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Gina Mucciardi

What works? Exploring the evidence base of rigorous homestead food production intervention studies conducted in South Asia: A systematic literature review of program component effectiveness to inform future intervention designs in this region.

By

Gina Mucciardi
MPH

Hubert Department of Global Health

Sheela Sinharoy, PhD, MPH
Committee Chair

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By

Gina Mucciardi
BS
Boston University
2013

Thesis Committee Chair: Sheela Sinharoy, PhD, MPH

An abstract of
A thesis submitted to the Faculty of the
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in partial fulfillment of the requirements for the degree of
Master of Public Health
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Abstract

What works? Exploring the evidence base of rigorous homestead food production intervention studies conducted in South Asia: A systematic literature review of program component effectiveness to inform future intervention designs in this region.

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Micronutrient malnutrition is a major global issue with nearly one third of the world's population suffering from at least one essential micronutrient deficiency, with women and children under five in South Asia experiencing the highest rates of nutrient deficiencies and resulting health problems. Homestead food production interventions have been implemented to improve maternal and child nutrition in LMICs for the past 30 years. The purpose of this review is to synthesize the evidence base of rigorous homestead food production intervention studies to discern patterns of effectiveness within the interventions by component type utilized. Four publications were initially sent to this author by a partnering research team at Emory University, and additional publications were identified through forward and backward snowballing search strategy where references were carefully scanned and read for relevancy.

In total, ten publications representing eight intervention studies were included for review detailing homestead food production intervention trials in South Asia. Nutrition outcomes and intervention component types were qualitatively coded, and results analyzed. All intervention components included group- and one-on-one education components; asset distribution and/or animal, poultry, or fish promotion were employed in six out of eight studies, marketing training was included in three studies, and a mass media component was included in one. More studies presented nutrition outcomes for women (n=8) than for children (n=5). The most common outcome measured was dietary intake, for which the studies nearly all reported significant improvements for women (n=7 with 1 mixed result) and children (n=3 with 1 mixed result).

No studies reported improvement children's anthropometry (n=3). Mixed results were reported for women's and children's anemia and women's anthropometry. Surprisingly, only one study examined women's micronutrient status and no studies examined children's micronutrients status.

While the intervention designs, nutrition outcomes measured, and methodology for measurement in these studies were largely heterogeneous, homestead food production interventions increase nutrient-rich food production and consumption at the household level, warranting continued research and support of programs in areas where micronutrient malnutrition is a public health problem.

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Table of Contents

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Introduction

Micronutrient malnutrition is a major global issue with nearly one third of the world's population suffering from at least one essential micronutrient deficiency, as food systems in many low- and middle-income countries (LMICs) are not delivering nutritionally adequate diets across all populations (Mkambula et al., 2020). Women and children under five are most vulnerable and are disproportionately affected, as pregnancy, lactation, and children's rapid growth and development yield high metabolic demand for micronutrients (Tam et al., 2020). To this effect, micronutrient deficiencies in utero can lead to low birth weight and brain and spinal defects. Forty-five percent of all deaths of children under five in LMICs are caused by maternal and child undernutrition, and pregnant women with anemia are twice as likely to die during or shortly after pregnancy than non-anemic women (Olson et al., 2021). Inadequate nutrition of the mother in the critical first 1,000 days of child growth and development can cause irreversible mental and physical stunting in the child, as nutrient-deficient diets of a pregnant or lactating woman result in limited nutrients being delivered to the fetus or child (Black et al., 2013).

Compared to other regions of the world, South Asia has a disproportionately high burden of micronutrient deficiencies, particularly dietary iron, iodine, zinc, and vitamin A (Han, Ding, Lu, & Li, 2022), and has the greatest number of children affected by stunting and wasting globally, with 54 million children stunted and 25 million wasted (UNICEF, WHO, & World Bank Group, 2021). Undernutrition in South Asia has many potential causes, including lack of

resources, inadequate quality and quantity of foods consumed or available for consumption, and frequent infections (Johns, Booth, & Kuhnlein, 1992). Additionally, lack of knowledge of the causes and consequences of nutritional deficiencies may perpetuate poor nutritional practices and further contribute to the burden of undernutrition (Black et al., 2013).

Historically, nutrition-specific interventions such as food fortification or high-dose vitamin or mineral supplementation have been used to treat or prevent micronutrient deficiencies in LMICs (Tam et al., 2020). While effective in the short term, micronutrient supplementation as an intervention to treat deficiency in low resource settings is limited by a strong dependency on international funding, unreliable and inconsistent delivery systems, dependence on individual compliance, and an inability to reach all high-risk populations (Jones et al., 2005). Research pertaining to vitamin A has found that high-dose supplementation alone is not sufficient to eliminate deficiency, and instead should be accompanied by nutrition and health intervention programs for maximum impact (Jones, 2005). Food fortification, although a safe, effective, and highly utilized strategy for preventing micronutrient deficiencies in high-income countries (HICs), is still less common in LMICs (Olson et al., 2021).

To address the limitations of nutrient-specific interventions, nutrition-sensitive approaches, promoting production of food at the homestead intended for home consumption have been increasingly implemented to strategically improve the micronutrient status of women and children in developing countries, and have been recognized as a potentially sustainable, long-term approach to addressing and preventing undernutrition of the entire household throughout the lifespan (Bushamuka et al., 2005). Delivered with supplementary nutrition education and sometimes paired with poultry or fish rearing, these agricultural production programs aim to create and improve year-round home gardens (also called ‘kitchen gardens’)

and encourage the consumption of homegrown, micronutrient-rich foods with seasonal harvesting and replanting of seeds for continued production and may lead to overall improvement in diet and ultimately support household independence (Jones et al., 2005).

Often tailored to women, since women typically do the gardening and cooking for the household, homestead gardening approaches to undernutrition are considered reasonable to implement at scale because home gardening is already a traditional practice of rural households of many LMICs (Talukder et al., 2010). Interventions of this type teach improved gardening techniques for increased and year-round production, promote or introduce more nutrient-dense species, and provide education regarding food-specific nutrient contents and their functions and significance in the body. Home garden approaches encourage the outputs of production to be consumed by the household, and therefore these programs, while primarily targeting women, may benefit nutrition status of the entire household by increasing the quality and quantity of foods produced, prepared, and available for home consumption (Berti et al., 2004).

International nonprofit Helen Keller International (HKI) has developed an integrated nutrition-sensitive and nutrition-specific program model to improve the nutrition status of rural, food-insecure women and young children. The program uses agriculture as a delivery platform and participating households receive a package of services, which encompass agriculture, nutrition, health, gender empowerment, and income generation strategies to promote optimal nutrition through increased food access and dietary diversity by enabling year-round home food production. This program model, called Homestead Food Production (HFP) was initiated in 1988 in Bangladesh, and has been employed throughout South Asia for over 30 years. The model eventually shifted to incorporate poultry rearing for home consumption of eggs and meat, and

this program model is known as Enhanced Homestead Food Production (EHFP) (Haselow, Stormer, & Pries, 2016).

Homestead food production interventions have the potential to reduce the prevalence of micronutrient deficiencies in women and children, as garden produce can be an important source of multiple micronutrients, including vitamins A, C, B-complex, and iron (Bushamuka et al., 2005). The promotion and training of raising small livestock, poultry, or fish in a homestead food production intervention may additionally contribute to food availability directly by introducing animal-source foods for production and household consumption, and will introduce essential fatty acids, protein, choline, vitamin A, vitamin B, and zinc into the diet. A small livestock, poultry, or fish component may also contribute to food availability indirectly via the sale of or exchange of animal-source products for other foods (Lambrecht et al., 2023).

The purpose of this review is to synthesize evidence from methodologically rigorous homestead food production intervention studies with nutrition outcomes in South Asia and explore the effect of each nutrition outcome by the intervention components. The objective of this review is to systematically examine nutrition outcomes measured and the individual components of homestead food production interventions in South Asia to discern patterns of effectiveness within the evidence base. This work seeks to inform best practice for future interventions in this region and may be considered with the needs of a population for maximum nutritional impact and sustainability.

Methods

A scoping review was carried out to identify homestead food production intervention studies that measured and reported on at least one nutrition outcome in South Asia. A scoping

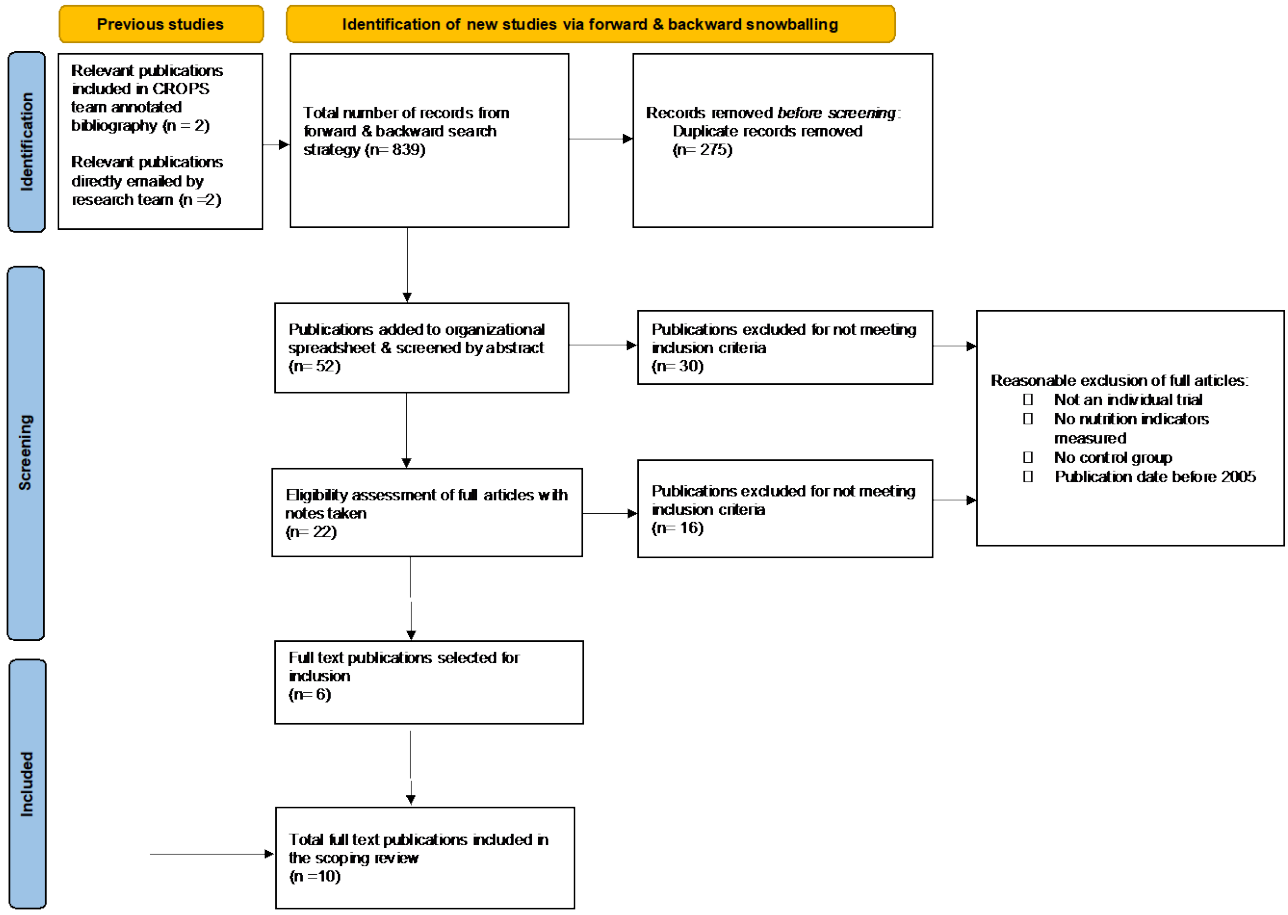
review is a preliminary assessment of the potential size and scope of available research literature. It aims to identify the nature and extent of research, including ongoing research (Grant & Booth, 2009). For studies to be considered, the food production must have been intended for household consumption, rather than for income generation, with women as the recipient of project activities, and women and/or children as the primary beneficiaries of the program. Nutrition outcomes include anemia, anthropometry, micronutrient status, and dietary intake (a broad indicator encompassing dietary diversity and maternal, infant, and young child nutrition (MIYCN)). Studies without a control or comparison group were considered to be less rigorous and were therefore excluded, as were publications that were not peer-reviewed, including reports and conference presentations. Articles published prior to 2005 were excluded, and due to language barriers, publications not written in English were also excluded.

At the onset of data collection, this author was provided with an annotated bibliography of literature pertaining to homestead food production intervention studies from around the world that had been compiled by researchers from Emory University, who at the time of this writing are planning to leverage a previously implemented water, sanitation, and hygiene intervention for improved nutrition through a homestead food production intervention trial in Odisha, India in partnership with Indian local non-governmental organization (NGO) Gram Vikas. Five of the 17 studies included in the annotated bibliography met the geographic criteria and all were read. Of the five, two met all criteria for inclusion and were ultimately included. The Emory research team later sent this author an additional two publications from 2022, one of which met all inclusion criteria. The other was a study protocol for a trial whose results were not yet published (Wendt et al., 2019), but it was known through personal communication that the trial had observed significant positive impacts on women's and children's dietary diversity. Using these

four papers and several systematic reviews from the annotated bibliography as a starting point, additional papers were identified by employing forward and backward snowballing, a search strategy where all studies cited and all citing studies for each paper were carefully explored and scanned for relevancy. As of March 2023, the results from the Wendt et al. study protocol were published and forwarded to this author, who employed additional forward and backward snowballing to exhaustively search the evidence base.

As part of the snowballing strategy, all references were first scanned for relevancy. Studies that were considered for review were added to a Google Sheets spreadsheet. Studies included in the spreadsheet were individually reviewed. If the publication met all criteria for inclusion, comprehensive notes were taken, with special attention paid to study objectives, methods, details of the intervention, and nutrition outcomes measured, with the methodology used for measurement. From the snowballing search strategy, 839 references were scanned in total, including duplicates. Of that number, 52 were added to the organizational spreadsheet and read. Comprehensive notes were then taken on 23 publications, of which 14 were eventually eliminated for not meeting all inclusion criteria upon closer inspection. Ultimately, ten publications were selected, detailing eight homestead food production intervention studies with publication dates ranging from 2005 to 2023 (Figure 1). Two studies, detailed in Wendt et al., 2019 and Schreinemachers et al., 2015, each have a second publication detailing additional nutrition-related results. Lambrecht et al., 2023 presents results from the Wendt et al., 2019 intervention trial, and Verbowski et al., 2018 presents additional results from the Michaux et al., 2019 trial.

Figure 1: Flow chart diagram and PRISMA checklist describing selection of publications for scoping review



For analysis, this author developed a qualitative coding system with codes representing different types of intervention components and nutrition outcomes to encompass all intervention activities employed and all nutrition outcomes measured across the studies. Intervention components were ultimately grouped into 1-on-1 education (including individual counseling or household visits providing technical assistance), group education (including the use of women's farmer groups, community or courtyard sessions, spousal group education, Participatory Learning and Action (PLA) groups, and any group activities conducted at a village model farm), asset distribution (including the distribution of seeds, saplings, trees, vines, poultry/chicks, tools,

feed, fertilizer, or monetary reimbursement for any intervention activities promoted), animals or fish (including the promotion of any poultry, fish, or livestock-rearing activities), marketing or income generation training activities, and the use of mass media to enforce the intervention's educational messaging. Codes for nutrition outcomes for women and children included anemia status (via hemoglobin measurement), micronutrient status, dietary intake (including dietary diversity, intakes of specific foods, food groups, or nutrients, as well as reported MIYCN practices), and anthropometry. Intervention and outcome codes were then applied to the detailed notes, and coded text segments were analyzed along with the study results for patterns across the included studies.

Results

The findings of the studies selected for inclusion are summarized in Table 1. The studies took place in Bangladesh (n=3), Nepal (n=3), India (n=1), and Cambodia (n=1), with results published between 2005 and 2023 All interventions (n=8) included group- and one-on-one educational components as part of the project activities. The interventions had an average of 3.8 coded component types, with a minimum of two (n=2) and a maximum of five (n=2). Intervention activities were conducted for an average of 33.8 months, and all involved the promotion of home gardens with agricultural training and nutrition education, as is common practice in homestead food production interventions globally (Berti et al., 2004).

Table 1. Summary of findings from nutrition-sensitive agriculture intervention studies with nutrition outcomes conducted in South Asia

Author(s), year, study location	**Evaluation design**	**Intervention**	**Nutrition outcomes measured**	**Nutrition Findings**	**Author's own conclusion**
Lambrecht et al., 2023. Bangladesh	1:1 Cluster RCT	See Wendt et al., 2019	Poultry ownership & egg production Women's & children's egg consumption	Significant improvement in poultry production & management practices observed Women's and children's egg consumption significantly increased (doubled) after 1 & 1.5 years, respectively, with increases sustained 1-year post-intervention Poultry production mediated only 12% of the intervention's impact on women's egg consumption	First study to show positive impacts of a multiyear HFP program on poultry production and egg consumption both during and post-intervention. Even without poultry distribution, poultry ownership still increased by ~0.5 chickens & egg production by ~2 eggs per week, comparable to other intervention studies where chicks were distributed. This research suggests that other intervention components like nutrition education and women's empowerment may have contributed more to women's increased egg consumption. Barriers related to shed use, vaccination, & other improved practices may have limited the potential of poultry production to contribute to diets.
Ahmed et al., 2022. Bangladesh	1:1:1:1 Cluster RCT	Tested combinations of trainings to rural spouses focused on **a**gricultural production plus poultry, small stock, & fishponds, **n**utrition BCC, & **g**ender sensitization to improve dietary diversity & diet quality over 17 months All arms: Group education of spouses at community centers. Lectures,	Production diversity, and diet quality	Significant improvement in diet quality, including consumption of homestead fruits, veg, dairy, eggs, & fish in individuals receiving ag & nutrition training together (T-AN, & T-ANG). Impacts observed were higher for women than for men. Production quantity & diversity increased in all intervention arms.	Ag training can increase production diversity, & this alone can improve diet quality. No significant impact of adding gender sensitization on production diversity or diet quality. Implementation fidelity by the Bangladesh Ministry of Ag was high & notable for such a large project. Ag extension workers, rather than health workers, were able to effectively provide integrated ag-nutrition training at a relatively large scale. This can be applicable to other settings where shifting ag

		interactive discussions, demonstrations, & question-answer sessions			production is key to achieving diet goals.
Kadiyala et al., 2021. India	1:1:1:1 Cluster RCT	Tested combinations of training techniques provided at fortnightly women's group meetings: AGRI Group: NSA videos only at meetings AGRI-NUT Group: NSA videos & nutrition-specific videos at meetings AGRI-NUT + PLA Group: NSA videos, nutrition-specific videos, plus PLA meetings Follow-up HH visits made to all participants	Primary: Children's dietary diversity & mean maternal BMI Secondary: Mother's dietary diversity & child wasting Also, maternal & child MUAC & hemoglobin	Increased dietary diversity in children in AGRI-NUT & AGRI-NUT + PLA groups (but not AGRI group) No observed effects on mean maternal BMI Increased maternal dietary diversity in AGRI & AGRI-NUT + PLA group (but not AGRI-NUT group) No observed effects on child wasting	The strongest associations were seen in groups with interventions plus PLA cycle meetings, suggesting that the participatory component of the PLA cycle could accelerate NSA intervention improvements in dietary quality. The participatory component of meetings could have created an enabling environment for women to implement the knowledge and strategies taught in the videos
Wendt et al., 2019. Bangladesh	1:1 Cluster RCT Study protocol paper	FAARM: 3-Year HKI HFP Intervention Women's group education: Farmer group trainings, led by & held at designated lead farmer family's VMF (topics: ag-nutrition + child feeding + poultry) Community group education: Courtyard sessions for participants & family members conducted by project staff (nutrition, health, & hygiene BCC) Asset distribution: Seeds & saplings plus	Women's & children's dietary diversity & anthropometry Women's & children's anemia status (hemoglobin), plus micronutrient status: vitamin A (RBP), iron (SF & transferrin receptors), & zinc (serum zinc)	See Lambrecht et al., 2023 for findings pertaining to women's and children's egg consumption Other results not yet published	None - Study protocol paper

		reimbursement for improved poultry shed, starter feed, & watering stations Household visits (nutrition, health, & hygiene BCC + garden/poultry TA) Marketing training in year 3			
Michaux et al., 2019. Cambodia	Longitudinal cluster RCT	EHFP: Home garden training, including asset distribution (seeds, seedlings, tools, etc.). BCC on nutrition, including MIYCN, plus hygiene, women's empowerment, & marketing EHFP+F: EHFP intervention plus training to build fishponds and fish-raising inputs Group training & 1-on-1 counseling both conducted at the VMF	Women's and children's Hemoglobin/anemia & anthropometry (maternal BMI, child WHZ & WAZ) Non-pregnant women's RBP, serum ferritin, sTfR, AGP, and CRP concentration	Compared with controls, statistically significant reduction in child anemia observed (-14% in EHFP group, P = .02) & improved RBP concentration in nonpregnant women (in EHFP+F group). No other statistically significant effects on anemia, nutritional biomarker concentrations, or anthropometry were observed.	This research shows a positive impact of a 22-month EHFP intervention on child's anemia prevalence & an increase in RBP concentrations among non-pregnant women receiving the EHFP+F intervention, compared to control. Clinical significance of increases in women's RBP is questionable as no women presented deficiencies at baseline. Longer duration studies are required to explore the full impact of NSA programs on nutrition status & anthropometry.
Verbowski et al., 2018. Cambodia	Longitudinal cluster RCT	Same as Michaux et al., 2019	Women's and children's nutrient intakes (via multiple-pass 24-h dietary recall)	Women had significantly higher zinc & vitamin A intakes in the EHFP & EHFP+F groups. Women in the EHFP+F group also had significantly higher iron & riboflavin intakes, & significantly lower prevalence of inadequate iron, vitamin A, & riboflavin. No significant differences in nutrient intakes observed in children.	In both intervention groups, increases in certain micronutrient intakes were observed among women, but not in children. The EHFP+F group also showed lower prevalence of nutrient inadequacy for certain micronutrients among women. Because very few women showed deficiencies at baseline, program impact is questionable.

Osei et al., 2017. Nepal	Prospective, non-blinded, multistage cluster RCT* *Independent cross-sectional survey data used for analysis	HKI EHFP program consisting of home garden, poultry raising, and nutrition education Monthly group education at a VMF & 1x distribution of seeds, saplings, & chicks at the start of summer & rainy seasons in year 1 Monthly meetings at the VMF to reinforce ag/poultry lessons, plus SBCC & provision of public health services offered in the communities Monthly home visits to provide TA, monitor progress, & reinforce educational messages	Maternal and child (12-48 months) anthropometry & anemia	*Anthropometry:* Children: No demonstrated impact on child anthropometry. Women: No significant change in BMI post-intervention. No significant change in underweight prevalence post-intervention in the treatment group, but multivariate logistic regression models showed that at the endline, women in the treatment group were 39% less likely to be underweight compared to controls. *Anemia:* Children: Prevalence was significantly lower at endline (30.8%) compared to controls (42.5%) Women: Prevalence was significantly lower in the intervention HHs at endline (24.6%) compared to baseline (19.6%) and prevalence in intervention group was significantly lower than controls at endline	This study showed that an integrated intervention including home gardening, backyard poultry rearing, & nutrition behavior change communication can play an important role in improving HH food security, maternal handwashing & child feeding practices, use of certain preventive health services, and maternal and child anemia as well as maternal underweight. However, there was no demonstrated impact on child growth. Further research over a long period is needed to assess the potential impact of HFP interventions on child growth. Study limitations: Pre- and post-intervention cross-sectional surveys were used to collect data, which reduced their ability to attribute the observed changes in outcomes to the intervention.
Cunningham et al., 2017. Nepal	Mixed methods (randomized, quasi-experimental)	Multi-sectoral nutrition plan to address undernutrition including mass media, community mobilization, & group & individual education Integrated programming across nutrition, health	Maternal & child dietary diversity, maternal & young child nutrition (MIYCN) practices,	In intervention areas, children 6-23 months had overall higher dietary diversity, & more children consumed dairy & eggs Significant increases observed in women's dairy, eggs, & 'other fruits and vegetables'	After only 2 years of full program intervention, large differences were found in exposure, knowledge, & some practices between comparison & intervention groups for MCH & nutrition, as well as WASH. Process evaluation results confirm effective scale (on some/many behaviors) & reach can be obtained in multi-sectoral nutrition programs, while simultaneously addressing

		services, family planning, WASH, & agriculture/HFP implemented primarily through Nepal's female community health volunteers (FCHVs) in routine home visits and mother's group meetings		consumption vs. control 10 out of 15 self-reported MIYCN practices increased significantly among women in the intervention group.	equity gaps. First process evaluation (PE) to assess not only overall program progress but also equity-based variation in program coverage and uptake.
Schreinemachers et al., 2015. Bangladesh	Mixed methods (randomized, quasi-experimental)	Women's group education: 1-day intensive training focusing on nutrition and improved garden establishment (classroom teaching + hands-on practice in demonstration garden) 1-on-1 Education: Home visits with technical assistance 1x/week for first 6 months, then 1x/month for next 6 months Asset distribution: Vegetable seed packs & sweet potato vines distributed during home visits	Veg production, micronutrient yields & quantity, & dietary diversity	Significant increase in diversity of veg consumption. Average number of months with regular harvesting increased from 4 to 10. Intervention group harvested significantly more veg per capita per year than control (37 kg vs. 20 kg). Intervention group produced significantly greater quantities of plant proteins, calcium, iron, vitamin A, & vitamin C through their garden produce, primarily due to more intensive cultivation of leafy vegetables.	While the intervention group produced greater quantities of nutrients, potential supply may not be fully realized due to spoilage or malabsorption. Nevertheless, an increase in the production & consumption of veg is a necessary precondition for nutritional improvements to occur. Although participants had to have expressed interest in participating to be part of the study, the study team took steps to minimize selection bias and do not consider it an issue.
Jones et al., 2005. Nepal	Mixed methods (randomized, quasi-experimental)	Five 2-hour group training sessions (brief lecture + hands-on activities) held weekly at an NDH: Nutrition education with recipe demonstration, WASH, & kitchen garden training with additional reinforcing group education at community centers	Adults' consumption of micronutrient-rich vegetables and animal-source foods, maternal nutrition practices	*Dietary intake:* Reported frequency of vegetable consumption was significantly higher in the intervention group. Animal-source food intake did not differ between groups, despite nutrition education to promote its consumption. 4 out of 5 self-reported MIYCN practices	Due to the cross-sectional design of the study, it is not possible to prove causality between participation in the intervention & better nutrition. The overall very poor performance on the nutrition knowledge test in both groups highlights the need for more extensive community nutrition education.

		(farmer/women's group meetings) Home visits by project staff providing TA, seeds, & nutritional education This intervention was layered onto the existing MARD project which aimed to increase production of high-income crops		increased significantly among women in the intervention group.	Nutrition practices were better in the intervention group, but practices were reported and not observed; possibility for respondent bias based on messaging received in the program. By providing quality seed & TA on veg production, the intervention increased HH access to micronutrient-rich plant-source foods.

Abbreviations

AGP: Alpha-1 acid glycoprotein
BCC: Behavior change communication
CRP: C-reactive protein
EHFP: Enhanced homestead food production
HFP: Homestead food production
HH: Household
HKI: Helen Keller International
MARD: Market Access for Rural Development
MCH: Maternal and child health
MIYCN: Maternal, infant, and young child nutrition
NDH: Nutrition demonstration household
NSA: Nutrition-sensitive agriculture
PLA: Participatory learning and action
RBP: Retinol-binding protein
RCT: Randomized controlled trial
SBCC: Social and behavior change communication
SF: Serum ferritin
sTfR: Soluble transferrin ferritin receptor
TA: Technical assistance
Veg: vegetables
VMF: Village model farm
WASH: Water and sanitation hygiene
WAZ: Weight-for age z-score
WHZ: Weight-for-height z-score

Tables 2 and 3 depict findings of the selected nutrition outcomes in women and children, respectively, by the coded intervention component types implemented in each study. In Tables 2 and 3, each publication is given a different symbol; symbols in black indicate that a positive, significant impact was observed on the nutrition outcome of interest, and symbols in red indicate no significant impact was observed. Studies that reported mixed findings for a given outcome are indicated by the presence of two symbols, one in black and one in red.

Table 2: Studies demonstrating effectiveness for improving selected nutrition outcomes in women by intervention component types.

Women's Outcomes	**Group Education** (n=8)	**1-on-1 Education** (n=8)	**Asset Distribution** (n=6)	**Animals/Fish** (n=6)	**Marketing Training** (n=3)	**Mass Media** (n=1)
Hemoglobin/Anemia	Ω ⦸ ♤	Ω ⦸ ♤	Ω ⦸	Ω ⦸	⦸	
Micronutrient Status	⦸ ⦸	⦸ ⦸	⦸ ⦸	⦸ ⦸	⦸ ⦸	
Dietary Intake	♛ ∇ ൭ ⇔ ↟ ➤ ♤ ♤	♛ ∇ ൭ ⇔ ➤ ♤ ♤	♛ ∇ ⇔ ↟ ➤	♛ ➤ ⇔ ↟	♛ ➤	൭
Anthropometry	♤ Ω Ω ⦸	♤ Ω Ω ⦸	Ω Ω ⦸	Ω Ω ⦸	⦸	

Table 3: Studies demonstrating effectiveness for improving selected nutrition outcomes in children by intervention component types.

Children's Outcomes	**Group Education** (n= 4)	**1-on-1 Education** (n=4)	**Asset Distribution** (n=2)	**Poultry/Fish** (n=2)	**Marketing Training** (n=1)	**Mass Media** (n=1)
Hemoglobin/Anemia	Ω ⦸ ♤	Ω ⦸ ♤	Ω ⦸	Ω ⦸	⦸	
Micronutrient Status						
Dietary Intake	♛ ♤ ♤ ൭	♛ ♤ ♤ ൭	♛			൭
Anthropometry	♤ Ω ⦸	♤ Ω ⦸	Ω ⦸	Ω ⦸	⦸	

Symbols denoted in black indicate positive, significant impact. Symbols denoted in red indicate no finding.

♛: Lambrecht et al., 2023
↟: Ahmed et al., 2022
♤: Kadiyala et al., 2021
⦸: Michaux et al., 2019
➤: Verbowski et al., 2018
൭: Cunningham et al., 2017
Ω: Osei et al., 2017
∇: Shreinemachers et al., 2015
⇔: Jones et al., 2005

Anemia

Four studies aimed to improve maternal anemia, of which three (Kadiyala et al., 2021, Michaux et al., 2019, & Osei et al., 2017) have published their findings at the time of this writing (Wendt et al., 2019 results pertaining to anemia status have not yet been published). All three included group- and one-on-one education formats, two included the promotion of either poultry or fish, but only one trial reported significant improvement in women's anemia status. This intervention, by Osei et al., employed an EHFP model designed in conjunction with HKI and promoted poultry rearing in addition to home gardens. Chicks, starter feed, and reimbursement for improved poultry sheds and home gardens were distributed by the project staff.

The same three studies also measured impacts on children's anemia. Two of the three studies (Osei et al. & Michaux et al.) reported a significant impact on children's anemia status. Both interventions included group- and one-on-one education, poultry (Osei et al.) or fish (Michaux et al.) production, and asset distribution to implement the technical production methods taught. Additionally, marketing training was included in project activities by Michaux et al. While not discernible from the results, marketing training may have contributed to improved anemia status in children by empowering women with tools to generate surplus income that was used to purchase supplementary foods for the child to consume. In all studies, hemoglobin was measured by HemoCue with the same cutoffs for anemia (Women: Hb < 120 g/L; Children: Hb < 110 g/L).

Anthropometry

Three intervention trials aimed to improve women's anthropometry. Kadiyala et al., 2021 measured nonpregnant maternal body mass index (BMI) and mid-upper arm circumference

(MUAC), Osei et al., 2017 measured nonpregnant maternal BMI and maternal underweight (with underweight defined as a BMI of <18.5 kg/m^2), and Micheaux et al., 2019 measured the prevalence of nonpregnant maternal underweight only (using the same cutoff of BMI <18.5 kg/m^2). All three studies were relatively robust in that they had at least three to five of the coded intervention components. However, only one study, by Osei et al., reported any significant improvement in women's anthropometry at endline, and improvement was only observed in one indicator (maternal underweight). No effect was observed on mean maternal BMI. Overall, across all studies, homestead food production interventions are not yet consistently measuring women's anthropometry, nor are they observing positive impacts on women's anthropometry at endline.

The same three studies also aimed to improve children's anthropometry and observed even less evidence of an impact. Across all three studies, no impact was observed on children's anthropometry, including child wasting (n=3), stunting (n=2), or underweight (n=2), even though two of the three studies promoted calorie-dense animal and fish food products and all of the interventions increased overall food availability for the households.

Micronutrient Status

Only one study (Michaux et al., 2019) examined micronutrient status of women. Venous blood samples were analyzed at endline, and mixed findings were observed. One arm of the intervention (EHFP plus fishponds) saw significant improvement in non-pregnant women's vitamin A status as measured by retinol binding protein (RBP) concentration, but no significant impacts were observed for iron status (via serum ferritin & sTfR concentrations). The intervention arm that saw significant improvements in women's vitamin A status included home

garden plus fishpond training in a group setting at a village model farm, ongoing ad-hoc technical support, asset distribution to begin home food production activities, and women's marketing training.

None of the studies examined micronutrient status of children. The study protocol detailed in Wendt et al., 2019 includes outcome indicators for women's and children's vitamin A, iron, & zinc status, but at the time of this writing those results have not yet been published.

Dietary Intake

Unsurprisingly, dietary intake was the most frequently measured nutrition outcome among the studies, with seven of the eight studies quantifying their intervention's effects on women's dietary intake in some way, and widespread success was observed. All seven reported significant positive impacts on dietary intake in at least one intervention arm. The dietary intake measures varied widely across studies: two measured women's dietary diversity (Kadayala et al. 2021 & Cunningham et al., 2017), two measured diversity of vegetable consumption specifically (Jones et al., 2005 and Schreinemachers et al., 2015), and one measured solely egg consumption (Lambrecht et al., 2023, although Cunningham et al. and Ahmed et al., 2022 also reported results on egg consumption). Additionally, Verbowski et al., 2018 estimated macronutrient and micronutrient intake and prevalence of nutrient inadequacy by applying food composition data to multiple-pass 24-hour dietary recalls as developed and validated by Gibson and Ferguson (2008). Lastly, Ahmed et al. measured diet quality, an adaptation of the Global Diet Quality Score (GDQS), a measure designed to be sensitive to multiple forms of malnutrition. It is important to note that in the Ahmed et al. study, results for diet quality were not presented separately for men and women, but it was mentioned that all impacts observed were larger for women than for men.

Both Kadiyala et al. and Cunningham et al. investigated and reported significant improvements in women's minimum dietary diversity and children's dietary diversity at endline, although different indicators for women's dietary diversity were used. For women, Kadiyala et al. used the Food and Agricultural Organization (FAO) Minimum Dietary Diversity for Women (MDD-W) indicator, which defines minimum dietary diversity as having consumed at least five of ten possible food groups in the previous 24 hours, while Cunningham et al. defined minimum dietary diversity for women as having consumed at least four out of eight possible food groups in the previous 24 hours. For children both studies, Minimum Dietary Diversity (MDD) was measured: the proportion of children ages 6-23 months consuming at least 4 of 7 food groups the previous day as reported by the mother via 24-hour recall. Both interventions included a group education and a 1-on-1 education component. Assets were not distributed, nor were animals or fish promoted, and no marketing/income generation trainings were provided. From these results, it appears as though homestead food production interventions that are purely educational in nature can have a significant impact on women's and children's minimum dietary diversity.

Both Jones et al. and Schreinemachers et al. investigated and reported significant improvements in the diversity of vegetables consumed by women at endline, with Jones et al. reporting that participants consumed significantly more of 13 out of 16 vegetables promoted by the program, and Schreinemachers et al. reporting that post-intervention, one additional type of vegetable was consumed on average by women in the intervention group. Both the Jones et al. and Schreinemachers et al. interventions included a group education component, a one-on-one education component, and asset distribution in which seeds were distributed by program staff. A follow-up paper published by Schreinemachers, Patalgsa, and Uddin in 2016 found that after two years, intervention households consumed 19.3 additional grams of vegetables and fruits per day

than controls. From these results, it appears as though a combination of group education, one-on-one education, and asset (seed) distribution can have a significant and lasting impact on women's vegetable consumption.

Both Jones et al. and Cunningham et al. promoted optimal MIYCN practices in their intervention programming, and significant improvements were reported by participating women in both studies at endline (Jones et al. reported improvement in 4 out of 5 practices and Cunningham et al. reported improvement in 10 out of 15 practices). In addition to group- and one-on-one education components, the Cunningham et al. intervention included a complementary mass media component to broadcast their program's educational messages to the population at large. Effect sizes for reported improvement in MIYCN practices were greater in the Cunningham et al. study, which might be attributed to the reinforcement of educational messaging through the mass media channels (radio, billboards, posters, and community events).

One publication (Lambrecht et al., 2023) reporting partial results from the Wendt et al., 2019 trial, described a significant observed impact on women's and children's egg consumption at endline and one year post-intervention. In total, three studies presented results on their intervention's impact on egg consumption. In addition to Lambrecht et al., Ahmed et al. and Cunningham et al. also report significant improvements in women's (Ahmed et al.), and women's and children's (Cunningham et al.) egg consumption at endline via their dietary diversity results. Interestingly, only one of the studies (Lambrecht et al.) directly trained participants in poultry rearing and provided assets and individual technical assistance to participating women. The training in Ahmed et al. only discussed methods for home poultry production during the group education sessions, and egg and poultry consumption were only encouraged in the nutritional education provided by Cunningham et al.. These results suggest

that increases in women's and children's egg consumption are possible by nutrition or technical education alone, without hands-on assistance or asset distribution for beginning a home poultry production practice.

While comparisons cannot be made across studies for nutrient intake or prevalence of nutrient inadequacy (only observed by Verbowski et al.) in women and children, or for the diet quality indicator examined by Ahmed et al., it is important to note that these studies reported significant improvements in these outcomes (in Verbowski et al., for women and children, and in Ahmed et al., for children).

Discussion

Overall, vast heterogeneity exists across the studies by intervention components employed, nutrition outcomes measured, and results observed. While all studies measured at least one nutritional outcome for women, only five measured any nutritional outcomes for children. Notably, no studies had any impact on children's anthropometry (n=3), and only one had an impact on women's anthropometry. Nearly all of the studies measured dietary intake for women (n=7), while only half of the studies measured dietary intake for children (n=4). Across the studies that measured dietary intake, significant improvement was widely observed for both women and children at endline. Although dietary intake is the precursor to improved nutrition and micronutrient status, the ultimate translation of agricultural-nutrition interventions to improved micronutrient levels of women and children in these interventions remains largely unknown, as none measured nutrient biomarkers in children, and only one measured any in women. Regarding anemia status, mixed findings were reported for both women and children, and were assessed by hemoglobin concentration alone. Although more success was observed in

reducing anemia in children (n=2) than in women (n=1), these results should be interpreted with extreme caution since anemia can be caused by more than just iron deficiency. Other biomarkers (ideally ferritin levels or transferrin saturation concentration) should be measured in conjunction with hemoglobin to detect differences in iron deficiency anemia (Al-Naseem et al., 2021).

The findings from this review are consistent with those of other reviews, which have concluded that the evidence base for the effects of agriculture-nutrition interventions on maternal and child nutrition outcomes globally is scant and has largely produced mixed results, most studies lack methodological rigor, and comparability across studies is difficult due to varying objectives and inputs, with difficulties faced in discerning which intervention components are driving impacts (Berti et al., 2004, Margolies et al., 2022, & Ruel, Alderman, & the Maternal and Child Nutrition Study Group, 2013). These findings also corroborate those of other reviews that have found that agriculture-nutrition programs have the capacity to improve the production and consumption of nutrient-rich foods at the household level (Ruel, Quisumbing, & Balagamwala, 2018), as well as improve the diet diversity scores of children under five (Margolies et al., 2022).

Implications/Recommendations

While some benefits are widely understood, more research is needed on the effects of agriculture-nutrition interventions on women's and children's nutrition outcomes in South Asia. To build the evidence base, additional randomized controlled trials are needed in a large variety of interdisciplinary projects in the region, with interventions jointly designed by public health practitioners, nutritionists, agricultural-, and social scientists. Based on the evidence, it is recommended that future interventions should include one-on-one intervention component in addition to group education to enforce the program's educational messaging, with at least one

other component type, particularly if the nutrition outcome of interest is to improve dietary intake. When designing future studies, nutrition outcomes should be both streamlined and standardized to increase comparability across studies, and whenever possible, gold-standard methods or next-best practices for measurement should be used for measuring nutrition outcomes. To the extent possible, intervention component design should also be standardized, so that combinations of components may be tested against the standardized outcomes. Communication and collaboration within the research community is essential to work toward standardization and will ultimately benefit all parties and advance the science. Implementation fidelity should be prioritized by program staff in future interventions, with quality control exercised over all program activities and outcome measurements to best estimate design effect and ensure data quality.

Not much is yet known about the long-term effects of agriculture-nutrition interventions, nor what is necessary to sustain nutrition benefits after the intervention period is over. Future research should be conducted to study the effects of these programs on women's and children's nutrition years after program completion, and future studies should be designed to measure their effects at endline as well as years after endline. A stronger evidence base supporting the efficacy and long-term effects of these programs has the potential to influence policy decisions that support the implementation of more interventions in more areas, ultimately empowering and supporting the health, independence, and resilience of more women and their families globally.

Strengths and Limitations

Strengths of this review include the use of only methodologically rigorous studies for evaluation including randomized controlled trials and quasi-experimental studies. The

publications included are timely and relevant, with six out of eight study results published within the last six years. Limitations include the inability to generalize results given the considerable variability in intervention component types, outcome indicators, and method of indicator measurement. Individual study components cannot be separated out from the intervention at large, so individual component effectiveness cannot be determined. Also, component types coded together may have been conducted very differently across studies (for example, while two studies may have both been coded for animal/fish promotion, one study may have employed intensive technical education for home animal or fish production, while another may have provided high-level classroom education encouraging production and consumption). Not discussed in this review are results for production quantity and diversity, which are necessary precursors for improved consumption. Also not discussed are improvements in nutritional knowledge which also may lead to improved nutritional practices over time.

Conclusion

While studies have shown that nutrition-sensitive agricultural interventions can improve food availability at the household level, on the macro scale, oil price volatility, climate change and related water shortages, diversion of resources from food to biofuels, armed conflicts, and natural disasters continue to strain the global food supply, with disproportionate effects observed on LMICs (Ruel, Alderman, & the Maternal and Child Nutrition Study Group, 2013). A recent review of the impacts of COVID-19 on diet quality, food security, and nutrition in LMICs found that while the pandemic's impact has been particularly detrimental to women, individuals with low socioeconomic status, informal workers, and individuals relying on daily wages, traditional smallholder farms and food systems with shorter value chains were more resilient to the impacts

of COVID-19 on food security (Picchioni, Goulao, & Roberfroid, 2022). This finding supports the theorized viability of homestead food production to promote self-sustainability even during unprecedented global emergencies. Homestead food production interventions have the potential to improve maternal health and reduce child mortality by increasing the consumption of micronutrient-rich foods for improved micronutrient status. They also have the potential to increase household income through the sale of products, giving women greater control over resources and impart knowledge to women via nutrition education, ultimately promoting gender equality as they empower women to take control over the quality of their families' diets through their own production of nutrient-rich foods and educated consumption choices (Talukder et al., 2010). For all of these reasons, continued research and support of agricultural-nutrition programs in countries where micronutrient deficiencies are a public health problem is absolutely critical to support the health of women and children worldwide.

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