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Original Article

Adding multiple micronutrient powders to a homestead food production programme yields marginally significant benefit on anaemia reduction among young children in Nepal

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Abstract

Anaemia affects 46% of preschool-aged children in Nepal. A cluster-randomised study was conducted in rural Nepal to test whether providing micronutrient powders (MNP) in addition to enhanced homestead food production (EHFP) programme, consisting of home gardens, poultry and nutrition education, could lead to a higher reduction in anaemia compared with providing only EHFP. This sub-study enrolled 335 children aged 6–9 months into one of three groups: (1) EHFP + MNP; (2) EHFP; or (3) control. The EHFP + MNP group received 60 sachets of MNP for flexible consumption at the start and 6 months later for a total supplementation period of 11 months. The MNP contained 15 micronutrients including iron (10 mg encapsulated ferrous fumarate). Haemoglobin and anthropometry were measured at baseline and post-MNP supplementation. Mean ± SE haemoglobin concentration increased significantly in all groups, with a slightly higher but non-significant increase in the EHFP + MNP and EHFP compared with control (difference-in-differences: 4.1 g L^{-1} for EHFP + MNP vs. control; 3.6 g L^{-1} for EHFP vs. control; 0.5 g L^{-1} for EHFP + MNP vs. EHFP). Anaemia decreased at a slightly higher magnitude in the EHFP + MNP [51.5 percentage points (PP)] than the EHFP (48.6 PP) and control (39.6 PP), with adjusted odds ratios (95% CI) at post-supplementation of 0.52 (0.25–1.12) for EHFP + MNP and 0.69 (0.35–1.36) for EHFP, compared with control. There was no impact on child growth. Combining EHFP and MNP programmes yielded a marginally significant reduction in anaemia among children.

Keywords: micronutrient powders, MNP, home fortification, homestead food production, children, Nepal.

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Introduction

Anaemia affects 46% of children under 5 years in Nepal, and inadequate dietary intake and infections are believed to be important factors that influence childhood anaemia in the country (MOHP & Macro International 2006). To address child anaemia in Nepal, the national strategic plan for nutrition from 2009 to 2014 prioritised the scaling up of a comprehensive behavioural change communication (BCC) intervention for improving infant and young child feeding (IYCF), along with supplementation of children aged 6–23 months with micronutrient powders (MNP). However, a clear context-specific distribution strategy for MNP is yet to be outlined for Nepal, despite pilot distributions through some health centres and use of MNP in some refugee camps (Rah *et al*. 2012).

Globally, home fortification of complementary foods using MNP coupled with BCC to ensure appropriate IYCF practices is well accepted as an effective strategy for reducing anaemia among children (De-Regil *et al*. 2011; Rah *et al*. 2012). In addition, several studies point to the role of MNP consumption in the resolution of some common childhood infections, particularly diarrhea diseases (Sharieff *et al*. 2006), although others have found evidence pointing to the contrary (Soofi *et al*. 2013). However, more information is still needed to detail the effectiveness of MNP consumption under programme conditions, particularly studies that monitor one cohort of children over an extended period of time.

As more and more countries have begun implementing MNP programmes, another necessary piece of information is the mechanism by which this intervention can be scaled up. As pointed out by Olney *et al*. (2012), multiple micronutrient interventions have been delivered mainly through health platforms, with limited use of other platforms, such as agriculture programmes. Thus, making use of other platforms in addition to the health system could potentially allow for wider coverage and use of MNP.

To this end, Helen Keller International (HKI) and other development partners undertook an operations research to assess if enhanced homestead food production (EHFP) programme, which offers home garden, animal husbandry and nutrition education to beneficiary families, could be used as a platform to deliver MNP to children. The primary objective of this study was to determine whether providing MNP to children in families who were potentially benefiting from the EHFP could result in a greater reduction in the prevalence of anaemia and improve growth compared with children in families who received only the EHFP or those in a control group who received neither of these interventions. The study team also assessed if MNP consumption resulted in lower reported cases of diarrhea and fever among children.

This study was conducted in Baitadi District, a remote hilly community, ~800 km west of Kathmandu, Nepal. The district borders India to the west and is administratively divided into 12 sub-districts called 'Ilakas', and each 'Ilaka' is further divided into 'village development committees' (VDCs), which consist of several (~9) villages. The population is engaged in subsistence farming, mainly cultivation of rice, wheat and maize, the main staple foods in the area. The district is not malaria endemic, although malaria cases are sometimes reported. The climate ranges from tropical to temperate, and there are two main seasons: rainy/monsoon (June–September/October) and winter (October/November–February). The months preceding the rainy season (March, April and May) are usually hot and dry. The EHFP programme was implemented from 2008 to 2012, but inputs for the gardens and poultry were distributed to beneficiary households from late 2009 to early 2010. The MNP supplementation began in March 2011, about a year after distributing the EHFP inputs to families. Surveys were conducted prior to the start and at the end of each of these interventions. In this paper, we report the findings from the assessments conducted before and after 11 months of the MNP supplementation. The details of the larger EHFP programme implementation and the findings from its impact evaluation, including changes in IYCF practices of caretakers and household food security, will be reported elsewhere. Both interventions targeted children 0–23 months of age, although the EHFP

Key Messages

- EHFP programmes that offer home garden, animal husbandry and nutrition education to beneficiary families could be used as a platform to deliver MNP to children.
- Either EHFP alone or EHFP + MNP programme yielded marginally significant benefit on childhood anaemia compared with control. However, combining EHFP and MNP programmes yielded no additional benefit on anaemia reduction.
- EHFP programme significantly reduced the longitudinal prevalence of reported diarrhea compared with control. However, adding MNP to EHFP did not yield any additional benefit on longitudinal prevalence of reported diarrhea cases.
- Neither EHFP alone nor EHFP + MNP programme yielded any significant impact on child growth.

intervention also targeted their mothers and pregnant women. Briefly, the EHFP programme was designed to increase the production and consumption of nutrient-rich vegetables, fruits and animal products by supporting the beneficiary families with the necessary inputs to establish home gardens and backyard poultry, while backing this up with BCC for improved dietary intake. At the start of the programme, each family received a one-time distribution of seeds, saplings and chicks for establishing their home garden and poultry. These inputs were placed in the hands of a woman in the family (mainly caregiver of beneficiary children), who also received nutrition education several times through the period of the intervention. Additionally, a demonstration farm was established for every group of about 20 beneficiary women. These demonstration gardens were used to provide ongoing supply of garden and poultry inputs, for disseminating improved agriculture techniques and as a platform for sharing knowledge and skills among the women.

The nutrition education focused on the Essential Nutrition Actions, providing key messages on adequate dietary intake, including optimal breastfeeding and complementary feeding practices, and consumption of iodized salt and foods rich in vitamin A and iron. The women and their children were also encouraged to participate in routine public health activities in their communities, including immunisation, growth monitoring, vitamin A supplementation and deworming. The communication messages were designed based on findings from initial formative research which included focus group discussions and key informant interviews with mothers, grandmothers and fathers of children in these communities (Locks *et al.* 2013).

Subjects and methods

In this prospective cluster-randomised controlled sub-study, 6–9-month-old children were randomised to one of three groups: (1) EHFP + MNP; (2) EHFP; or (3) control. The children in the EHFP + MNP and EHFP groups benefited from the EHFP intervention whereas those in the control group had no intervention. Children in the EHFP + MNP group also received MNP. Placebo was not used and investigators and field workers were not blinded to the treatment assigned to children. However, the assignment of clusters rather than individuals to the study groups prevented participants in one group from knowing the treatment received by those in the other groups. Children aged 6–9 months were chosen for inclusion because it was anticipated that they would be less than 2 years of age after the period of MNP supplementation. Other criteria for inclusion were that the child was not severely anaemic (haemoglobin <70 g L^{-1}), underweight [weight-for-age z-score (WAZ) <-3], stunted [length-for-age z-score (HAZ) <-3] or wasted [weight-for-length z-score (WHZ) <-3] at baseline, as well as the mother's willingness to remain in the study area for at least 1 year from the start of the MNP supplementation. None of the children screened were severely anaemic and children found to suffer from severe undernutrition were referred to the nearest community health centre for treatment. At the start of the MNP supplementation, there were no micronutrient interventions targeted at young children in the area, apart from the EHFP intervention and the routine government programmes of semi-annual vitamin A supplementation (targeting children 6–59 months old) and deworming (targeting children 12–59 months old). In addition, other programmes on integrated management of childhood illnesses were implemented by the government in both the intervention and control communities during the period of the study.

Sample size and sampling procedure

The sample size for this study was calculated using a statistical significance of 0.017 (to account for three group comparisons): a power of 0.80, design effect of 2, and an assumed reduction in anaemia of 30 percentage points (PP) among the EHFP + MNP group compared with the control after the MNP supplementation. We assumed a baseline anaemia prevalence of 41.3%, similar to the prevalence reported for this region by the Demographic and Health Survey (MOHP & Macro International 2006). The assumed change in anaemia prevalence was taken from a similar MNP intervention in Haiti (Menon *et al.* 2007). The estimated sample size was adjusted upward by 10% to account for loss to follow-up, resulting in 330 children required for the study ($n = 110$ per group).

The children were selected from 22 VDCs (clusters): 7 for the EHFP + MNP group, 8 for the EHFP, and 7 for control, using a multistage cluster sampling procedure (Fig. 1). At the baseline survey for this MNP supplementation study, the EHFP intervention had been introduced in 21 VDCs in the district. A baseline survey for the impact evaluation of this larger EHFP intervention had also been conducted, with a random sample of 2106 households. Details of the methods used for this larger EHFP baseline survey will be presented elsewhere. In summary, information from the 2001 National Census of Nepal was used to arrange the names of Ilakas in the district in pairs based on their comparability on several socio-economic indicators, including food availability, life expectancy, poverty index, and total number of VDCs, wards and households. A simple random sampling procedure was then used to select four pairs of Ilakas. The same procedure was used to assign one of the selected Ilakas in each pair to EHFP or control. The VDCs under these Ilakas were then stratified by whether they belonged to an EHFP ($n = 21$) or control ($n = 20$), and 14 VDCs were randomly selected from each stratum to participate in the baseline assessments for this larger EHFP study. However, all the VDCs in the EHFP programme communities received the EHFP intervention, regardless of their participation in the surveys. Furthermore, no EHFP or MNP intervention was implemented in the control VDCs throughout the period of this study.

To select the children for this MNP sub-study, a list of the 21 treatment and 20 control VDCs in the larger EHFP study was obtained from the HKI office in Kathmandu. Seven of the 21 VDCs that were receiving the EHFP intervention were randomly selected and 115 children were chosen from these VDCs to serve as the EHFP + MNP group. Eight of the

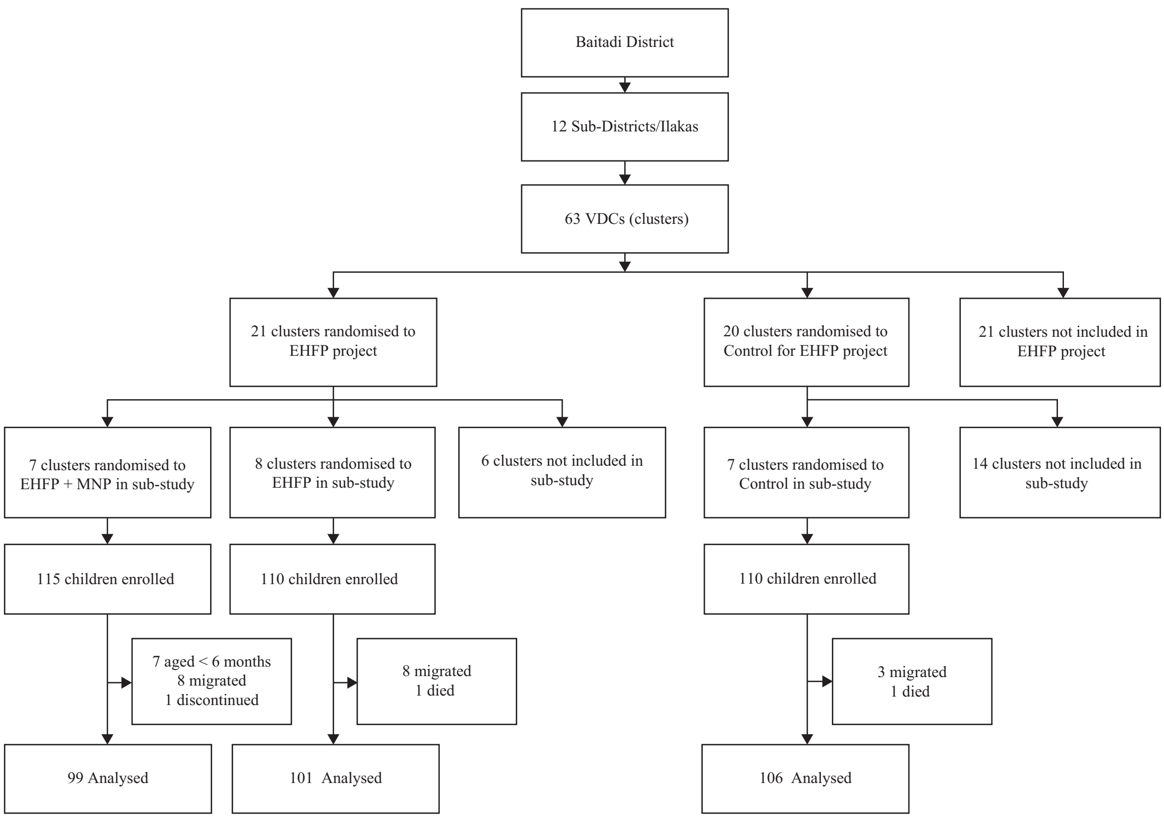

Fig. 1. Trial profile.

remaining 14 VDCs were randomly selected and 110 children were chosen from these VDCs to serve as the EHFP group. Of the 20 VDCs with no EHFP intervention at the time, seven VDCs were randomly selected and 110 children were chosen from these VDCs to serve as control for the MNP sub-study. The number of households to be visited in each selected VDC was first determined using the probability proportional to size technique, and from each household one child aged 6–9 months was chosen. For households with more than one eligible child, the youngest was chosen.

MNP composition, distribution and dosage

The MNP were donated by Micronutrient Initiative (MI), and were packaged as individual sachets with each sachet containing 15 vitamins and minerals in a powder form, including: 10 mg iron (encapsulated ferrous fumarate), 4.1 mg zinc (zinc gluconate), 90 μg iodine (potassium iodide), 400 μg vitamin A (vitamin A acetate), 150 μg folic acid, 0.5 mg vitamin B1 (thiamine mononitrate), 0.5 mg vitamin B2 (riboflavin), 0.5 mg vitamin B6 (pyridoxine), 0.9 μg vitamin B12 (cyanocobalamin), 30 mg vitamin C (ascorbic acid), 5 μg vitamin D3 (cholecalceferol), 5 mg vitamin E (vitamin E acetate), 6 mg niacin (niacinamide) and 0.6 mg copper (cupric gluconate). MNP were distributed to children for flexible consumption, approximately 4 months after the baseline survey and at 6 months after this first distribution, for a total supplementation period of 11 months. Every child in the EHFP + MNP group received 60 sachets of MNP during each of these distribution periods. Overall, 16 500 sachets of MNP were donated by MI, although only 13 800 were needed for the two-time distribution to the 115 study children who consumed MNP. Trained cadre of Female Community Health Volunteers (FCHVs) distributed the MNP to mothers of the children during mother's group meetings in each village. In Nepal, FCHVs are married women who are selected by their villages as volunteers for health promotion through the government's Ministry of Health and Population (MOHP). The FCHVs also provided each mother with instructions on how to prepare and feed the MNP, a compliance card for documenting each day MNP were fed, and counselling on proper breastfeeding and complementary feeding practices. Mothers were instructed to feed MNP on any day of their preference but ensure that they did not feed more than one sachet per day and that all 60 sachets from each distribution were consumed within 6 months.

Prior to the start of interventions, all the mothers and FCHVs in the communities who received the EHFP intervention were trained on home gardening and poultry raising techniques, as well as appropriate breastfeeding and complementary feeding practices. In addition, the mothers and FCHVs in the EHFP + MNP communities were trained on proper procedures to fortify complementary foods using MNP and how to complete the compliance cards.

Data collection

Baseline data were collected from September to October 2010, after which MNP were distributed in March 2011 (first distribution) and August 2011 (second distribution), and post-MNP supplementation assessments were conducted in February 2012. Data were gathered through interviews with mothers at home. Data obtained included: socio-demographic characteristics, IYCF practices, and infections (diarrhea and fever) suffered by the child in the 2 weeks before the interviews. Diarrhea was defined as maternal report of whether the child experienced one or more loose stools with or without blood on any day in the 2 weeks before each interview. The weight, recumbent length/height and haemoglobin of each child and mother were measured at enrollment and at the end of MNP supplementation using standard WHO procedures (World Health Organization 1995). Weight was measured to the nearest 0.1 kg using an electronic weighing scale (Seca, UNICEF). Recumbent length of children was measured with a portable length board and height of their mothers was measured with a locally made height board to the nearest 0.1 cm. Haemoglobin was measured from a finger prick of blood using a portable HemoCue analyzer (Angelholm, Sweden). Finger pricks were made using a sterile lancet after cleaning the finger with methylated spirit. For the children, underweight, stunting and wasting were defined as WAZ <−2, HAZ <−2 and WHZ <−2, as computed using the 2006 WHO Child Growth Standards (World Health Organization Multicentre Growth Reference Study Group 2006). Anaemia was defined as haemoglobin <110 g L^{-1} after adjusting for the influence of altitude on haemoglobin concentration using the appropriate WHO reference values (World Health Organization, United Nations Children's Fund & United Nations University 2001). The altitude of participating households ranged from 663 to 2201 m above mean sea level, as measured using a handheld global positioning system (GPS) device (model-eTtrex H, Garmin Ltd., Chicago, IL, USA). Ethical approval for this study was granted by the National Health Research Council in Nepal. The objectives of the study were explained and verbal consent was obtained from the mother and the head of the household of each child before the assessments.

Monitoring the intervention

Each FCHV was given a register to record the name, date of birth, house address, the date of MNP distribution as well as the number of MNP sachets given to each child. We 'estimated the efficiency' of MNP distribution using a ratio of the total number of MNP sachets that were given to all the children over the study duration to the total number of MNP sachets that were required to provide each child with 120 sachets. The enumerators conducted biweekly home visits to each child in all three groups, with each enumerator assigned to monitor children in a given supervision area which comprised of several villages. The mother was interviewed on illnesses suffered by the child over the 2 weeks before each home visit. When a child was found to be suffering from any illness on the day of the visit, the mother was advised to send the child to the nearest health centre for treatment. For children in the EHFP + MNP group, consumption of MNP was assessed on each visit by abstracting this information from the compliance cards and confirming this by counting the number of MNP sachets remaining on the day of the visit. Estimated compliance with intake of MNP by each child was computed as the ratio of total number of MNP sachets consumed over the study period to the total number of MNP sachets provided to the child (120 sachets). For children who dropped out of the study, the information gathered up to the point of dropout was included in this analysis. During each home visit, enumerators also reinforced the education messages on breastfeeding and complementary feeding (to all mothers) as well as proper procedures of preparing and feeding MNP (only to mothers in the EHFP + MNP group).

Statistical analysis

Data were analysed using SPSS version 20 (IBM, New York, USA) and STATA version 11 (StataCorp LP, Texas, USA). Statistical significance was accepted when $P < 0.05$. All analyses accounted for the cluster design by using the svyset command in STATA with 'VDC' as the strata variable or by including both VDC and ward (village) variables as covariates in SPSS. Proportions, means ± SD and medians (range) were used to describe the sample. At baseline, proportions were compared between the groups using Rao–Scott chi-square test, and these were confirmed with mixed model logistic regression. Means and medians were compared between groups using mixed model analysis of covariance (ANCOVA) with Bonferroni and Wilcoxon tests, respectively. Within each group, the change in outcomes (haemoglobin, anaemia, WAZ, WHZ, HAZ, underweight, stunting and wasting) between baseline and post-supplementation was assessed using mixed effects ANCOVA and logistic regression models for means and proportions, respectively. Mixed effects ANCOVA and logistic regression models were also used for between-group comparisons of the change in means and proportions from baseline to post-supplementation, respectively, with the post-supplementation values of each outcome as the dependent variable, while accounting for their respective baseline values and other covariates. Using data from the baseline and post-supplementation surveys as well as the biweekly monitoring visits, the longitudinal prevalence of reported cases of diarrhea and fever was computed based on intention-to-treat principle and following similar procedures as described by Sharieff *et al.* (2006). For each child, the longitudinal prevalence was estimated as the ratio of the total number of visits that he/she was reported as having any of these infections to the number of visits made to that child during the supplementation period, multiplied by 100. The estimated longitudinal prevalence was skewed and was therefore normalised by adding 1 to each computed value and taking the natural log. The mean of the log-transformed longitudinal prevalence was then compared between the study groups using mixed effects ANCOVA.

The baseline age and sex of children were included in all between-group comparisons, except the baseline analysis with anthropometric variables as outcomes. For each analysis that compared changes in outcomes, the education of the mother and the household wealth index were also included as covariates, as these indicators were significantly different between the groups at baseline. Furthermore, the baseline WHZ and HAZ were included in all the ANCOVA and logistic regression models, which compared changes in haemoglobin, anaemia and infection. A household wealth index was created from several household socio-economic status variables using principal component analysis, following procedures as described by Vyas & Kumaranayake (2006). Variables included occupation of head of the household, the household's source of drinking water, type of toilet, presence of electricity/solar power, as well as ownership of durables including radio, television, fridge, fan, computer, mobile phone, watch, bed and cupboard. Gender of head of household, type of fuel used in the house, and ownership of land, livestock, motorcycle, bicycle/rickshaw and car/truck were excluded from the wealth index because of their limited variation among the sample.

Results

There were 335 children aged 6–9 months at entry into the study (Fig. 1). Of these, data on 306 were available for analysis at post-supplementation, distributed across the study arms as: EHFP + MNP = 99; EHFP = 101; and control = 106. Reasons for dropout included: younger than age criteria for inclusion at baseline ($n = 7$), death ($n = 2$), refusal to continue participation ($n = 1$) and relocation ($n = 19$). The number (%) of children who dropped out was different between the EHFP + MNP [16 (13.9%)] and the control groups [4 (3.6%)], $P < 0.05$. However, none of these were significantly different from the EHFP group [9 (8.2%)]. The baseline characteristics of those who dropped out of the study were not different from those who completed the study (data not shown).

Characteristics of the sample by group are displayed in Table 1. The mean ± SD age of the children was 7.2 ± 1.1 months and 47% of them were female. Children in the three groups were not significantly different with regard to age, sex, WAZ, HAZ, underweight, wasting, haemoglobin concentration, prevalence of anaemia and illnesses at baseline. The groups were also similar with regard to several maternal and household characteristics (Table 1). However, stunting was significantly lower among children in the EHFP than those in the EHFP + MNP and control groups. WHZ was also lower among children in the EHFP than those in the control group, $P < 0.05$. A greater proportion of children in the control group had mothers with no formal education compared with children in the EHFP + MNP and EHFP groups, $P < 0.05$. All the households of children in the EHFP + MNP and almost all those in the EHFP groups had a home garden, compared with 94.5% of households of children in the control group. However, the proportion of households with home gardens was only significantly different between the EHFP + MNP and control groups. More than three quarters of families of the children in the EHFP + MNP and EHFP groups owned poultry compared with only one in five of the control households, $P < 0.05$. In general, the proportion of children from poor socio-economic status families was significantly higher in the control than in the EHFP + MNP and EHFP groups, as shown by the distribution of the sample across the wealth index terciles (Table 1).

Estimated efficiency of distribution and compliance with intake of MNP

For the 108 children in our baseline sample who were eligible for MNP supplementation, we estimated that 13 800 sachets of MNP were required to provide each child with 120 sachets of MNP. Two of the children

Table 1. Characteristics of children in the sample

	Total sample	EHFP + MNP	EHFP	Control
n	328	108	110	110
Child characteristics				
Age (months)	7.2 ± 1.1	7.3 ± 1.2	7.2 ± 1.1	7.1 ± 0.9
Sex (female) (%)	47.0	50.0	46.4	44.5
WAZ	−1.1 ± 1.2	−1.02 ± 1.09	−1.16 ± 1.17	−1.10 ± 1.25
<−2 (%)	24.1	19.4	25.5	27.3
HAZ[†]	−0.79 ± 1.30	−0.77 ± 1.25	−0.59 ± 1.17	−1.01 ± 1.44
<−2 (%)	15.3	17.6[a]	8.3[b]	20.0[a]
WHZ[†]	−0.75 ± 1.20	−0.67 ± 1.27[a,b]	−1.02 ± 1.05[a]	−0.58 ± 1.26[b]
<−2 (%)	13.1	12.0	14.7	12.7
Haemoglobin	103.4 ± 13.3	101.8 ± 12.9	104.5 ± 13.7	103.9 ± 13.0
<110 g L^{-1} (%)	66.2	70.4	64.5	63.6
Sick in the past 2 weeks (%)	61.3	56.5	65.5	61.8
Diarrhea only (%)	2.1	0	3.6	2.7
Fever only (%)	9.1	11.1	8.2	8.2
Cough only (%)	4.0	4.6	2.7	4.5
More than one of the above illnesses (%)	46.0	40.7	50.9	46.4
Maternal characteristics				
Age (years)	25.4 ± 5.5	25.0 ± 5.1	25.1 ± 5.5	26.1 ± 6.0
Main caretaker of study child (%)	69.5	75.0	63.6	70.0
Number of living children	2.0 (1–9)	2.0 (1–7)	2.0 (1–9)	3.0 (1–9)
Education (no formal education) (%)	60.7	54.6[a]	47.3[a]	80.0[b]
BMI (kg m^{-2})	20.2 ± 2.1	20.2 ± 2.3	20.1 ± 2.0	20.3 ± 1.9
<18.5 (%)	20.1	26.9	17.3	16.4
≥18.5 – <23 (%)	71.6	62.0[a]	76.4[b]	76.4[b]
≥23 (%)	8.2	11.1	6.4	7.2
Haemoglobin (g L^{-1})	125.2 ± 16.5	124.0 ± 16.9	124.4 ± 14.6	127.2 ± 17.6
<120 (%)	32.3	33.3	35.5	28.2
Household characteristics				
Male head of household (%)	97.6	99.1	98.2	95.5
Dalit/disadvantaged caste (%)	36.3	41.7	35.5	31.8
Household size	7.0 (3–28)	7.0 (3–28)	7.0 (3–18)	6.5 (3–15)
Has home garden (%)	97.6	100.0[a]	98.2[a,b]	94.5[b]
Has poultry (%)	59.8	83.3[a]	75.5[a]	20.9[b]
Wealth tercile (%)				
Lower tercile	32.6	25.9[a]	28.2[a]	43.6[b]
Middle tercile	33.8	32.4	35.5	33.6
Upper tercile	33.5	41.7[a]	36.4[a]	22.7[b]

EHFP, enhanced homestead food production; MNP, micronutrient powders; WAZ, weight-for-age z-score; HAZ, length-for-age z-score; WHZ, weight-for-length z-score; BMI, body mass index. Values are mean ± SD; median (range) or proportions. Haemoglobin concentrations were adjusted for altitude. Proportions or means in the same row with different superscript letters denote significant differences between groups.
[†]n = 327.

had migrated out of the study area before the start of the MNP distribution. Therefore, MNP were distributed to 106 children, with all but three of them receiving 120 sachets. For the three children who received only 60 sachets of MNP, two had migrated out of the study area and one had discontinued the study before the second round of MNP distribution. Thus, overall, 12 540 sachets of MNP were distributed to children in this study, leading to an estimated MNP distribution efficiency of 90.8%. The estimated compliance with MNP intake by children over the 11-month period was 96.9%, with a median (range) number of MNP sachets consumed as 120.0 (18.0–120.0).

Impact on haemoglobin and anaemia

The adjusted mean haemoglobin concentration increased among children in all groups ($P < 0.05$),

Table 2. Haemoglobin concentration and prevalence of anaemia among children before and after 11 months of MNP supplementation

	n	Baseline	After 11 months	Difference (after 11 months minus baseline)	Difference of difference	
					Minus control	Minus EHFP
Haemoglobin (g L^{-1})						
EHFP + MNP	99	101.9 ± 1.3	120.3 ± 1.3*	18.4 ± 1.7	4.1 ± 2.4	0.5 ± 2.4
EHFP	100	104.4 ± 1.4	122.3 ± 1.4*	17.9 ± 1.9	3.6 ± 2.4	
Control	106	103.7 ± 1.3	118.0 ± 1.4*	14.3 ± 1.7		
Anaemia (%)						
EHFP + MNP	99	71.7	20.2*	−51.5	−11.9	−2.9
EHFP	100	64.4	15.8*	−48.6	−9.0	
Control	106	65.1	25.5*	−39.6		

EHFP, enhanced homestead food production; MNP, micronutrient powders. Values are adjusted mean ± SE and proportions. Means were adjusted for altitude, age and sex of children. *Significantly different from corresponding baseline, $P < 0.05$.

with a slightly higher magnitude of change in the EHFP + MNP and EHFP groups compared with the control group (Table 2). However, the difference-in-differences in adjusted mean haemoglobin concentration was not statistically significant (EHFP + MNP vs. control = 4.1 g L^{-1}; EHFP vs. control = 3.6 g L^{-1}; EHFP + MNP vs. EHFP = 0.5 g L^{-1}).

Anaemia decreased significantly in all groups at the end of the study and the extent of reduction was slightly higher in the EHFP + MNP (51.5 PP) and EHFP (48.6 PP) groups compared with the control group (39.6 PP) (Table 2), although these differences were not statistically significant. Furthermore, a bivariate analysis using only a subgroup of children who were anaemic at baseline ($n = 71$ for EHFP + MNP; 65 for EHFP; 69 for control) revealed that 74.6% of the children in the EHFP + MNP group were no longer anaemic at post-supplementation compared with 81.5% in the EHFP group and 69.6% in the control group. For the children who were not anaemic at baseline ($n = 28$ for EHFP + MNP; 36 for EHFP; 37 for control), new cases of anaemia over the supplementation period were 7.1% in the EHFP + MNP group compared with 11.1% in the EHFP group and 16.2% in the control group, although none of these differences were statistically significant. After adjusting for baseline differences in covariates, a mixed model logistic regression using the entire sample of children showed no significant difference in anaemia prevalence between the groups at post-supplementation (Table 3).

Table 3. Multivariate logistic regression for the effect of the interventions on anaemia prevalence at post-supplementation

	Anaemia		
	%	Odds ratio	95% CI
EHFP + MNP	20.2	0.52	0.25–1.12
EHFP	15.8	0.69	0.35–1.36
Control (reference)	25.5–	1.0	

EHFP, enhanced homestead food production; MNP, micronutrient powders. Values are proportions and odd ratios and 95% CI, $n = 305$. Adjusted for age, sex and baseline anaemia, HAZ and WHZ of children, mother's education and household wealth.

Impact on anthropometric indicators

The mean WAZ and HAZ decreased in all groups ($P < 0.05$), with no significant benefit of either the MNP supplementation or the EHFP intervention. WHZ did not change significantly in any of the groups (Table 4). None of the adjusted ANCOVA models showed a significant difference in the mean changes of these anthropometric indices between the groups (data not shown).

Underweight and wasting did not change significantly in any of the study groups. Stunting increased in all groups, $P < 0.05$, with no significant between-group differences (Table 4). None of the multivariate logistic regression models with stunting, underweight or wasting as outcomes showed a significant difference in changes of these outcomes between the study groups (Table 5).

Table 4. Anthropometric indicators of children before and after 11 months of MNP supplementation

	n	Baseline	After 11 months	Difference (after 11 months minus baseline)	Difference of difference	
					Minus control	Minus EHFP
WAZ						
EHFP + MNP	99	−1.03 ± 0.11	−1.60 ± 0.10*	−0.57 ± 0.08	0.15 ± 0.13	−0.12 ± 0.14
EHFP	101	−1.14 ± 0.11	−1.57 ± 0.09*	−0.44 ± 0.10	0.27 ± 0.13	
Control	106	−1.13 ± 0.12	−1.84 ± 0.11*	−0.71 ± 0.10		
HAZ						
EHFP + MNP	99	−0.71 ± 0.13	−2.03 ± 0.12*	−1.32 ± 0.93	0.06 ± 0.14	0.09 ± 0.14
EHFP	100	−0.59 ± 0.11**	−2.01 ± 0.10*	−1.41 ± 0.96	−0.03 ± 0.14	
Control	106	−1.03 ± 0.14	−2.40 ± 0.12*	−1.38 ± 0.11		
WHZ						
EHFP + MNP	99	−0.74 ± 0.13	−0.73 ± 0.10	0.01 ± 0.13	0.22 ± 0.18	−0.27 ± 0.18
EHFP	100	−0.99 ± 0.10**	−0.71 ± 0.11	0.28 ± 0.13	0.49 ± 0.18*	
Control	106	−0.59 ± 0.12	−0.80 ± 0.10	−0.21 ± 0.13		
Underweight (%)						
EHFP + MNP	99	19.2	31.3	12.1	−0.10	5.8
EHFP	101	25.7	32.7	6.3	−5.9	
Control	106	27.4	39.6	12.2		
Stunting (%)						
EHFP + MNP	99	16.2	53.5*	37.3	2.4	−2.8
EHFP	100	7.0**	48.0*	40.1	5.2	
Control	106	20.8	55.7*	34.9		
Wasting (%)						
EHFP + MNP	99	13.1	6.1	−7.0	−7.0	−5.0
EHFP	100	13.9	11.9	−2.0	−2.0	
Control	106	13.2	13.2	0		

MNP, micronutrient powders; EHFP, enhanced homestead food production; WAZ, weight-for-age *z*-score; HAZ, length-for-age *z*-score; WHZ, weight-for-length *z*-score. Values are mean ± SE and proportions. *Significantly different from corresponding baseline ($P < 0.05$). **Different from corresponding control group, $P < 0.05$.

Table 5. Multivariate logistic regression for the effect of interventions on underweight, stunting and wasting among children after 11 months of MNP supplementation[†]

	Underweight[†]		Stunting[‡]		Wasting[‡]	
	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Group						
EHFP + MNP	31.3	0.78 (0.38–1.61)	53.5	1.27 (0.69–2.36)	6.1	0.83 (0.36–1.91)
EHFP	32.7	0.86 (0.44–1.67)	48.0	1.30 (0.70–2.43)	11.9	0.39 (0.15–1.04)
Control (reference)	39.6	1	55.7	1	13.2	1

MNP, micronutrient powders; EHFP, enhanced homestead food production. Values are proportions and odds ratio (95% CI). Adjusted for respective baseline values of each outcome variable together with age, sex of child, mother's education and household wealth. [†]$n = 306$. [‡]$n = 305$.

Impact on reported diarrhea and fever

The adjusted mean longitudinal prevalence of reported diarrhea was higher among the children in the control group compared with the EHFP + MNP and EHFP groups. However, only the difference between the EHFP and control groups was statistically significant, $P < 0.05$ (Table 6). The longitudinal prevalence for reported cases of fever was slightly higher among the control children than the EHFP + MNP and EHFP groups, although the differences were not statistically significant (Table 6).

Table 6. Longitudinal prevalence of reported cases of diarrhea and fever among children during the study period

	Mean longitudinal prevalence		*P*-value	
	%	95% CI	vs. control	vs. EHFP
Diarrhea				
EHFP + MNP	2.61	2.27–2.93	0.114	1.000
EHFP	2.43	2.13–2.73	0.010	
Control	3.08	2.76–3.39		
Fever				
EHFP + MNP	2.56	2.18–2.93	0.212	1.000
EHFP	2.53	2.18–2.87	0.116	
Control	3.02	2.67–3.38		

MNP, micronutrient powders; EHFP, enhanced homestead food production. Values are log-transformed mean longitudinal prevalence, 95% CI or *P*-value. Adjusted for age, sex of child, mother's education, household wealth and cluster design.

Discussion

The findings from this research demonstrate that it may be feasible to use EHFP programme as a platform to distribute MNP. An estimated 91% of the MNP required for distribution was given out to children in this study, with an estimated compliance with intake of 97%. To our knowledge, this is the first study that used a large-scale nutrition sensitive agriculture intervention as a platform to distribute MNP. Under these programmatic conditions, we found a slight but non-significant improvement in haemoglobin concentration among children in the intervention groups compared with the control group (difference-in-differences: 4.1 g L^{-1} for EHFP + MNP vs. control; 3.6 g L^{-1} for EHFP vs. control; 0.5 g L^{-1} for EHFP + MNP vs. EHFP). Additionally, anaemia declined at a slightly higher magnitude in the intervention groups than in the control group, although the difference-in-differences was not statistically significant (11.9 PP for EHFP + MNP vs. control; 9.0 PP for EHFP vs. control; 2.9 PP for EHFP + MNP vs. EHFP). The longitudinal prevalence of reported diarrhea was significantly lower only among children in the EHFP group compared with control. There were no statistically significant between-group differences in longitudinal prevalence of fever and anthropometric outcomes.

Other studies have shown a higher change in haemoglobin concentration and anaemia due to MNP consumption than that realised in our study. In Haiti, children 9–24 months of age who were already receiving fortified wheat-soy blend (WSB) in a maternal and child health nutrition programme were randomly assigned to receive 60 sachets of MNP for daily consumption (one sachet per day – 12.5 mg of iron) (WSB + MNP) or to a control group (WSB). At the end of 2 months, the difference-in-differences of mean haemoglobin concentration and anaemia prevalence between children in the WSB + MNP and WSB groups was 6.5 g L^{-1} and 25 PP, respectively (Menon *et al*. 2007). These differences were higher than the difference-in-differences in mean haemoglobin concentration and anaemia prevalence of 0.5 g L^{-1} and 2.9 PP, respectively, realised between children in the EHFP + MNP and EHFP groups in our sample. However, the Haiti study is slightly different in that the children were provided with a 'direct' food supplement in addition to MNP, whereas our study used an agriculture programme as a platform for MNP distribution. In addition, the Haiti study used MNP that contained 12.5 mg of iron, which was fed daily over a shorter duration (2 months) compared with our study which used MNP that contained 10 mg of iron, fed at the caretaker's own schedule, which might have averaged out to feeding one sachet to a child every 3 days for a period of 11 months.

In general, effectiveness studies for MNP that were conducted under programme conditions over a long duration (≥1 year) without provision of a food supplement to children have yielded relatively smaller magnitudes of change in haemoglobin and anaemia. In the Kyrgyz Republic, anaemia decreased by only 6.8 PP over 12 months of intervention among children aged 6–24 months who were given 30 sachets of MNP (12.5 mg iron per sachet) every 2 months for 'flexible' consumption as part of a large-scale infant and young child nutrition programme (Serdula *et al*. 2013). Furthermore, about a 10 PP reduction in anaemia was realised among children 6–23 months of age living in refugee camps in Nepal after about 2 years of MNP intake (Bilukha *et al*. 2011). The overall reduction in anaemia seen in these studies is similar to that found among children in the EHFP + MNP or EHFP groups compared with the control group in our sample. Moreover, because the authors of these two studies used pre-post cross-sectional surveys without a control group, we believe that not all changes in the outcomes they assessed can be attributable to the MNP supplementation.

The lack of a significant impact of the MNP and EHFP interventions on anaemia compared with the control group in our sample was likely due to insufficient sample size. Although our sample size estimates were based on power calculations, we assumed a 30 PP difference in the change in anaemia between the EHFP + MNP and the control groups from baseline to post-supplementation. This was larger than the 11 PP anaemia reduction found among the EHFP + MNP group relative to the control group. Such lack of difference in changes in anaemia between the groups might also be attributable to factors other than iron deficiency influencing anaemia among the children. These factors may include high rates of infections, helminths and inadequate hygiene practices. The role of iron deficiency and intestinal worm infection in anaemia prevalence among the children could not be assessed because we did not measure the iron status and intestinal helminths due to limited financial resources. Prevalence of common childhood infections is likely to be high in our sample as reflected in 61% of the children being sick in the 2 weeks before the baseline survey. Additionally, the biweekly monitoring home visits by health workers to the children might have influenced the behaviour and practices of caretakers in all the three groups.

Furthermore, the lack of significant difference in changes in anaemia between the EHFP + MNP and the EHFP groups could be explained by the possibility of no additive impact of the EHFP and MNP interventions on anaemia resolution. However, each of these interventions has been shown to reduce anaemia among children in other studies (Talukder *et al*. 2010; De-Regil *et al*. 2011; Rah *et al*. 2012). Other potential explanations for a lack of additional impact of combining EHFP and MNP on anaemia compared with EHFP alone could be that although the children were enrolled into the study at 6–9 months of age, the MNP supplementation started 4–5 months after enrollment, by which time the children were about 10–13 months old and less vulnerable to anaemia relative to the age at which they were enrolled. The daily iron requirement of children below 6–11 months (11 mg) is higher than that of children aged 12–36 months (7 mg). Furthermore, some of the children might not have been fed with MNP adequately, as not all the caretakers might have adequately followed the fortification and feeding instructions. Our study was unable to directly verify this, because compliance with MNP intake was assessed only through a proxy indicator based on number of sachets reportedly fed to the children and not through direct observation.

The lack of impact of the EHFP and MNP interventions on child anthropometry is similar to findings from several studies on homestead food production or MNP. In general, homestead food production programmes have yet to show a successful impact on child growth as previous impact evaluations of these programmes have been limited by a lack of rigorous approach in the methods used. Additionally, MNP programmes have generally found limited impact on growth (Jack *et al*. 2012; Soofi *et al*. 2013).

The longitudinal prevalence for reported diarrhea was significantly lower in the EHFP group compared with the control group. The number of home visits that the children reportedly had fever was also lower in the EHFP group compared with the control group, although this was not statistically significant. To our knowledge, there is no published study of the impact of EHFP interventions on longitudinal prevalence of diarrhea or other infections among children. However, a study in Vietnam showed that homestead food production plus nutrition education significantly reduced the incidence and severity of acute respiratory infections and incidence of diarrhea among children (English *et al*. 1997). As the EHFP intervention promotes adequate dietary intake and encourages caretakers to use the preventive health services in their communities for the benefit of children, there is no doubt that this intervention can lead to reduced infections among children. There was no added benefit of MNP consumption on longitudinal prevalence of reported diarrhea or fever. Studies that have assessed the impact of MNP consumption on childhood infections such as diarrhea have yielded mixed results, with some pointing to reduced cases of infections and others suggesting increased infections. It is also difficult to compare the findings across these studies because of differences in the way infections are assessed and analytical methods used. We found two studies that used longitudinal prevalence of infections as their analytic outcome to assess the impact of MNP consumption on child diarrhea. Among 6–12-month-old Pakistani children, the researchers found a significantly lower mean longitudinal prevalence of diarrhea due to MNP intake compared with control (Sharieff *et al*. 2006). This finding was different from another study from Pakistan which reported a higher longitudinal prevalence of diarrhea associated with MNP intake by children (Soofi *et al*. 2013). The major differences between these two studies are that the latter used a larger sample size (>2000 vs. 205 children) and MNP containing a lower iron content (12.5 mg vs. 30 mg) than the former. Diarrhea was assessed more intensively in both studies compared with ours, in that health workers who visited the children were to inquire every week about infections, compared with the biweekly visits in our study. Moreover, the researchers in the Pakistan studies used standardised data collection tools and well-defined criteria to identify episodes of diarrhea. Thus, it is possible that their approach allowed capturing diarrhea prevalence better than ours. Aside from differences in the methods of assessing infections, our study was conducted under real public health programme conditions and children were fed with MNP according to any schedule wished by the mother, with few directions that no more than one sachet is consumed in a day and all 60 sachets be consumed within 6 months. However, the Pakistan study was conducted under 'simulated' public health programme conditions and mothers were instructed to feed their children with MNP daily. The age of the children at the start of the MNP supplementation may also partly explain the differences in impact of MNP on infections realised in our study and the Pakistan studies. In the Pakistan studies, MNP supplementation started right when the children were enrolled at an average age of ~8 months for the earlier study and 6 months for the recent study, about 2 and 4 months younger than when the children in our sample started consuming MNP, respectively. Because diarrhea is likely to be highly prevalent around the period when complementary feeding begins (6 months of age), it is possible that the Pakistan studies captured a lot of diarrhea at younger ages, which our study could not capture. This was likely the case as the authors in the most recent Pakistan study reported more days with diarrhea among children aged 6–17 months (range: 5.7–6.7%) than children aged 18–23 months (3.8–4.3%). Furthermore, the baseline prevalence of stunting (15%) and wasting (13%) among the children in our sample was quite lower than that found among the children of a similar age (below 1 year) in the recent Pakistan study (~25% for stunting and 22% for wasting). Thus, our study population may be relatively better nourished and likely to resist infections than the children in the Pakistan study.

The limitations of our study include the small sample size which could have reduced the power to detect significant differences in outcomes between the study groups. The non-blinding of the data collectors may have also introduced some potential bias in our findings. In addition, the study did not assess several factors including iron status and helminth infections among the children, which could have partly explained the lack of significant impact on anaemia and growth among the children. Despite these limitations, the findings from our study add to the growing body of literature on effectiveness of EHFP and MNP programmes, and the combination of both programmes under real public health conditions. Our findings on the impact of MNP consumption on reported cases of diarrhea should also encourage the design of a larger confirmatory study on the relationship between MNP consumption and incidence of infections among children.

Conclusion

This study showed that it may be feasible to use the EHFP as a platform to distribute MNP to children in Nepal. There was a marginally significant reduction in anaemia in the EHFP + MNP and EHFP groups compared with the control group. However, adding MNP to EHFP programme yielded no significant benefit on anaemia reduction among children in Baitadi District of Nepal. Further studies are needed to confirm the findings obtained in this study with regard to using agriculture interventions as a platform for MNP distribution and if such a combined programme provides any significant additive benefit on child nutritional status compared with providing each programme separately.

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Conflicts of interest

The authors declare that they have no conflicts of interest. However, after this research, D. Adhikari accepted an appointment with USAID.

Contributions

AKO, PP, DS and NH conceptualised the study. AKO, PP, DS, DA and DD designed and conducted the research. AKO, DA and CM analysed the data and wrote the manuscript. PP, DS and DD provided comments on the paper. AKO and PP had the primary responsibility of final contents. All authors read and approved the final manuscript.

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