants (level 2), which are nested in the villages where the children resided (level 3). The interaction terms between follow-up time and age at enrolment were added to estimate the difference in WAZ changes between children groups with different ages at the enrolment. For the fixed-effect covariates, the regression model included follow-up time in months, child age category at enrolment, interaction terms between follow-up time and the child age category, adjusting for age at enrolment, the quadratic terms of age at enrolment, WAZ at enrolment, child sex, living location, and the time of PD/Hearth participation (first, second, and third cohorts). To assess differences in the estimated average monthly changes in WAZ, the unit of follow-up time variable was in months. The random effects comprised the random intercepts at both child subjects and their living location level.

For the dichotomous outcome of being underweight, multivariable Poisson regression with robust variance was used to examine the ratio of the probability of rehabilitation between age groups. The final regression model of the probability of rehabilitation was a function of child age category at enrolment, adjusting for WAZ at enrolment, child sex, living location, and the PD/Hearth cohort in which the child participated. Data management and statistical analysis were performed using Stata 16.0 (Stata Corp.).

Results

A total of 5227 children were enrolled, with the number of child participants slightly decreasing after 12 d (n 5225), 1 month (n 5224), 3 months (n 5200), and 6 months (n 4968) (see online Supplemental Fig. 1). The reasons for loss to follow-up included the following: (1) child age over 60 months (n 191); (2) child death (n 4); (3) child migrated or left the village (n 15); (4) child admitted into the hospital (n 4); (5) contact to mother lost (n 16); and (6) reasons unknown (n 29).

The baseline characteristics were explored by child age groups (Table 1). The composition within each age group showed no significant difference between the age groups regarding child sex and living location (see online Supplemental Fig. 2). Older children groups had higher percentages of vitamin A supplementation compared to the younger groups ($P < 0.001$). The statuses of immunisations and deworming were explored only amongst the two older children groups over the first 24 months, for which full immunisation and deworming are expected. No significant difference was found between children groups of 24–35 months and 36–60 months in terms of immunisation and deworming.

The mean WAZ of child participants showed the overall nutritional rehabilitation throughout the follow-up time. The mean WAZ (SD) of all participants increased by 0·71 from –2·80 (0·64) at the time of enrolment to –2·09 (0·92) after 6 months of follow-up (Fig. 1(a)). Also, the prevalence of being underweight decreased from 100 % to 54·5 % after 6 months of follow-up (Fig. 1(b)). The prevalence of being underweight stagnated as it came to the last follow-up, especially amongst child groups aged 12–23, 24–35, and 36–60 months (Fig. 2). The mean WAZ had no significant difference between age groups at enrolment and improved over follow-up time for all age groups (Table 2). The WAZ increased most rapidly in the youngest group, compared to three older groups, between all follow-up times (Fig. 3).

In the multilevel mixed-effect linear regression analysis, older enrolment age was associated with a lower rehabilitation rate of WAZ at all measurement times, and the differences in the rehabilitation rate across the different enrolment ages became attenuated over the follow-up time (Table 3). At 1 month of follow-up, compared to children

Table 1 Characteristics of the PD/Hearth child participants at enrolment (*n* 5227)

	Total (*n*)	Child age				
		6–11 months‡	12–23 months	24–35 months	36–60 months	
		n 654	*n* 1742	*n* 1505	*n* 1326	
	n 5227	%	%	%	%	*P**
Sex						
Male	2571	47·86	50·57	49·97	47·13	0·221
Female	2656	52·14	49·43	50·03	52·87	
District						
Dhamoirhat	1561	36·39	29·91	28·31	28·36	0·011
Joypurhat	1840	32·11	34·67	36·54	35·90	
Panchbibi	1826	31·50	35·42	35·15	35·75	
Vitamin A supplementation						
Yes	5136	92·81	98·68	99·20	99·32	<0·001
No	91	7·19	1·32	0·80	0·68	
Immunisation (*n* 2831)†						
Full	2788	N/A	N/A	98·74	98·19	0·235
Non or partial	43	N/A	N/A	1·26	1·81	
Deworming (*n* 2831)‡						
Yes	2818	N/A	N/A	99·47	99·62	0·544
No	13	N/A	N/A	0·53	0·38	
PD/Hearth cohort§						
First	2092	49·08	52·87	45·85	12·07	<0·001
Second	1860	30·43	25·77	30·03	57·32	
Third	1275	20·49	21·35	24·12	30·62	

*The statistical significance of difference between groups was tested by χ^2 test.
†The percentages of immunisation and deworming for children aged 6–11 months and 12–23 months are not applicable as full immunisation and deworming are expected only for children over 24 months old.
‡Out of 654 children, a total of 19 children were aged 5·0–5·9 months.
§For the first cohort of the Hearth sessions, the data collection started in September 2018 for enrolment and was completed in March 2019. The data collection of the second cohort was conducted from November 2018 to May 2019, and the data collection of the third cohort was conducted from March 2019 to October 2019.

enrolled at 6–11 months of age, the estimated monthly improvements in WAZ were 0·14 lower for 12–23 months, 0·23 lower for 24–35 months, and 0·30 lower for 36–60 months aged children (all $P < 0·001$). At 3 months of follow-up, the estimated monthly rehabilitation rates were 0·06 lower for 12–23 months, 0·10 lower for 24–35 months, and 0·14 lower for 36–60 months of age in WAZ, compared to the enrolment age of 6–11 months (all $P < 0·001$). At 6 months of follow-up, the estimated monthly rehabilitation rates were 0·05 lower for 12–23 months, 0·06 lower for 24–35 months, and 0·09 lower for 36–60 months in WAZ, compared to the enrolment age of 6–11 months (all $P < 0·001$).

The multivariable Poisson regression with robust variance showed that the probability of rehabilitation to non-underweight status at 6 months after the PD/Hearth participation was highest in the 6–11 months old group and lowest in the 36–60 months child group (Table 4). The probability of rehabilitation was similar in the 12–23 months and 24–35 months of age group. Compared to the youngest children (6–11 months of age), the probability of rehabilitation was 16·7 % lower amongst children aged 12–23 months (RR = 0·83; 95 % CI 0·77, 0·91), 15·5 % lower amongst children aged 24–35 months (RR = 0·84; 95 % CI 0·78, 0·92), and was 34·9% lower amongst children aged 36–60 months (RR = 0·65; 95 % CI 0·59, 0·72).

Discussion

Using the secondary data of monitoring records from the PD/Hearth programme in rural Bangladesh, our study showed the PD/Hearth programme led to an increase of 0·71 in the mean WAZ and a decrease of 45·5 % in the prevalence of being underweight amongst child participants at 6 months of follow-up and indicated that the programme's impact was differential based on the child's age. The study focused on the association between child age at enrolment, the rehabilitation rates of WAZ, and the rehabilitation ratio from underweight status at enrolment. Significant associations were found between the younger child age groups at programme enrolment and higher monthly increases in WAZ. These associations were strongest during the first month of follow-up and attenuated over time. The change to non-underweight status (WAZ ≥ -2) after participating in the Hearth sessions was observed least frequently amongst the oldest child age group. This result suggests that children who received a nutritional intervention from the PD/Hearth programme at a younger age are more successful in making nutritional improvements.

The impact of the PD/Hearth programme on reducing child undernutrition has been positive but mixed due to various study designs that have been modified according to their context[38]. A randomised controlled trial that

https://doi.org/10.1017/S1368980021003189 Published online by Cambridge University Press

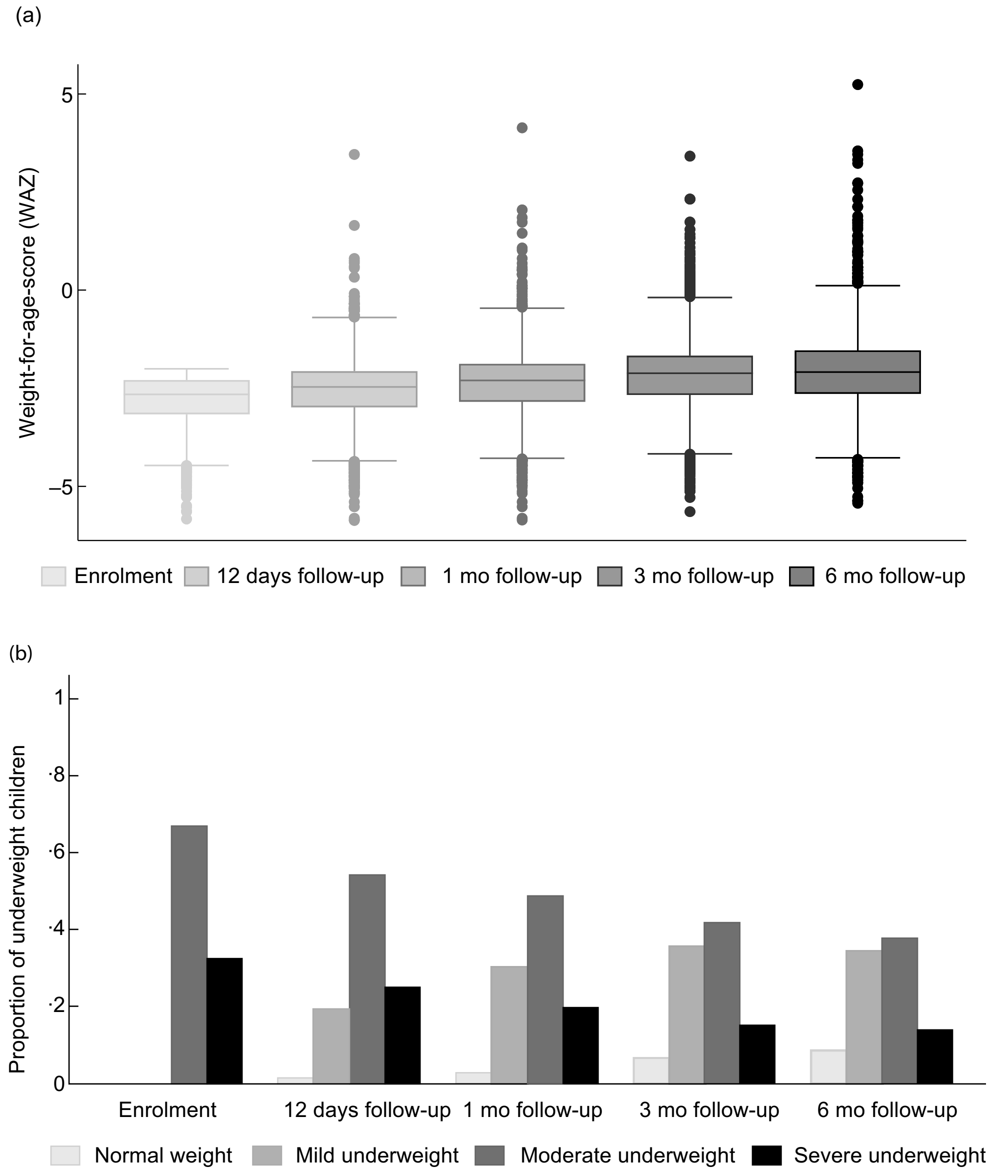

Fig. 1 Nutritional status of child participants over the 6 months of follow-up (*n* 5227). (a) Weight-for-age *Z*-score (WAZ). (b) Percentage of participants by underweight severity levels (Normal: $-1 \leq$ WAZ; Mild underweight: $-2 \leq$ WAZ < -1; Moderate underweight: $-3 \leq$ WAZ < -2; Severe underweight: WAZ < -3)

assessed the impact of a PD/Hearth programme (*n* 179) in rural Malawi reported that the PD/Hearth model reduced WLZ and WAZ by 0·85 and 0·73 amongst underweight children aged <2 years during the 21 d of PD/Hearth period[39]. A cluster randomised trial in Ethiopia that examined the effectiveness of the 2-week PD/Hearth modified approach demonstrated that the monthly growth amongst children 6–24 months of age in the intervention area was 0·02 higher in LAZ; 0·03 higher in WAZ; and 0·04 higher in WLZ, compared to children in the control area during 12 months of the follow-up period[23]. A quasi-experimental study to assess the impact of a 12-d PD/Hearth programme in Ecuador found that the PD/Hearth children aged <2 years had a 0·17 higher increase in WAZ compared to the control group and a decrease from 30·4 % to 23·7 % in the prevalence of being underweight at the 6 months of follow-up[24]. Despite the limitation of not having a control group and including children older than 36 months of age, our PD/Hearth programme in rural Bangladesh led to a notable improvement in WAZ of 0·71 and a reduction in underweight prevalence by 45·5 % at 6 months of follow-up.

On the other hand, some studies found no significant impact of the PD/Hearth programme. A non-randomised cross-sectional study in Rwanda, which compared children who had older siblings participating in the PD/Hearth to those who did not, found no difference in the percentage of underweight status (WAZ < -2) between the intervention and control groups[40]. Another randomised trial, which

https://doi.org/10.1017/S1368980021003189 Published online by Cambridge University Press

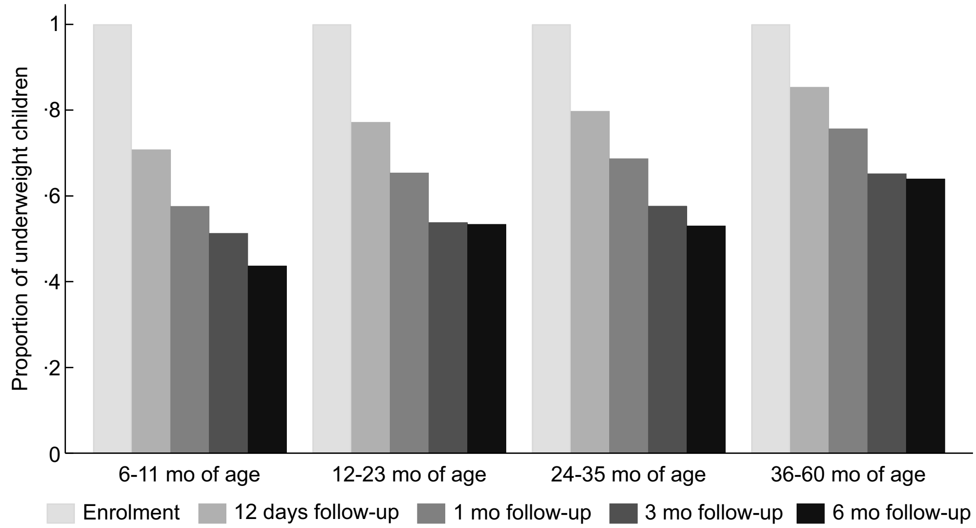

Fig. 2 Proportion of underweight children over 6 months of follow-up by enrolment age (*n* 5227)

Table 2 Nutritional status at enrolment, 12 d, 1 month, 3 months, and 6 months of follow-up amongst the PD/Hearth participants (*n* 5227)

	Child age								
	6–11 months		12–23 months		23–35 months		36–60 months		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P**
Weight-for-age *Z*-score (WAZ)									
At enrolment	−2·83	0·69	−2·80	0·65	−2·79	0·64	−2·80	0·60	0·778
12 d follow-up	−2·44	0·91	−2·52	0·79	−2·55	0·76	−2·63	0·65	<0·001
1 month follow-up	−2·19	0·94	−2·31	0·87	−2·39	0·76	−2·47	0·67	<0·001
3 months follow-up	−1·95	1·03	−2·11	0·88	−2·20	0·80	−2·33	0·70	<0·001
6 months follow-up	−1·76	1·19	−2·05	0·94	−2·12	0·83	−2·27	0·73	<0·001
Underweight (WAZ < -2)									
At enrolment									
%	100·0		100·0		100·0		100·0		–
12 d follow-up									
%	70·8		77·2		79·8		85·4		<0·001
1 month follow-up									
%	57·6		65·4		68·7		75·7		<0·001
3 months follow-up									
%	51·3		53·8		57·7		65·2		<0·001
6 months follow-up									
%	43·7		53·4		53·1		64·0		<0·001

*The statistical significance of the difference between the child age groups were tested by χ^2 test for categorical variables and one-way ANOVA for continuous variables.

compared an intervention group who received the PD/Hearth nutrition programme to a control group who had no intervention, also found no improvement in nutritional outcomes[28].

The greater rehabilitation after the Hearth sessions observed amongst younger children in the present study is possibly related to several factors. First, caregivers may pay more attention when their kids are younger. Caregivers with younger underweight children may be more likely to practice the feeding behaviour learned from the Hearth sessions. Second, the meals prepared in the Hearth sessions might be better suited for children <24 months of age as a semi-solid complementary food[41]. These meals may not be providing enough nutrients to older children as they did to younger ones.

The first 1000 d of life, including pregnancy and the child's first 2 years, are widely accepted as a critical period for the healthy growth of children[7,8]. The importance of early nutritional interventions can explain the differences in the rehabilitation rate and ratio of probability of rehabilitation between child age groups in our study. The finding that younger children had greater rehabilitation from underweight status is consistent with previous studies, which showed that earlier interventions in childhood are more effective for nutritional growth and overall development. One cluster randomised trial compared two maternal

Public Health Nutrition

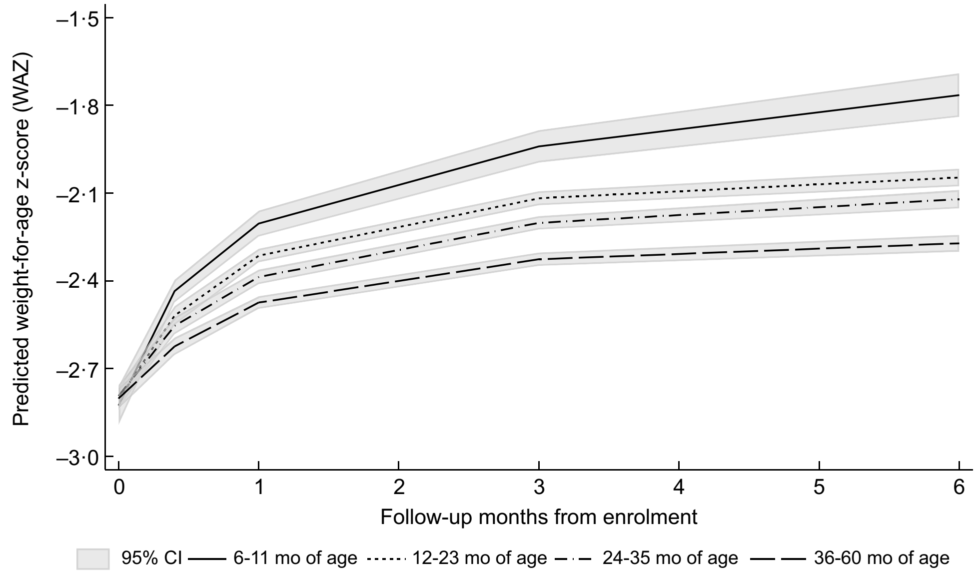

Fig. 3 Estimated weight-for-age *Z*-score (WAZ) change of child participants over 6 months of follow-up by age at enrolment (*n* 5277): Fractional polynomial fitted plot with 95 % confidential intervals was used to estimate the relationship between follow-up months and WAZ of child participants

Table 3 Differences in the estimated monthly change of WAZ between children with older enrolment age (12–23 months, 24–35 months, and 36–60 months) and children enrolled at 6–11 months of age in the Positive Deviant (PD)/Hearth programme (*n* 5227)

	Difference in estimated monthly change of weight-for-age *Z*-score (WAZ)*		
	β		P
1 month follow-up			
(Ref: 6–11 months)	–		–
12–23 months	−0·140	0·026	<0·001
24–35 months	−0·227	0·027	<0·001
36–60 months	−0·301	0·027	<0·001
3 months follow-up			
(Ref: 6–11 months)	–		–
12–23 months	−0·063	0·010	<0·001
24–35 months	−0·095	0·010	<0·001
36–60 months	−0·136	0·010	<0·001
6 months follow-up			
(Ref: 6–11 months)	–		–
12–23 months	−0·052	0·006	<0·001
24–35 months	−0·064	0·006	<0·001
36–60 months	−0·090	0·006	<0·001

*Multilevel mixed-effects model estimated the differences in monthly change in nutritional outcome, adjusting for age in months at enrolment, the quadratic terms of age in months at enrolment, WAZ at enrolment, child sex, child living location, and PD/Hearth cohorts in which children participated; and the time variable in months was used in order to estimate average monthly change in WAZ and difference between enrolment age groups.

Table 4 Rehabilitation ratio between children with older enrolment age (12–23 months, 24–35 months, and 36–60 months) and children enrolled at 6–11 months of age in the Positive Deviant (PD)/Hearth programme (*n* 5227)

	Rehabilitation ratio* (RR)	*P*	95 % CI
(Ref: 6–11 months)	1·000	–	–
12–23 months	0·833	<0·001	0·766, 0·906
24–35 months	0·845	<0·001	0·776, 0·919
36–60 months	0·651	<0·001	0·588, 0·721

*Multivariable Poisson regression model estimated the ratio of probability of rehabilitation to non-underweight status, adjusting for WAZ at enrolment, child sex, child living location, and the time of PD/Hearth participation.

and child nutrition programmes, which offered similar services but have different age eligibility criteria, between baseline and 3 years later[27]. After 3 years, the preventive programme targeting children aged 6–23 months had 0·14 higher in HAZ, 0·24 higher in WAZ, and 0·24 higher in WLZ than the recuperative programme targeting children aged 6–60 months. The Community Empowerment Nutrition Programme (CENP) study in Vietnam found that younger children at baseline had significantly better growth in WAZ than older children[28]. Another supplementary feeding programme in rural Guatemala reported that programme impacts on weight gain were modified by age; more weight gain in the first year of life was found than the second year of life; and no significant improvement amongst children between 3 and 7 years of age[30]. In a cluster randomised trial in India involving an educational intervention to promote adequate complementary feeding practices, a significant increase in height was only found amongst children aged 6–12 months, compared to children aged >12 months[29].

The strengths of our study included the use of a large sample size and an advanced regression model incorporating longitudinal cohort data with repeated measurements. Also, the repeated anthropometric measurements up to 6 months of follow-up allowed for long-term analysis of changes in the PD/Hearth participants' growth. The WV's

https://doi.org/10.1017/S1368980021003189 Published online by Cambridge University Press

PD/Hearth programme in Bangladesh was one of the largest scale PD/Hearth programmes, thus our study gained a high statistical power to detect statically significant differences in outcomes using high observation numbers.

Our study had several limitations. First, the current study design was not able to demonstrate a causal inference between the enrolment age of PD/Hearth programme and the change in the nutritional status of children. Future research using a randomised trial design involving children who are not exposed to a PD/Hearth intervention will help confirm the effect-modifying role of child age on the nutritional improvement of the PD/Hearth participants. Second, we had an insufficient set of measured confounding variables, such as socioeconomic factors, because regular programme monitoring data were used, which only collected the weight data of the programme participants. Since the monitoring activities were mainly planned for the beneficiary support, not for the research purpose, additional data collection was discouraged not to make a burden of programme implementation. Third, our study might include measurement errors caused by the lack of standardised measurement methods amongst the 285 community facilitators. Random errors in weight measurement might have been caused by different ways of reading scales and affected the quality of *Z*-scores. Lastly, the PD/Hearth children might be exposed to other types of interventions, such as asset distribution and nutrition education at the village level, which were implemented by the WVB project team. However, the PD/Hearth monitoring data did not include the involvement in and frequency of other interventions for the participants, which could influence the nutritional status of the study children.

This study provides evidence for improvement in weight for age of PD/Hearth child participants in rural Bangladesh until 6 months after programme discharge with an in-depth understanding of the effect of age at enrolment to the PD/Hearth programme. Our results suggest that younger children will benefit from greater rehabilitation from underweight status than older children. The target age of the PD/Hearth programme, according to the guideline, is younger than 36 months[34]. During the implementation of the BRDMCN programme; however, the age range of the actual child participants was expanded to 6–60 months of age to accommodate demands from the community. Based on our findings, we suggest that PD/Hearth be implemented in accordance with the original age criteria for enrolment to target younger children (i.e., <6–36 months of age) and achieve more substantial child nutritional improvement in the community. Also, when the PD/Hearth programme includes older children for contextual purposes, it requires a flexible interpretation to account for the size of the programme's impact potentially appearing smaller due to the older age of the child participants. Therefore, our findings will help the programme practitioners and community to have a better understanding of the success and failure of the PD/Hearth programme in connection with child age and to achieve more sustainable and cost-effective impacts.

Acknowledgements

Acknowledgements: All authors thank all staff at Joyphurhat project office, World Vision Bangladesh, for kindly providing detailed information. We also thank Bipasha Dutta, World Vision Bangladesh, for her administrative support to this research. We acknowledge World Vision Korea for communication with World Vision partners and providing administrative support during field visits. We appreciate Anna Marie Young and Alec Aron's kind editing support. *Financial support:* This research was kindly supported by World Vision Bangladesh (WVB), Dhaka, Bangladesh; the Korea International Cooperation Agency (KOICA), Sungnam-si, South Korea; World Vision Korea (WVK), Seoul, South Korea. *Conflict of interest:* The authors had no conflict of interest related to the study. *Authorship:* Y.K. and Y.K. contributed to the study design. J.P.B. and M.I.H. carried out data collection. Y.K. conducted data analysis and wrote the draft version of the article. J.P.B, M.I.H., D.B., K.R., S.M., and Y.K. contributed content and edits to the manuscript. All authors read and approved the final manuscript. *Ethics of human subject participation:* Verbal consent for the programme participation and weight measurement of children was obtained from all participants and witnessed and formally recorded by World Vision Bangladesh. The current study involved secondary analysis of existing, de-identified data to examine the impact of the Positive Deviance/Hearth programme on recovery from underweight in Bangladesh. Thus, the present study was deemed to be exempt from IRB review of the Johns Hopkins Bloomberg School of Public Health, MD, USA.

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021003189

References

1. UN-IGME (2019) *Levels & Trends in Child Mortality: Report 2019, Estimates Developed by the United Nations Inter-Agency Group for Child Mortality Estimation*. New York: United Nations Children's Fund.
2. Adepoju AA & Allen S (2019) Malnutrition in developing countries: nutrition disorders, a leading cause of ill health in the world today. *Paediatr Child Health* **29**, 394–400.
3. Worku BN, Abessa TG, Wondafrash M *et al.* (2018) The relationship of undernutrition/psychosocial factors and developmental outcomes of children in extreme poverty in Ethiopia. *BMC Pediatr* **18**, 45.

4. Asmare B, Taddele M, Berihun S *et al.* (2018) Nutritional status and correlation with academic performance among primary school children, northwest Ethiopia. *BMC Res Notes* **11**, 805.
5. Prado EL & Dewey KG (2014) Nutrition and brain development in early life. *Nutr Rev* **72**, 267–284.
6. Kesari KK, Handa R & Prasad R (2010) Effect of undernutrition on cognitive development of children. *Int J Food Saf Nutr Public Health* **3**, 133–148.
7. Black RE, Alderman H, Bhutta ZA *et al.* (2013) Maternal and child nutrition: building momentum for impact. *Lancet* **382**, 372–375.
8. Schwarzenberg SJ, Georgieff MK & Committee on Nutrition (2018) Advocacy for improving nutrition in the first 1000 d to support childhood development and adult health. *Pediatrics* **141**, e20173716.
9. Martorell R (2017) Improved nutrition in the first 1000 d and adult human capital and health. *Am J Hum Biol* **29**, e22952.
10. Victora CG, Adair L, Fall C *et al.* (2008) Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* **371**, 340–357.
11. Amare ZY, Ahmed ME & Mehari AB (2019) Determinants of nutritional status among children under age 5 in Ethiopia: further analysis of the 2016 Ethiopia demographic and health survey. *Global Health* **15**, 62.
12. Aboud FE & Singla DR (2012) Challenges to changing health behaviors in developing countries: a critical overview. *Soc Sci Med* **75**, 589–594.
13. Sunil TS (2009) Effects of socio-economic and behavioural factors on childhood malnutrition in Yemen. *Matern Child Nutr* **5**, 251–259.
14. Walters CN, Rakotomanana H, Komakech JJ *et al.* (2019) Maternal determinants of optimal breastfeeding and complementary feeding and their association with child undernutrition in Malawi (2015–2016). *BMC Public Health* **19**, 1503.
15. Scherbaum V & Srour ML (2016) The role of breastfeeding in the prevention of childhood malnutrition. *World Rev Nutr Diet* **115**, 82–97.
16. Bhutta ZA, Das JK, Rizvi A *et al.* (2013) Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *Lancet* **382**, 452–477.
17. Ijarotimi OS (2013) Determinants of childhood malnutrition and consequences in developing countries. *Curr Nutr Rep* **2**, 129–133.
18. Pascale R, Sternin J & Sternin M (2010) *The Power of Positive Deviance: How Unlikely Innovators Solve the World's Toughest Problems*, 1st ed. Boston: Harvard Business Review Press.
19. Hegsted DM (1967) Comment on agricultural development and economic growth. In *Agricultural Development and Economic Growth*, pp. 361 [HM Southworth and BF Johnston, editors]. Ithaca: Cornell University Press.
20. Wollinka O, Keeley E, Burkhalter BR *et al.* (1997) *Hearth Nutrition Model: Applications in Haiti, Vietnam, and Bangladesh*. Arlington: BASICS.
21. Sternin M, Sternin J & Marsh D (1996) Rapid, sustained childhood malnutrition alleviation through a "positive deviance" approach in rural Vietnam: preliminary findings. In *The Hearth Nutrition Model: Applications in Haiti, Vietnam, and Bangladesh. Report of a Technical Meeting at World Relief Corporation Headquarters*, pp. 49–61 [O Wollinka, E Keeley, RB Burkhalter *et al.*, editors]. Baltimore: World Relief Corporation.
22. Mackintosh UAT, Marsh DR & Schroeder DG (2002) Sustained positive deviant child care practices and their effects on child growth in Vietnam. *Food Nutr Bull* **23**, Suppl. 4, 18–27.
23. Kang Y, Kim S, Sinamo S *et al.* (2017) Effectiveness of a community-based nutrition programme to improve child growth in rural Ethiopia: a cluster randomized trial. *Matern Child Nutr* **13**, e12349.
24. Roche ML, Marquis GS, Gyorkos TW *et al.* (2017) A community-based positive deviance/hearth infant and young child nutrition intervention in Ecuador improved diet and reduced underweight. *J Nutr Educ Behav* **49**, 196–203.
25. Pachón H, Schroeder DG, Marsh DR *et al.* (2002) Effect of an integrated child nutrition intervention on the complementary food intake of young children in rural North Vietnam. *Food Nutr Bull* **23**, Suppl. 4, 59–66.
26. NIPORT & ICF (2019) *Bangladesh Demographic and Health Survey 2017–18: Key Indicators*. Dhaka, Rockville: National Institute of Population Research and Training (NIPORT), ICF.
27. Ruel MT, Menon P, Habicht JP *et al.* (2008) Age-based preventive targeting of food assistance and behaviour change and communication for reduction of childhood undernutrition in Haiti: a cluster randomised trial. *Lancet* **371**, 588–595.
28. Schroeder DG, Pachón H, Dearden K *et al.* (2002) An integrated child nutrition intervention improved growth of younger, more malnourished children in Northern Vietnam. *Food Nutr Bull* **23**, Suppl. 4, 50–58.
29. Bhandari N, Mazumder S, Bahl R *et al.* (2004) An educational intervention to promote appropriate complementary feeding practices and physical growth in infants and young children in rural Haryana, India. *J Nutr* **134**, 2342–2348.
30. Schroeder DG, Martorell R, Rivera JA *et al.* (1995) Age differences in the impact of nutritional supplementation on growth. *J Nutr* **125**, Suppl. 4, 1051S–1059S.
31. Bangladesh Bureau of Statistics (2011) *The Bangladesh Population and Housing Census 2011*. Dhaka: Bangladesh Bureau of Statistics, Ministry of Planning.
32. World Vision Bangladesh & The Nielsen Company (2018) *Report on Baseline Survey of Rajshahi Maternal and Child Nutrition Project*. Dhaka: World Vision Bangladesh, The Nielsen Company.
33. Kang Y, Cho M, Rahman MM *et al.* (2020) Design of a collaborative monitoring and evaluation system for a community-based nutrition project in rural Bangladesh. *Eval Program Plann* **84**, 101892.
34. Klaas N, Baik D & McNulty J (2015) *Training of Facilitators for Positive Deviance/Hearth: Facilitators Manual*. Middlesex: World Vision International.
35. CORE (2003) *Positive Deviance/Hearth: A Resource Guide for Sustainably Rehabilitating Malnourished Children*. Washington, DC: Nutrition Working Group, Child Survival Collaborations and Resources Group.
36. ACF (2012) *Emergency Nutrition Assessment for Standardized Monitoring and Assessment of Relief and Transitions (ENA for SMART)*. Toronto: Action against Hunger Canada.
37. WHO (1997) *WHO Global Database on Child Growth and Malnutrition*. Geneva: World Health Organization.
38. Bisits Bullen PA (2011) The positive deviance/hearth approach to reducing child malnutrition: systematic review. *Trop Med Int Health* **16**, 1354–1366.
39. Seetha A, Tsusaka TW, Munthali TW *et al.* (2018) How immediate and significant is the outcome of training on diversified diets, hygiene and food safety? An effort to mitigate child undernutrition in rural Malawi. *Public Health Nutr* **21**, 1156–1166.
40. Brackett C (2007) Malnutrition interventions in developing nations: strengths and weaknesses of the Positive Deviance/Hearth program in rural Rwanda. PhD Thesis, California State University.
41. Moats S, Suitor CW, Yaktine AL *et al.* (2011) *Child and Adult Care Food Program: Aligning Dietary Guidance for All*. Washington, DC: National Academies Press.