4   A 3-year Cohort Study to Assess the Impact of an Integrated Food- and Livelihood-based Model on Undernutrition in Rural Western Kenya

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Abstract

Reducing extreme poverty and hunger is the first Millennium Development Goal (MDG). With undernutrition contributing to nearly half of all child deaths, improving nutrition is a precondition for accelerating progress towards other MDG targets. While the role of technical interventions such as micronutrient fortification and supplementation in reducing morbidity and mortality has been well documented, evidence to support more comprehensive multi-sectoral approaches remains inconclusive. This chapter aims to evaluate the impact of an integrated food- and livelihood-based model on nutrition-related outcomes in rural western Kenya.

A 3-year prospective cohort study was undertaken among 300 randomly selected wealth-stratified households. Detailed socio-economic and health surveys were conducted. A nutrition module assessed household levels of food security, food consumption frequency and diet diversity. This was complemented by anthropometric measurement and assessments of serum levels of vitamin A among children under 5 years old.

The average food insecurity score decreased from 5.21 at baseline to 4.13 at follow-up ($P < 0.0001$). Average diet diversity scores for daily, weekly and monthly time periods increased from 6.7 to 7.3; from 10.7 to 11.2; and from 12.4 to 12.6, respectively ($P < 0.0001$). Daily consumption for 14 out of 16 food groups increased significantly. For children under 2 years of age, underweight and stunting decreased from 26.2% to 3.9% ($P = 0.002$) and from 62.3% to 38.3% ($P = 0.014$), respectively. Vitamin A deficiency as measured by serum vitamin A levels decreased from 70.0% to 33.3% ($P = 0.007$) for children under 5 years old.

This study presents encouraging evidence that a multi-sectoral food- and livelihood-based model can improve diet quality, enhance food security and positively affect childhood nutritional outcomes. The wider application of this approach to a diversity of agro-ecological zones in sub-Saharan Africa is currently being assessed.

Keywords: diet diversity, multi-sectoral, food security, vitamin A, stunting, food-based

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Introduction

Globally, undernutrition contributes to roughly half of the 8.8 million child deaths that take place each year (1), representing nearly one-third of the global burden of disease among children (2). Micronutrient deficiencies weaken the health, growth and productivity of over two billion people worldwide, placing constraints on the development potential of households, communities and countries (3). The number of undernourished children has increased in many countries over the past decade, with reductions in levels of child mortality levelling off or increasing in a number of countries (4). This disturbing trend has been compounded recently by global food crises and an economic downturn that have compromised fragile gains and plunged many more households into a state of vulnerability and deprivation (5). Decisive action is required to address interdependent relationships between undernutrition and wider Millennium Development Goal (MDG) targets including poverty reduction, maternal mortality and child survival. Despite this urgency, international action in support of new innovations and strategic partnerships to address undernutrition has been limited (6).

The first 1000 days of a child's life (minus 9 months to 2 years) is considered the 'critical window of opportunity' where the potential exists to affect not only child growth and nutritional status, but also cognitive development (7). However, nutrition throughout the life cycle is of critical importance. Although the significance of this time period has been well documented, interventions to improve early childhood nutrition have been fragmented and narrowly focused. Prevailing approaches have generally emphasized supplementation and fortification, relying heavily on the external delivery of target nutrients (8). Broader strategies to address the complex challenges associated with the determinants and consequences of undernutrition remain poorly understood or embraced. Food- and livelihood-based models that enhance the security and quality of the diet through local production, processing and storage of foods, the promotion of agricultural biodiversity, all complemented with community education

and development, which often falls outside the traditional scope of clinical nutrition, have been under-researched and under-developed. As a consequence, well-defined scalable food and livelihood interventions linked to improvements in maternal or child health outcomes have been less embraced by the development community (9).

Recent calls for greater attention to nutrition – including the United Nations' Millennium Project, the recently formed High-Level Task Force on the Global Food Security Crisis, the reform of the World Committee on Food Security and the establishment of the High-Level Panel of Experts on Food Security and Nutrition and the Policy Brief on 'Scaling up Nutrition: A Framework for Action' – highlight the importance of integrating technical interventions with wider efforts to address its underlying causes, incorporating perspectives from agriculture, water and sanitation, infrastructure, gender and education (10–14). Such approaches would build on the knowledge and capacities of local communities to transform and improve the quality of diets for better child health and nutrition. Recent research has documented potential synergies between health and economic interventions, suggesting multi-sectoral approaches may generate a wider range of benefits than approaches of a single sector acting alone (11,15). While these findings may seem intuitive, the testing of complex multi- and cross-sectoral interventions to improve child nutrition and health remains at an early stage of development. Further operational research is urgently required if the benefits of improved food security and economic development are to be expanded and channelled into conventional health and nutrition intervention programmes.

The Millennium Villages Project (MVP) involves the systematic delivery of a package of health and development interventions with the aim of accelerating progress towards the MDG targets (16,17). The project implements a concurrent package of scientifically proven interventions in agriculture, health, education, water and sanitation, and infrastructure at an annual cost of US$110 per person per year sustained over a 5- to 10-year period. The interventions were recommended as

important components in achieving the MDGs by the United Nations' Millennium Project (11,12). The MVP operates in 14 sites in ten sub-Saharan African countries with project sites drawn from a diversity of agro-ecological zones in 'hunger hot-spots' where rates of child undernutrition exceed 20% (17).

The nutrition strategy adopted within the Millennium Villages centres upon an integrated food- and livelihood-based approach. The model has three main components (Fig. 4.1). Clinical interventions are introduced to prevent and mitigate macro- and micronutrient deficiencies among infants and young children. School-based interventions work to improve health, nutrition, school attendance and learning outcomes among primary-school children. Community- and household-based interventions foster increased agricultural production, greater diet diversity and enhanced livelihood security to address longer-term nutritional needs.

We conducted a prospective evaluation of the MVP site in rural western Kenya to assess effects of this multi-sectoral approach on undernutrition over a 3-year project period. Our aim was to test the hypothesis that a food- and livelihood-based model can enhance household food security and diet diversity, increase vitamin A levels, and lead to improvements in anthropometric indicators among children.

Methods

Setting

In December 2004, the MVP was launched in collaboration with the Kenyan government in the Sauri village of the western Nyanza Province. This rural community of 63,500 persons is located in the Kenya highlands, 1400–1500 m above sea level and 30 km north of Lake Victoria with annual rainfall of 1800 mm (18). The main occupations are subsistence farming, consisting primarily of maize, sorghum and cassava and animal husbandry, including goats, chickens and cattle. Before the project started, 79% of the population

lived on less than US$1/day and 90% on less than US$2/day. The infant mortality rate was 149 per 1000 live births, the under-five child mortality rate was 95 per 1000 live births, and 63% of children under 5 years of age tested positive for malaria (16,18).

Integrated multi-sectoral approach to improving nutrition

The major aim of the nutrition programme is to assist communities to eliminate hunger and improve nutrition security. The three components of the strategy are outlined in Fig. 4.1. Interventions were implemented concurrently over a 3-year period with the agriculture and health initiatives being identified by community members at project commencement as the most urgent.

Clinical interventions focused on persistent macro- and micronutrient deficiencies in children, including vitamin A supplementation, treatment of severe acute malnutrition and regular growth monitoring. For cases of moderate malnutrition, families received InstaFlour (United States Agency for International Development) or locally made nutrient-rich flour consisting of millet, soybean, sorghum, cassava and groundnuts. In addition, basic maternal health interventions such as antenatal care and institutional delivery were supported by efforts to promote adequate weight gain and improve coverage with iron and folic acid supplementation.

School-based interventions included home-grown school meals, gardens and nutrition activities after school, along with deworming campaigns. Balanced school meals have been demonstrated both to increase school attendance as well as improve learning outcomes (19). Currently, 20,584 children – nearly all those of primary-school age – receive a home-grown school meal consisting primarily of maize and beans complemented with vegetables such as tomatoes and leafy greens.

Household- and community-based interventions engaged longer-term issues of food and livelihood security. Interventions include subsidized seed and fertilizer to increase
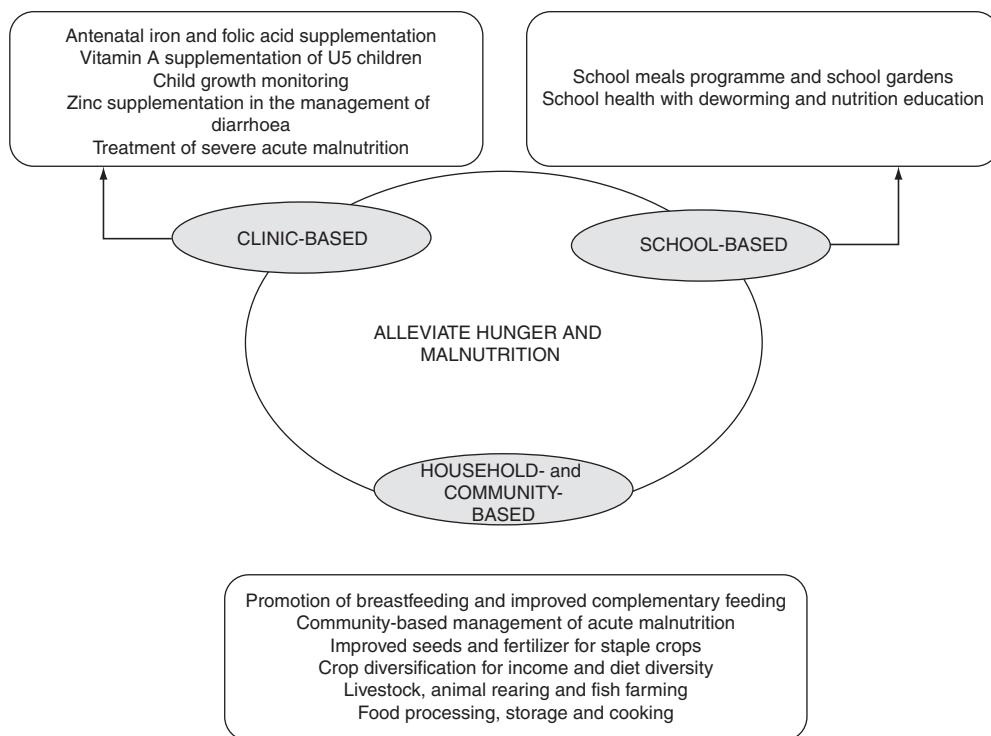
Antenatal iron and folic acid supplementation
Vitamin A supplementation of U5 children
Child growth monitoring
Zinc supplementation in the management of diarrhoea
Treatment of severe acute malnutrition

School meals programme and school gardens
School health with deworming and nutrition education

CLINIC-BASED

SCHOOL-BASED

ALLEVIATE HUNGER AND MALNUTRITION

HOUSEHOLD- and COMMUNITY- BASED

Promotion of breastfeeding and improved complementary feeding
Community-based management of acute malnutrition
Improved seeds and fertilizer for staple crops
Crop diversification for income and diet diversity
Livestock, animal rearing and fish farming
Food processing, storage and cooking

Fig. 4.1. Nutrition strategy of the Sauri Millennium Village (U5, under 5 years of age).

agricultural productivity; the introduction of high-value crops; agro-processing initiatives; and microfinance programmes to stimulate small-business development. Taken together, these efforts were an attempt to enhance nutritional in take and diet diversity, while affording households the additional income required to address nutritional needs in a sustainable fashion. This was complemented by a community health worker programme to promote exclusive breastfeeding and locally appropriate complementary feeding, home-based fortification and proper food storage techniques.

Study population

Detailed household mapping was conducted prior to the initiation of interventions. This process included a population census, Global Positioning System coordinates for most dwellings and the generation of a household wealth score. Following this process, proportional sampling was used to represent the geographic spread of the sub-administrative units within the village. From these administrative units, a total of 300 wealth-stratified households were randomly selected to undergo detailed periodic assessments. Consenting households were followed longitudinally over 3 years. In the event of refusals or household attrition, random replacement from baseline wealth strata was conducted to maintain the sample size. This chapter compares baseline data taken in June 2005 with those from an assessment conducted after 3 years of intervention exposure, in June 2008.

Within each participating household, individuals were recruited for study inclusion based on the results of preliminary demographic assessment. Household members were defined as those who have lived in the household for at least three of the past 12 months and who 'normally eat from the same pot'.

Within each household, specific demographic groups were sampled. Household heads provided information on household demography, education, employment, agricultural and non-agricultural sources of income, assets, expenditure, consumption and access to basic services including water and sanitation, energy, transport and communication. Surveys were administered to adults in the household aged 13–49 years old and assessed health-related MDG indicators, nutrition and food security, alongside common causes of child mortality including diarrhoea, pneumonia and malaria, and health-seeking behaviour. Further, biological data were collected on adults and children and anthropometry data for children under 5 years of age. A full explanation of the study procedures, purpose, risks and benefits were explained to participants during the informed consent process. The study received ethical approvals from the Institutional Review Board at Columbia University and the Kenya Medical Research Institute.

Study procedures and generation of indicators

Indicators, their definitions and sources of data within this project are listed in Table 4.1.

Food insecurity

A Food Security Questionnaire (FSQ) was administered to the head of each household and/or the person primarily responsible for preparing and serving food in the household. Surveys were administered in the same time period of the agriculture season, before the harvest of the crop from the main rainy season, which corresponds to the hunger period.

The FSQ consisted of 11 questions on food insecurity and coping aimed at assessing the household's access to food, as a measure of food insecurity. The questions were locally modified from Food and Nutrition Technical Assistance Project (FANTA) questions (20). For each of the 11 questions, the percentage of individuals answering 'yes' to that question was determined. A Food

Insecurity Score (FIS) was calculated as the total number of food insecurity questions answered with 'yes', indicating that the subject had to deal with that specific food shortage situation. All questions were treated with equal weight for FIS calculation.

Consumption frequency and diet diversity

A food-frequency questionnaire (FFQ) was administered to household heads and/or the person primarily responsible for preparing and serving food at both baseline and year 3. Similar to the FSQ, surveys were administered in the preharvest period. The FFQ contained 121 locally available food items, for which frequency of consumption (times per day, week, month or year) was assessed. A Consumption Frequency Score (CFS) for each food item was calculated as the number of times the food item was consumed per week. A frequency of once weekly received a score of 1, consumption of once daily received a score of 7, with other values scaled accordingly (21).

Food items were grouped into 16 food groups based on the Food and Agriculture Organization of the United Nations (FAO)/ FANTA Household Dietary Diversity Questionnaire and Guidelines (22). The 16 food categories were: cereals; vitamin-A rich vegetables and tubers; white tubers and plantains; green leafy vegetables; all other vegetables; legumes; nuts and oily fruits; vitamin A-rich fruit; all other fruit; meat; eggs; milk; fish; oils and fats; sweets; and spices and condiments. No distinction was made between organ meat and flesh meat in the list of 121 food items used for the FFQ. The CFS for each food group was calculated as the sum of CFSs of food items in the respective food group (21).

Food items and food groups were categorized for consumption frequency 'at least daily', 'at least weekly' or 'at least monthly', with criteria for CFS set at 7, 1 and 0.25, respectively, based on the CFS scoring strategy (21). For each food group, the percentage of individuals consuming the food group on a daily basis was determined.

Individual Diet Diversity Scores (DDS) were generated for daily, weekly and monthly

Table 4.1. Indicators.

	Indicator	No. of items for composite indices	Source
Food insecurity	Answered YES to Food Insecurity Question X, with X being one of 11 food insecurity questions	N/A	FSQ
	Food Insecurity Score (FIS) (total number of food insecurity questions answered with YES; possible range 0–11)	11	FSQ
Food consumption frequency and diet diversity	Consumption Frequency Score (CFS) for food item X (= times consumed per week; e.g. once weekly = 1, twice weekly = 2, once daily = 7, once monthly = 0.25), with X being one of 121 FFQ items	N/A	FFQ
	CFS for food group Y (= sum of consumption frequency scores of food items in food group Y), with Y being one of 16 food groups	N/A	FFQ
	Consumes food group Y on a daily basis (i.e. consumption frequency score of food group Y is 7 or above)	N/A	FFQ
	Food Variety Score (FVS) – day (number of food items consumed on a daily basis; i.e. CFS of food item X is 7 or above; possible range 0–121)	121	FFQ
	FVS – week (number of food items consumed on at least a weekly basis; i.e. CFS of food item X is 1 or above; possible range 0–121)	121	FFQ
	FVS – month (number of food items consumed on at least a monthly basis; i.e. CFS of food item X is 0.25 or above; possible range 0–121)	121	FFQ
	Diet Diversity Score (DDS) – day (number of food groups consumed on a daily basis; i.e. CFS of food group Y is 7 or above; possible range 0–13)	13	FFQ
	DDS – week (number of food groups consumed on at least a weekly basis; i.e. CFS of food group Y is 1 or above; possible range 0–13)	13	FFQ
	DDS – month (number of food groups consumed on at least a monthly basis; i.e. CFS of food group Y is 0.25 or above; possible range 0–13)	13	FFQ
Anthropometry	Underweight (weight-for-age Z score ≤−2)	N/A	Anthropometric measurements
	Stunting (height-for-age Z score ≤−2)	N/A	Anthropometric measurements
	Wasting (weight-for-height Z score ≤−2)	N/A	Anthropometric measurements
Vitamin A deficiency	Vitamin A-deficient (serum vitamin A level <20 µg/dl)	N/A	Serum sample analysis
	Received vitamin A supplementation during the last 6 months	N/A	Children and Women Health Questionnaire

N/A, not applicable; FFQ, food-frequency questionnaire.

time periods based on 13 food categories. As recommended by FAO/FANTA (22), sweets, spices and condiments, and beverages were excluded for this purpose and legumes, nuts and oily fruits were combined as one food group. DDS per day, DDS per week and DDS per month were calculated as the number of food groups (of 13 in total) consumed on a daily, weekly or monthly basis, respectively. In addition, Food Variety Scores (FVS), including FVS per day, FVS per week and FVS per month, were calculated as the number of food items (out of 121 food items) consumed on a daily, weekly or monthly basis, respectively.

Anthropometry

Body weight was obtained in two separate measures using an electronic balance (Seca, Hanover, Maryland, USA) or on a hanging spring scale (Salter Ltd, Tonbridge, UK) read to the nearest 0.1 kg. Standing height (for children aged >24 months) or recumbent length (for infants aged 0–24 months) was read to the nearest 0.1 cm on a steel tape attached to a wooden board with a foot-plate and sliding head block (Shorr Productions, Woonsocket, Rhode Island, USA). All anthropometry measures were done by standard practices (23). Anthropometric indices were calculated with Stata macros provided by the World Health Organization (WHO) with use of the new growth references (24). Underweight, stunting and wasting were defined as weight-for-age Z score (WAZ) ≤ -2, height-for-age Z score (HAZ) ≤ -2 and weight-for-height (WHZ) Z score ≤ -2, respectively. Extreme Z scores, WAZ ≤ -6 or ≥ 5 for underweight, HAZ ≤ -6 or ≥ 6 for stunting and WHZ ≤ -5 or ≥ 5 for wasting, were excluded as outliers, as suggested by the WHO protocol. In this chapter, we compare data on children under 2 years of age at follow-up, who were conceived or born during the intervention period, to the same age range at baseline.

Vitamin A deficiency

Individual serum samples were collected from children under 5 years old and women between the ages of 13 and 49 years to determine vitamin A deficiency. Aliquots of 100 µl from five individuals were pooled to represent a single sample, resulting in a total of 30 pooled serum samples (from 150 individuals) for baseline and 23 samples for year 3 follow-up. The same pooling was done for women, resulting in a total of 30 serum samples from both baseline and the year 3 analysis (25).

The levels of vitamin A were measured by high-performance liquid chromatography (Shimadzu Corporation, Kyoto, Japan). Vitamin A was de-proteinized from the serum/plasma sample using ethanol and extracted with hexane. The extract was dried, re-dissolved with ethanol and injected into the chromatograph. Retinyl acetate was used as the internal standard. This assay was standardized using calibrators from the National Institute of Standards and Technology. The minimum required volume for this assay is 150 µl. Vitamin A deficiency was defined as a level <20 µg/dl (26).

A health questionnaire was administered to adult women, above 13 years, to assess women's and children's health status and access to health care. In this questionnaire, it was asked if the child under 5 years of age received a vitamin A dose in a capsule during the last 6 months. The percentage of children for whom vitamin A supplementation was reported was determined from these data.

Statistical analysis

Data from questionnaires were entered electronically using CSPro data entry software (US Census Bureau, Washington, DC, USA) and cleaned for structural and logical errors in both CSPro and Stata version 10 (StataCorp., College Station, Texas, USA). All statistical analyses were performed with Stata. Normal distribution was checked by Shapiro–Wilk tests. Differences between means were checked by two-sample t tests. Two-proportion z tests were used to test for differences between proportions. Percentage change was calculated as

the difference between year 3 and baseline divided by the value at baseline.

Results

Three hundred households were surveyed at baseline and follow-up. The study population for each component of the evaluation is detailed in Fig. 4.2. Results are summarized in Table 4.2.

Food insecurity

The decrease in average FIS at year 3 compared with baseline indicated improved food security in the community (Table 4.2). For eight of the 11 food insecurity questions, the percentage of individuals coping with the respective food shortage situation reduced significantly from baseline to year 3 ($P < 0.01$) (Table 4.3). In contrast to the results of the other food coping strategies, the proportion of the population that 'changed the family diet to cheaper or less-preferred foods in the past week' was higher at year 3 (75.2%) than at baseline (56.9%; $P < 0.0001$). The proportion of the population who borrowed food or money for food from others due to insufficient food did not change over the course of the three years. Further, the average number (95% confidence interval) of daily meals increased significantly from 2.56 (2.50, 2.62) to 2.70 (2.63, 2.77) ($P = 0.036$).

Consumption frequency and diet diversity

Higher average DDS and FVS were observed for daily, weekly and monthly time periods at year 3 as compared with baseline, indicating improved dietary diversification in the community (Table 4.2). Figure 4.3 shows changes between baseline and year 3 in daily consumption for 16 food groups. For 14 out of the 16 food groups, consumption on a daily basis increased from baseline to year 3. Most pronounced was the increased consumption of legumes, which increased from 14.6% at baseline to 44.3% by year 3 ($P < 0.0001$). This can be explained by the increased consumption frequency of common beans as a maize-and-beans dish and beans alone (data not shown).

The consumption of animal-source protein increased including fish, milk and milk products, eggs and meat ($P < 0.01$ for each of these food groups). For vitamin A-rich plant-based food products, including vitamin A-rich vegetables and tubers, vitamin A-rich fruits and green leafy vegetables, daily consumption was high at baseline (96.5%) and no change was observed by year 3 (96.1%; $P = 0.756$) (Table 4.2). Some shifts of food items within the vitamin A-rich plant group were noted, including a decrease in consumption of vitamin A-rich fruits (particularly guava and papaya) and an increase in consumption of some dark-green leafy vegetables (particularly kale, black nightshade, amaranthus and spiderweed) and vitamin A-rich vegetables and tubers (carrots, pumpkin) (data not shown). Consumption of vitamin A-rich
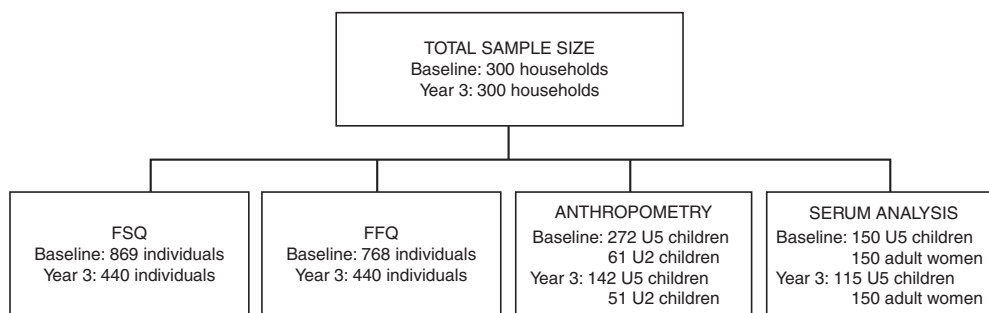

Fig. 4.2. Sampling design (FSQ, Food Security Questionnaire; FFQ, food-frequency questionnaire; U5, under 5 years of age; U2, under 2 years of age).

Table 4.2. Outcome measures.

Indicator	Baseline	Year 3	% change	P value
Food insecurity				
Mean FIS (95% CI)	5.21 (5.04, 5.38)	4.13 (3.92, 4.30)	−20.7	<0.0001
Food consumption frequency and diet diversity				
Mean FVS – day (95% CI)	9.6 (9.4, 9.9)	11.8 (11.3, 12.3)	22.1	<0.0001
Mean FVS – week (95% CI)	31.8 (31.1, 32.5)	35.5 (34.5, 36.5)	11.7	<0.0001
Mean FVS – month (95% CI)	56.7 (55.8, 57.6)	63.0 (61.8, 64.3)	11.2	<0.0001
Mean DDS – day (95% CI)	6.67 (6.54, 6.80)	7.33 (7.17, 7.50)	9.9	<0.0001
Mean DDS – week (95% CI)	10.66 (10.56, 10.76)	11.17 (11.04, 11.29)	4.8	<0.0001
Mean DDS – month (95% CI)	12.37 (12.30, 12.44)	12.63 (12.57, 12.69)	2.1	<0.0001
Consuming vitamin A-rich plant products on a daily basis	741/768 (96.5%)	423/440 (96.1%)	−0.4	0.756
Consuming vitamin A-rich animal products on a daily basis	427/768 (55.6%)	300/440 (68.2%)	22.5	<0.0001
Anthropometry				
Children aged 0–2 years underweight	16/61 (26.2%)	2/51 (3.9%)	−85.0	0.002
Children aged 0–2 years stunted	33/53 (62.3%)	18/47 (38.3%)	−38.5	0.014
Children aged 0–2 years wasted	3/56 (5.4%)	1/45 (2.2%)	−58.5	0.386
Vitamin A deficiency				
Children aged 0–5 years vitamin A-deficient	21/30 (70.0%)	8/24 (33.3%)	−52.4	0.0073
Women aged 13–49 years vitamin A-deficient	1/30 (3.3%)	0/30 (0%)	−100.0	0.3132
Children aged 0–5 years who received vitamin A supplementation during the last 6 months	168/235 (71.5%)	156/225 (69.3%)	−3.2	0.613

FIS, Food Insecurity Score; CI, confidence interval; FVS, Food Variety Score; DDS, Diet Diversity Score.

Table 4.3. Detailed outcome measures of food security from Food Security Questionnaire.

| Indicator	Baseline	Year 3	% change	P value
Food insecurity				
Because of insufficient food:				
Had a day without eating anything in the past week	289/869 (33.2%)	101/440 (23.0%)	–33.0	<0.0001
Reduced the size and/or number of meals eaten in the past week	632/869 (72.7%)	280/440 (63.6%)	–12.5	0.0007
Changed the family diet to cheaper or less-preferred foods in the past week	494/869 (56.8%)	331/440 (75.2%)	32.3	<0.0001
One or more children from the HH discontinued school in order to save money or to work for additional income in the past 12 months	179/872 (20.5%)	43/440 (9.8%)	–52.4	<0.0001
One or more of the HH went to another neighbourhood, village, town or city to find work in the past 12 months	393/872 (45.1%)	122/440 (27.7%)	–38.5	<0.0001
Used money that was intended for investing in small business in the past 12 months	541/872 (62.0%)	204/440 (46.4%)	–25.3	<0.0001
Sold some household possessions, agricultural tools or productive tools in the past 12 months	218/872 (25.0%)	39/440 (8.9%)	–64.6	<0.0001
Borrowed food or money for food from relatives, friends, neighbours, bank or money lenders in the past 12 months	582/872 (66.7%)	290/440 (65.9%)	–1.2	0.7626
Sold or consumed seeds meant for planting next season's crops in the past 12 months	486/872 (55.7%)	122/439 (27.8%)	–50.1	<0.0001
Sold livestock in the past 12 months	643/872 (73.7%)	257/440 (58.4%)	–20.8	<0.0001
Sold or pledged land or house in the past 12 months	78/872 (8.9%)	26/440 (5.9%)	–33.9	0.0546

HH, household.
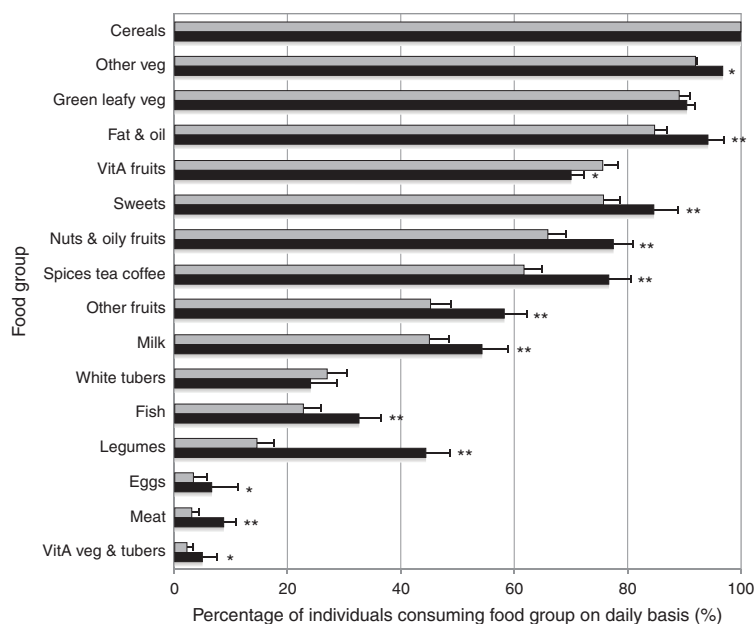
Fig. 4.3. Daily consumption of 16 food groups at baseline (▧) and year 3 (■). Bars represent percentage of the population consuming the food group on a daily basis, with 95% confidence interval represented by error bar. Number of individuals: *n* = 768 at baseline and *n* = 440 at year 3. Percentage value was significantly different from that at baseline: *$P < 0.05$, **$P < 0.01$ (vitA veg & tubers, vitamin A-rich vegetables and tubers; veg, vegetables; vitA fruits, vitamin A-rich fruits).

animal-based food products increased from 55.6% to 68.2% ($P < 0.0001$) (Table 4.2).

Anthropometry

The results of the anthropometric assessment are presented in Fig. 4.4. For children under 2 years of age, the proportion of those underweight and stunted was reduced by 85% and 39%, respectively. Levels of wasting were relatively low at baseline (5.4%) and remained unchanged by year 3 (2.2%; $P = 0.431$).

Vitamin A deficiency

The proportion of children under 5 years old with vitamin A deficiency was reduced by 52.4% over the study period ($P = 0.0073$) (Table 2). Compared with children under 5 years of age, vitamin A deficiency among

adult women was low at baseline (3.3%) and did not change. Between baseline and follow-up, the proportion of children who received vitamin A supplementation in the past 6 months remained nearly identical at approximately 70% (Table 4.2).

Discussion

We assessed the effects of an integrated food- and livelihood-based model on nutrition-related outcomes in rural western Kenya. Over a 3-year study period, we observed improvements in diet diversity and food security, both essential for long-term nutrition gains (3). At follow-up, the number of children who were vitamin A-deficient was reduced by half, and levels of stunting and underweight were reduced by 39% and 85%, respectively. These changes among children under the age of 2 years are critical for
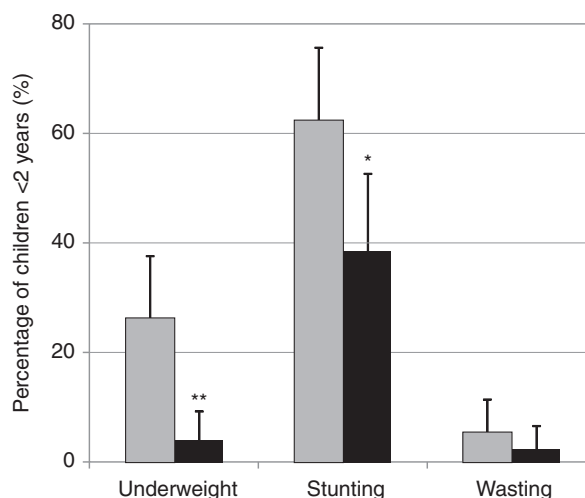
Fig. 4.4. Underweight, stunting and wasting of children under 2 years of age at baseline (▫) and year 3 (▪). Bars represent the percentage of children under 2 years old with the nutritional deficit, with 95% confidence interval represented by error bar. Number of individuals: $n = 61$ at baseline and $n = 51$ at year 3. Percentage value was significantly different from that at baseline: *$P < 0.05$, **$P < 0.01$.

longer-term growth, cognitive development and lifetime health (7). Taken together, these findings provide encouraging evidence that an integrated food- and livelihood-based approach can generate rapid progress towards the first MDG on reducing hunger and undernutrition.

While this assessment followed a cohort of households over a sustained period, employed previously validated tools and assessment methods, and measured changes in a series of objective pathway and outcome variables, there are also important limitations to underscore. The use of historical controls makes it difficult to separate the effect of the intervention from wider secular changes that may have taken place in the study site in the absence of the intervention. Indeed, a number of important contextual factors may have affected nutrition-related outcomes during the period of study. During 2007 and 2008, the second and third years of the intervention, the world witnessed an unprecedented increase in global food and fertilizer prices, pushing many marginal households deeper into poverty, with profound effects in sub-Saharan Africa (27). Accompanying this was a wave of post-election political violence in

Kenya, from December 2007 to March 2008, which had its most direct consequences in the western region of the country where the study site is located (28,29). This instability took place several months before the follow-up surveys were conducted for this assessment. The combined effect of these factors served to exacerbate economic and food insecurity in much of the region. While further experimental research is clearly warranted, we suggest that it is likely that the programme provided an important buffer against these crisis events and that the results of our assessment are likely to underestimate the effects of the intervention package.

The results of this study point to major reductions in children stunted or underweight, which are important findings for a number of reasons. First, chronic undernutrition is a major public health challenge in Kenya and the Millennium Villages study site had substantially higher baseline levels than the national average. While levels of moderate or severe underweight (26.2%) were comparable to the 20% national figure, the levels of stunting observed at baseline (62.3%) were twice the 30% national average (30). Notably, the study was unable to detect changes in

wasting, where prevalence at baseline was already low and in line with national figures. Second, the changes in stunting and underweight were observed in children under 2 years old – those conceived and born after the initiation of the intervention. As noted earlier, maximizing gains during this period has the potential to lead to longer-term nutritional and developmental benefits and make the greatest contribution to lifetime health (31). There is evidence to suggest that damage done to a child's physical or cognitive development during this period may be irreversible. Previous research in rural western Kenya has demonstrated that the prevalence of underweight and stunting was highest in children 3–24 months of age, whereas in children over 24 months of age, underweight and stunting stabilized, but they remained below the reference median (32).

In a complex multi-component approach to address undernutrition, it is difficult to make definitive statistical statements regarding the underlying mechanisms through which changes in growth outcomes were observed. However, the design of the study and results of our assessment do offer a number of potential explanations. First, changes in growth took place alongside parallel shifts in a number of theoretically grounded pathway indicators (33), including improvements in food security, diet diversity and micronutrient levels. It has been previously demonstrated that dietary diversity predicts diet quality particularly among infants and young children (34). Second, there is an association between the diversity of a child's diet and his/her nutritional status that is independent of socio-economic factors, with dietary diversity potentially associated with diet quality (35). Our data indicate a significant positive correlation between the WAZ (underweight) of children under 2 years of age and the monthly DDS ($P = 0.02$) (data not shown). Other surveys have confirmed this as well (36). Yet multivariate models controlling for socio-economic factors are critical to further analyse and interpret these associations. Finally, the extent to which food security results in good nutrition depends on a set of non-food factors such as sanitary conditions, water quality, infectious diseases and

access to primary health care (3,37). Although not described in this chapter, other improvements in the infrastructure and health system of Sauri have taken place, perhaps contributing to the improved nutrition status.

Positive shifts in diet diversity were also likely to be the potential mechanism through which changes in vitamin A levels were observed. While the clinical component of the intervention involved vitamin A supplementation, this intervention was initiated prior to the onset of our project, with proportions of children who had received vitamin A in the past 6 months being high (70%) and nearly identical between baseline and follow-up. It is also important to note that clinical trials have not found an association between vitamin A supplementation and growth (38–40). We suggest that in this study, improvements in micronutrient deficiency may be a biological outcome of more complex changes in diet quality and diversity. Previous research has examined the association of dietary vitamin A intake with growth and the incidence of recovery from stunting, and demonstrated that dietary carotenoid intake was associated with a greater incidence of reversal of stunting, with the greatest impact on children under 2 years old (41–43).

Documentation of the portfolio of interventions undertaken during the initial study period lends further support to the potential role and importance of food- and livelihood-based approaches in contributing to changes in nutritional status. Subsidized hybrid maize seeds and fertilizers were provided in the initial stages of the project to improve food yields and boost food security. In two years, the maize yield tripled from 2.0 t/ha to 6.2 t/ha (17). Since 2006, the community worked with agricultural extension officers to diversify their crops for markets and to improve household nutrition. Farmers also engaged in other income-generating activities such as livestock for dairy production, poultry, fish farming and bee keeping. Taken together, this portfolio of interventions, when viewed alongside documented shifts in pathway variables, lends support to the contribution of food- and livelihood-based strategies to observed growth improvements among children less than 2 years old.

A recent series reviewed the evidence on mainly child-focused interventions proven to reduce stunting, micronutrient deficiencies and child mortality (9,44). The spectrum of interventions reviewed generally reflected single, stand-alone health-focused interventions that were amenable to experimental design. Little previous research has assessed the potential impact of more complex 'packages' that combine clinical with food- and livelihood-based interventions. Even less research has been done on strategies to enhance delivery systems to improve coverage.

The United Nations' commitment to ending food insecurity, as affirmed by the High-Level Task Force on the Global Food Security Crisis and the Alliance for a Green Revolution in Africa, has generated renewed attention to the need of making our world more food secure. This study suggests that integrated food- and livelihood-based models offer one potential approach. We demonstrated that such a model is feasible to deliver, with intervention components generating complementary and potentially synergistic effects. The project site in western Kenya covered 63,500 people, which is sufficiently large to extract lessons for district-wide scale up. Certainly any scale up would benefit from economies of scale and greater integration into district or national systems. More research is underway to assess the potential for similar gains to be observed in other MVP sites in sub-Saharan Africa, which will ultimately enhance the external validity and ability to generalize the findings presented here. We hope that the approach and evidence from this study can provide lessons of replicability, scale up and transfer to other contexts.

Acknowledgements

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