Integration of nutrition counseling, nutrition supplementation and parenting support into Madagascar’s national nutrition program: The Mahay cluster-randomized effectiveness trial

Endline Impact Evaluation Report

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Development Economics Research Group, Health Nutrition and Population Global Practice and the Strategic Impact Evaluation

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Executive summary

Madagascar is one of the few countries in Sub-Saharan Africa with a long-term commitment to nutrition. Despite its low-income status and multiple development challenges, Madagascar has a large infrastructure for a community-based nutrition program operating at scale nationwide. A long-term evaluation of the program (spanning 14 years) showed that during a period of expansion, key aspects of the quality of service delivery (namely the number of children/worker ratios as well as the training and knowledge of community workers) worsened significantly over time.[1] In response to the results of the long-term evaluation and to reduce the burden for local nutrition workers, the target age for eligible children was narrowed to 0-2 years, which represents a focus on the first 1000 days.

A 4-year political and economic crisis (2009-2012) in Madagascar further strained the quality of service delivery of nutrition, health and education services alike. Five regions of Southern and South-Eastern Madagascar (Amoron'i Mania, Androy, Atsimo Atsinanana, Haute Matsiatra, and Vatovavy-Fitovinany) with a high prevalence of child stunting and/or food insecurity were selected as part of a World Bank Health, Nutrition and Education loan (PAUSENS); an emergency loan to restore and preserve basic service delivery after the crisis. The end of the crisis also marked a shift in priority from tackling underweight and acute malnutrition to reducing chronic malnutrition, or stunting, as an attainable policy goal; and Madagascar's joining of the SUN (scaling up nutrition) movement.

Even with restoration of the quality of the nutrition services to levels achieved before the crisis and full scale-up of the U-PNNC, there was a renewed interest and reflection by the ONN and the Government of Madagascar to reconsider the design of the old community nutrition program. The original program was not likely sufficient to tackle the new challenge of addressing chronic malnutrition. There was a clear understanding of the need to change the intensity of the current program and consider an expansion of the scope of the program to improve the chances of addressing chronic malnutrition.

The Mahay study originated from brainstorming sessions with the technical counterparts of U-PNNC, the World Bank operational team, and a team of international and national researchers in 2012. The main motivation for the study was to enhance the existing community-based nutrition program (U-PNNC) with increasing layers of intensity and scope, and test the most effective (and cost-effective) way to tackle chronic malnutrition with an eye to potential redesign and scalability of the enhanced variants. In addition, we aimed to promote child development during the first 1000 days with a home-visiting component for early child stimulation. The key motivation of introducing an early stimulation component came from the growing consensus of the need to address risk factors detrimental to child development beyond illnesses, lack of access to health care and nutritional deficiencies. Limited psychosocial and cognitive stimulation are equally limiting factors that put children at risk of not developing to their full potential.

The design of the program components was based on deep knowledge of the local context, international evidence from the nutrition and child development literature about what works, as well as formative research and south to south exchanges between the ONN team and BRAC/Alive and Thrive in Bangladesh to strengthen the intensity and quality of the counseling within the PNNC program. At the

[1] Weber, Ann, Emanuela Galasso and Lia C.H. Fernald (forthcoming) The perils of Scaling Up: Long Term effects of a Community Nutrition Program, Maternal and Child Nutrition

time this study was conceived, we used the 2011 Lancet series on Early Child Development to identify papers examining the associations between participating in parenting support programs and children's cognitive development in low-income and middle-income countries. We identified papers that had examined the efficacy of parenting support programs in randomized, controlled trials in Jamaica, Pakistan, and Bangladesh, but none that had examined a program's effectiveness at-scale. We also reviewed the literature exploring the associations between lipid-based nutritional supplementation (LNS) during pregnancy and infancy and child development outcomes. Although there was no evidence prior to this study about LNS and child development, while this study was in place, new evidence emerged that LNS may be beneficial to child development in Bangladesh, Burkina Faso, and Ghana, but not Malawi.

The final study design consisted of five study arms, which are summarized briefly here and described in more detail below. The existing community-based nutrition program with growth monitoring and education (T0) or "status quo" program was our comparison group against which the enhanced program variants were compared. The first treatment arm (T1) added intensive and personalized counseling during home visits by a local community nutrition worker to the existing community-based program. The second treatment arm (T2) consisted of T1 with the addition of lipid-based supplementation to children 6-18 months of age ("Kalina Zaza"), delivered in a weekly ration of supplement providing 20 g/day/child. The third arm (T3) built on T2 with the addition of supplementation for pregnant and lactating women (children -6 to 6 months of age) ("Kalina Reny"), which was delivered in a weekly ration of supplement providing 40 g/day/pregnant women and mothers of 0-6 months old. In T3, children received the 20 g/day/child of "Kalina Zaza" once they turned 6 months of age. In the last and fourth treatment arm (T4), T1 intensive nutrition counseling was enhanced with parenting support for early childhood stimulation and development for children 6-30 months.

For the impact evaluation, we randomly assigned 25 community nutrition sites to each of the treatment arms for a total of 125 study sites. Sites eligible for inclusion were active government nutrition program sites as of January 2014. Pregnant women during their second or third trimester of pregnancy, women with children 0-5 months of age, and women with children 6-11 months of age living in the program catchment area were eligible for enrolment in the trial. The study planned to interview 2490 children younger than 1 year of age, and 1250 pregnant women at baseline. The target children, their caregivers were assessed and tracked longitudinally at 1 and 2 years intervals. We evaluated the impact of the different variants of the program on child nutritional status and on child, cognitive, language and socio-emotional development as primary outcomes. We also measured program effects on anemia, hygiene, feeding and parenting knowledge and practices, intermediate outcomes that are along the impact pathways.

There were no main effects of the treatment arms on anthropometry or child development (intention to treat estimates) for all ages/cohorts combined at endline. However, the average effects masked important heterogeneity by age groups: youngest children who received full exposure to the child LNS ("Kalina Zaza") in T2 and T3 had better height-for-age Z-scores [T2 0.210 SD (95% CI: -0.004, 0.424), T3 0.216 SD (95% CI: 0.044, 0.388)] and lower stunting prevalence [T2 -8.2% (95% CI: -16.84, -1.16), T3 -8.9% (95% CI: -15.65, -0.7)] than same-age children in T0.

We found a positive and statistically significant effect on the animal source food and dairy consumption for both children and primary caregivers (~9 percentage points for animal source food and 2-3 percentage points for dairy), but no effects on the consumption of vitamin A rich foods, dietary diversity score or morbidity. We did not find significant effects on the quality of the home environment on any of the treatment arms.

At midline, there were benefits of being enrolled in T2 and T3 compared with the other groups for hemoglobin 0.26-0.28 mg/dL during the age of potential supplementation, and for anemia, with 12-13 lower odds of being anemic if exposed to the LNS supplementation. These results did not persist after supplementation had ended at endline. When combining data across survey rounds, the difference in anemia was greatest between the ages of approximately 8-20 m. Consistent with these results, a subsample of the youngest cohort of children who were 18-24 m old at endline evidenced benefits from LNS in T2 and T3 with a significant increase in hemoglobin and reduction in the prevalence of anemia. These interim results of the study informed the design of the new operation.

Overall, our study results show that intensive counselling can be effective in shifting behaviors, but it may not sufficient by itself to address nutritional deficiencies over and above group messaging in a context of high poverty and food insecurity. Our LNS results support the potential for LNS to be used effectively to increase linear growth and decrease stunting as a preventive component of a nutrition package, provided that supplementation starts at 6 months of age. Mediation analyses suggest that the T2 and T3 effects on anthropometric outcomes are a result of a *direct* effect of the supplementation and not indirect effects through behavioral or caregiver knowledge changes. Despite the lack of impact of the stimulation arm, reports from various actors (CHW, parents, T4 coaches, and test administrators) suggested that T4 children were more engaged and dynamic during activities and development assessments. Current work is ongoing to improve our understanding of the pathways through which the stimulation arm may or may not have impacted developmental outcomes for children, including possible fade-out of program benefits from midline to endline. In the future, we plan to evaluate program design variations on the stimulation component in Madagascar to fill in the knowledge gap on the role of key design features of integrating child stimulation with health and nutrition programs.

Intervention Design

The rationale of the proposed study was to identify the most outcome-effective interventions to improve child growth and development in the context of a country with a persistently high prevalence of stunting. In the literature, the three most common strategies used to improve nutritional status in pregnant or lactating women, infants and young children include: 1) promotion of behavior change to increase dietary quality; 2) fortification of food to improve micronutrient content of staple foods; or 3) nutritional supplementation targeted to vulnerable population groups. Our study tested the added value of variations of these strategies over and above the existing program delivered through a public sector platform operating at scale. We also tested the added value of promoting early child stimulation. Specifically, 125 cluster (sites) were randomized into 5 groups, stratified by region (5), with, 25 clusters per arm:

- T0: control group representing the existing U-PNNC program with monthly community based growth monitoring and nutritional/hygiene education;
- T1 is T0 home visits for intensive nutrition counseling ;
- T2 is T0 + lipid-based supplementation (LNS) for children 6-18 months old;
- T3 is T2 + LNS supplementation of pregnant/lactating women; and
- T4 is is T1 + bi-weekly home visiting program to support child development.

Interventions in T1-T3 were delivered to all eligible households in the program sites. Intervention in T4 was delivered only to the study sample, in order to allow the added community worker sufficient time to perform the preventive home visits for both nutritional counseling as well as counseling on early stimulation.

The study was designed to track a longitudinal cohort of pregnant women and children below the age of 12 months over a period of two years. Data were collected prospectively, with sampled households interviewed at three points in time: a baseline survey administered before the launch of the interventions (June-August 2014), and two follow-up surveys administered one (midline, September-October 2015) and two (endline, September-November 2016) years after the baseline survey. Households were randomly selected within clusters, stratified on child age. At baseline, we recruited 30 households per cluster, equally distributed across 3 age cohorts: A) pregnant women during their last two trimesters of pregnancy, B) children aged 0-5 months and C) children aged 6-11 months.

Study protocols were reviewed and approved by the local Ethics Committee at the Ministry of Health in Madagascar, as well as the Institutional Review Board at the University of California, Davis. Mothers provided written and verbal consent before study enrollment. The trial was registered (Current Controlled Trials ISRCTN14393738) and its protocol published in a peer reviewed public health journal. [2]

The study asked the follow research and operational questions:

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[2] Fernald LCH, Galasso E, Qamruddin J, et al. (2016) A cluster-randomized, controlled trial of nutritional supplementation and promotion of responsive parenting in Madagascar: The MAHAY study design and rationale *BMC Public Health*.

1. What is the benefit of each enhanced intervention arm as compared to the status quo community based program on child nutritional and development outcomes?

2. What is the relative benefit (and cost-benefit) on nutritional and child development outcomes of supplementing children in-utero and during the lactation period up to 18 months as opposed to supplementing children during the window of 6-18 months of age?

3. What is the value added (and cost-benefit) of providing home visits with early stimulation compared to only providing intensive counseling on nutrition and hygiene?

Intervention description

The interventions were the following (see Figure 1):

T0) Existing U-PNNC program ("status quo" control group): community-based nutrition program (*Programme National de la Nutrition Communautaire* or PNNC) with growth monitoring and education.

The national nutrition program covers all districts of the country. To maximize geographical coverage as well as to provide quality services on a large-scale, the program is contracted out to local NGOs for implementation (management, delivery, operations research and supervision) at the local level, reporting to the regional units of the National Nutrition Office. The services are delivered locally by community nutrition workers (*agent communautaire de la nutrition, ACN*), who are usually women elected by the local communities. Key messages include information about maternal nutrition, early initiation of breastfeeding, exclusive breastfeeding for the first 6 months, continued breastfeeding through 2 years, dietary diversification, and food conservation and preparation using locally available products, together with the promotion of age-appropriate infant feeding practices and hygiene practices. The messages are delivered at monthly growth monitoring sessions attended by pregnant/lactating women as well all eligible children (0-2 years). The promotion of behavioral change (besides the growth monitoring sessions) includes cooking demonstrations by the community nutrition worker where she emphasizes appropriate complementary feeding practices and prepares recipes that rely on locally available products to promote a healthy and diversified diet.

T1) Intensive counseling: the existing community-based program enhanced with preventive home visits that focus on personalized counseling on nutrition, hygiene and food security.

Growth monitoring and education only strategies have been found to be successful when they involve intensive counseling and strongly emphasize dietary diversity and the promotion and consumption of animal source foods. The quality of counseling and its intensity are believed to be a necessary condition for growth monitoring programs to be effective. The findings are in line with the evidence from behavioral economics on the importance of the way the messages are framed, perceived and internalized. After the long-term results of the existing nutrition education program, the ONN reviewed past experiences and exchanged experiences with Alive and Thrive/BRAC in Bangladesh through a South to South Exchange. The brainstorming led to testing whether an added community nutrition worker (ACDN) fully dedicated to home visits to complement the existing community worker (ACN) who delivers group growth monitoring activities would improve on behavioral change and improve final outcomes. The objective of the intensive counseling is to act preventively, with home visits before growth faltering occurs. In addition, having a home visitor helps tailor the advice and counseling to the specific needs of the child and caregiver. The nutrition counseling was designed to reach all children in the community up to 2 years of age (one visit during pregnancy, monthly visits during the first 8 months, bimonthly visits during the window of 9-12 months, and quarterly visits from 12 to 24 months). Counseling interventions were based upon an underlying behavioral theory of change utilizing constructs from an Integrated Behavioral Model (IBM).

The added worker had to have at least lower secondary education and live within the cluster. The added workers received ten days of intensive training in August 2014[3] after the administration of the baseline survey, with special emphasis on active listening and interpersonal communication skills, problem solving for exclusive breastfeeding, introduction of complementary feeding, and food security.

Implementation: The ACDN recruitment and training proceeded as planned, with training on interpersonal communication and active listening. The original training included the ACDNs, the ACNs and the NGO teams and the regional Nutrition Offices of ONN. The ACDN training included a component of small scale food security actions, with emphasis on short cycle planting[4] (rich in vitamins and proteins), vaccination/protection from livestock infection (including vaccination of poultry) and use of high yield seeds. A refresher training and coaching in the field was conducted in November 2014, and subsequently supervised by the local NGO's. ACDNs reported that access to seeds for short cycle planting and vaccines, to be provided by ONN, was available only at the onset of the pilot. Emphasis on interpersonal training and active listening was novel in the training, and developed for the study, with situation analysis on key behavioral barriers faced by mothers and role play to discuss possible solutions. Coaching of the ACDNs in the field was challenging. The team who developed the interpersonal training was hired in 2015 to develop and lead the new Human Centered Design activities and had, as a consequence, more limited time on the supervision and refresher training of the nutritional counseling. Qualitative work suggested that a few challenges existed for the implementation of home visits for counselling: (i) time constraints of ACDN to complete all home visits due to remoteness of households from the site center and general insecurity, especially in sites with poor road access and low population density and (ii) time constraints of mothers in all intervention sites during planting and harvesting.[5]

T2) Intensive counseling + lipid based supplementation to children 6-18 months ("Kalina Zaza")

In spite of encouraging results in other settings, intensive counseling and behavioral change may not be sufficient to address severe nutritional deficiencies in settings with high food insecurity and poverty depth. Thus, nutritional supplementation may be a more effective option for addressing chronic malnutrition. In T2, children 6-18 months of age were supplemented with 20 g/day of LNS (two sachets of 10 mg each), which provided 118 kcal/day and approximately 100% of the recommended nutrient intakes (RNI) for young children (Table B1). U-PNNC and the research team worked with Nutriset to define the content of the supplements and the packages. Families were instructed to mix the 10 g

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[3] Alban Ramiandrisoa Ratsivalaka (2014) Rapport de l'Atelier de Formation Comm des ACDNs sur le Counseling Intensif, Volet Communication (ONN)

[4] Emphasis was given on manioc, sweet potatoes, vegetable gardens (bredes, squashes, eggplants) and citrus plans.

[5] Manajaniaina Randriamanarintsoa and Voahanginirina Claudine Rakotozafy (2017) Resultats De Suivi De L'etude Lns Kalina Dans Les Regions Amoron'i Mania, Sud Est, Androy, Haute Matsitra Et Vatovavy.

Alain Pierre Randianjoahary (2017). Evaluation de processus de l'etude Mahay.

Fitovinany Lisy Rasifandrihamanana (2018) Rapport sur l'Atelier d'Appreciation du Programme de Stimulation Precoce.

sachets of supplement into their children's typical food twice per day. A weekly supply of LNS was provided to mothers for all children in the household within the target age of 6-18 months of age by distributing the LNS at the program site by the ACDN.

T3) Intensive counseling + lipid based supplementation to children 6-18 months + pregnant and lactating women [-6,+6] ("Kalina Reny")

The existing data and evidence relating to LNS interventions suggest that lipid-based supplements have the potential to improve size at birth and growth through infancy, but the optimal timing and composition of the supplements is not clear. It is possible that if supplementation were to cover both mothers and infants during critical periods of growth and development, the effect sizes could be larger than supplementing at one time point alone. Therefore, in the T3 arm, there was an added supplement for pregnant women and breastfeeding women (within the first six months postpartum). The supplement was 40 g/day, providing about 200 kcal/day and 1-2 times the recommended dietary allowance (RDA) of micronutrients for pregnant women (Table B1). A monthly supply of supplements was provided to mothers in a similar way as described above for the child supplements.

For groups T2 and T3, the manufacturer worked with ONN to develop culturally appropriate brand names and packaging for the supplements (Kalina-Be: Kalina Zaza for children and Kalina Reny for pregnant and lactating women). In addition, the research team, in collaboration with U-PNNC, conducted an acceptability trial[6] including a taste test and two-week in-home trial to evaluate mothers' opinions of the product's taste, consistency, and their ability to integrate it into their usual food preparation practices.

Implementation T2-T3: The LNS was securely stored at the district level and transported monthly to the NGOs. The NGOs were in charge of delivering the supply of LNS to the project sites. The LNS was to be stored by the ACDN, either at the site or at her home, 14 sachets were delivered to each child (Kalina Zaza) per week (to be consumed twice a day, morning and evening) and 7 sachets per week were delivered to pregnant and lactating women (to be consumed once a day, with breakfast). Empty sachets had to be returned to the ACDN to minimize reselling. Instances of disruption or significant delays in the delivery of LNS were isolated (temporary delay in six sites in three regions).[7]

T4) Intensive counseling based on infant and young child feeding practices + early childhood stimulation and development for children 6-30 months.

A fourth program variant added home visits on early stimulation to the home visits on intensive counseling. High quality parenting can be a powerful buffer for the potentially negative effects of adverse environments. Parenting behaviors have been shown to mediate the associations between poverty and poor development, suggesting interventions that improve caregiving quality could buffer the negative effects of poverty on child cognitive development. Inadequate child stimulation ranks among the most common causes of delayed child development in low- and middle-income countries.

[6] Robert Ackatia and Christine Stewart (2014). Acceptability of high and low iron dose LNS among pregnant and lactating women in two regions of Madagascar (Analamanga and Amoroni'mania).

[7] Manajaniaina Randriamanarintsoa And Voahanginirina Claudine Rakotozafy (2017) Resultats De Suivi De L'etude Lns Kalina Dans Les Regions Amoron'i Mania, Sud Est, Androy, Haute Matsitra Et Vatovavy.

Child stimulation strategies have demonstrated success in promoting child development in these contexts.

The structured curriculum on early stimulation was extensively adapted from the Reach Up and Learn home visiting program[8], originally developed in Jamaica as part of a "best practices" collaboration. The materials, books, pictures and training modules were adapted to fit the local context by a team of child development specialists led by the psychologist in the research team [LR]. In order to ensure sufficient intensity of the cognitive stimulation component of the home visit, and considering the workload of the added community nutrition workers (ACDN), only households selected to be participating in the baseline survey were considered eligible to receive the stimulation home visits in the T4 communities. Home visits were planned to take place bi-monthly, over and above the home visits for the nutrition counseling, and were tailored to the target child identified in the baseline survey. The curriculum started at age 6 months old and was administered until 24 months old. The end date was subsequently extended to 30 months of age. After the first few months of implementation of the pilot, the activities of home visiting program generated interest in early childhood development among households living in T4 communities at large. As a response, U-PNNC agreed to set up a *ludotheque*, in each community next to the community program site (or next to the ACDN house) supplemented with a basic package of toys. The ludotheque was open to all households with children in the 6-30 age range in T4 communities, independently of whether they were sampled or not for the baseline survey.

Implementation:

The activities in T4 were developed with a high investment in supporting training and on-site coaching. Coaching was only provided to T4 by the ECD team with a mobile team visiting each site for week-long coaching. Coaching was introduced after the first training in the Spring of 2014 and in Spring and Summer of 2015. Coaching was also provided to new ACDNs recruited after the first training or following ACDN turnover. Refresher training (theoretical and practical) took place after the first year at about 6 months intervals to reinforce the internalization of the protocol. ACDNs in T4 combined their 30 biweekly home visits with the nutrition counseling in T1, hence resulting in a more significant workload for the ACDN in T4 compared to T1. The first training for T4 took place in tandem with the overall training of all ACDNs, though lacked integration, as curricula and training materials were developed independently. Materials were provided to the ACDN for the home visits, though, given the large number of households to be covered, a set of materials (e.g., toys and books) could not be left with the household from one visit to the next. The *ludotheque* was provided with a limited number of confectioned toys starting in 2015.

Methods

Sample

Community sampling: The sampling frame was provided by the universe of project sites in the 5 regions of intervention of the PAUSENS project. The randomization was carried out by the research team using

[8] Christine Powell from the Reach Up and Learn team interacted with the ECD team at the onset of the design and shared materials to be adapted to the Malagasy context. The ECD team developed materials (books, visual aides, puzzles, toys and a collection of tales and songs) specifically for the T4 arm and developed monitoring and tracking instruments for the ACDN activities and home visits.

administrative data in January 2014. To minimize contamination of treatment across supervisors and minimize the number of supervisors within the same NGO whenever possible, NGOs were randomly sampled within regions, with 1 site per NGO supervisor. A stratified random sample of 5 sites per treatment per region were selected for a total of 125 sites. The obtained evaluation sample was balanced along average underweight prevalence and along the average size of the target population, using monitoring data.

Household sampling: Within communities, an up-to-date registry of the community nutrition site was used as a sampling frame to select target children and their caregivers/households. In each community 30 households were selected, stratified by child's age cohort: 10 households with a pregnant woman (cohort A), 10 households with a child aged 0-5 months (cohort B), and 10 households with a child aged 6-11 months (cohort C). If the program site did not have a sufficient number of pregnant women or children in the age range, a household listing exercise was conducted in the catchment area of the program site to draw the sample. Due to the nature of the interventions, it was impossible to blind participants to their intervention group assignment. Participants were informed about their assignment status after the baseline was completed.

Replacements at midline and endline: Mothers or children who died before final assessment were not replaced. Children who had permanently moved outside the program site catchment area before final assessment were replaced with a randomly drawn child from the community program within the same age range. Children and their households who returned to the site between the baseline and final assessment were re-interviewed. Post-test replacement information is available in Supplementary Table A1).

Subsample selection for specialized data collection: a subsample of 64 (out of 125) communities was selected with the objective of adding in-depth biochemichal markers and direct child assessments to a subsample of communities and children of the endline household survey. A list of relatively accessible subset of 64 communities (out of the 125) was randomly selected (16 cluster each from T0, T2, T3, T4. T1 was excluded due to cost-constraints). Within the selected communities, a random sample of 6 children in the youngest age cohort (18-24 months) was administered biomarkers and a random sample of 6 children in the oldest age cohort (28-34 months) was administered a direct infant assessment using the Bayley Scales of Infant Development (BSID). The objective was twofold. The first component aimed at measuring the impact of the interventions on iron deficiency anemia, vitamin A deficiency, and inflammation. More specifically, we ued a finger stick blood draw to measure serum ferritin (pF) and transferrin receptor (TfR), as indicators of iron status, retinol binding protein (RBP), as an indicator of vitamin A status, and C-reactive protein (CRP) and alpha-1-acid glycoprotein (AGP). The second component aimed at complementing existing maternal report data on child development outcomes with the administration of a direct infant assessment using the Bayley Scales, considered to be a "gold standard" test of child development.

Treatment duration

As described above, there were three age cohorts at baseline, ranging from -6 to 12 months old. At midline, target children were 6-24 months old, and at endline, they were 18-36 months old. Due to their differing age at the start of the trial and the varying age eligibility by treatment arm (see Figure 2), children experienced different exposure durations to the interventions.

The status quo program (T0) covered children during pregnancy through 24 months of age. Because the program was operational prior the start of the trial, all children sampled for the study were exposed to T0 from pregnancy onward. Women and children were also eligible for intensive counseling (T1) during pregnancy through 24 months of age. However, counseling did not begin for the oldest cohort C until they were ≥6 mo and stopped 1 year later, whereas the youngest cohort A was eligible for the maximum duration of counseling during their first 1000 days (Figure 2, first panel).

In T2, the LNS was delivered when children were 6-18 months old. Children in cohorts A and B (-6 to 5 mo at baseline) were eligible to receive the full 6 months of supplementation. However, children in cohort C (6 to 11 months) had ≤6 months of supplementation, and stopped receiving supplements a year or more before the endline survey (Figure 2, second panel).

In T3, LNS was additionally provided to mothers during pregnancy and lactation. The youngest cohort A maximally benefited from the maternal supplements, whereas cohort B benefited very little and cohort C not at all (Figure 2, third panel).

Finally, in T4, the intervention was provided for children 6-30 months of age. In this last arm, the oldest cohort C maximally benefited, whereas the youngest cohort did not have the opportunity to be fully exposed to the intervention before the endline survey (Figure 2, fourth panel).

A timeline of the study is presented in Appendix B. Implementation of the nutrition counseling and early stimulation counseling started in September 2014, right after the end of the baseline survey. As for T2 and T3, the LNS supply were delivered to the NGOs in September 2014. The ACDN LNS distribution to the households started in October 2014. Supplementation ended in May 2016.

Measures

Primary outcomes

Child growth: Child length-for-age and weight-for-length were the primary nutritional outcomes of interest. Height and weight were measured at each survey wave in duplicate using techniques described for the WHO Multicenter Growth Reference Study.[9] Calculation of the nutritional Z-score was completed using the computer software, Anthro, and growth standards issued by World Health Organization.[10] All anthropometrists were trained and standardized prior to beginning data collection, following the procedures used in the MGRS. Mid upper-arm circumference was also measure but was not a primary outcome.

Child development: Children's development, also a primary outcome, was assessed at baseline using the Ages and Stages Questionnaire Inventory (ASQ-I), which is a comprehensive self-report maternal assessment of child development. ASQ-I is a continuous scale version of the more widely-used ASQ-3 screening tool, which is subject to ceiling effects when assessing normally-developing children. The subscales measure skills in Communication, Gross Motor, Fine Motor, Personal-Social and Problem-

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[9] de Onis, M., Garza, C., Victora, C. G., Onyango, A. W., Frongillo, E. A., & Martines, J. (2004). The WHO Multicentre Growth Reference Study: planning, study design, and methodology. Food & Nutrition Bulletin, 25(Supplement 1), 15S-26S.

[10] World Health Organization. (2007). Anthro for personal computers, version 2, 2007: Software for assessing growth and development of the world's children.Geneva: WHO.

Solving domains.[11] At endline, a subsample of 64 accessible communities (T0, T2, T3 and T4) was drawn for an administration of serum samples and direct assessments of child development. Within the same subsample of communities, a random sample of the oldest cohort (C) was measured using the Bayley Scales of infant and toddler development-Third edition (BSID-III), a direct assessment of child development.[12] The oldest cohort was selected as they would have had the most complete exposure to T4.

Secondary outcomes

Weight-for-age, anemia, and iron status were secondary outcomes. Anemia was defined as hemoglobin concentration <110 g/L.[43,44] and assessed using the portable HemoCue system.[13] Hemoglobin was collected from 1/3 of the sample children at baseline and midline, and from all sampled children at endline.

At endline, serum samples were collected from a subsample of the youngest cohort of children (A) as they would have been exposed most recently to LNS in T2 and T3 in a sample of 64 communities. The following were measured from the serum samples: ferritin and transferrin receptor as markers of iron status, retinol binding protein as a marker of vitamin A status, and c-reactive protein (CRP) and alpha-1 acid glycoprotein (AGP) as markers of inflammation. Iron and vitamin A biomarkers were adjusted for inflammation using the method developed by Thurnham et al.[14]

Intermediate measures

Intermediate indicators were measures of caregiver-reported child morbidity and diet diversity (from a 24-hour dietary recall),[15] caregiver knowledge of child care and feeding practices (including breastfeeding history and status, timing of complementary feeding), household food security (using FAO's Household Food Insecurity Scale), and home stimulation practices (adapted from UNICEF's Family Care Indicators).[16] All intermediate measures were obtained using survey questionnaires administered to the primary caregiver of the target child. Additional information obtained from the caregiver included child appetite and responsive feeding practices. Caregivers' perception of their child's growth and development status (at endline). A detailed list of questionnaire content and instruments is available in Appendix B.

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[11] Squires, J., & Bricker, D. (2009). Ages & Stages Questionnaires. Baltimore, Maryland, 257-182.

[12] Bayley N. Bayley scales of infant and toddler development - third edition. San Antonio, TX: The Psychological Corporation; 2006.

[13] Cohen, A. R., & Seidl-Friedman, J. (1988). HemoCue system for hemoglobin measurement. Evaluation in anemic and non-anemic children. American journal of clinical pathology, 90(3), 302-305.

[14] Thurnham DI, McCabe LD, Haldar S, Wieringa FT, Northrop-Clewes CA, McCabe GP. Adjusting plasma ferritin concentrations to remove the effects of subclinical inflammation in the assessment of iron deficiency: a meta-analysis. *Am J Clin Nutr* 2010; **92**(3): 546-55.

[15] World Health Organization (WHO). (2008). Indicators for Assessing Infant and Young Child Feeding Practices: Conclusions of a Consensus Meeting Held 6-8 November 2007 in Washington DC, USA. World Health Organization (WHO).

[16] Kariger P, Frongillo EA, Engle P, Britto PM, Sywulka SM, Menon P. Indicators of family care for development for use in multicountry surveys. *J Health Popul Nutr* 2012; 30(4): 472-86.

Statistical Analysis

The data analysis follows the analysis outlined in the published protocol, consistent with the four-arm cluster randomized trial. Primary analyses were intention-to-treat (ITT) to minimize the selection bias from selective take-up rates. The intention-to-treat provides the lower bound on the estimated impact of the program, and represents the parameter of interest for cost-benefit analysis.

Testing and estimation

We used unadjusted linear regression for the initial estimation of our causal parameters for the linear outcome measures (e.g., anthropometric z-scores, developmental outcomes, stunting, severe stunting, wasting, severe wasting, and anemia. We complemented these estimations using parametric regression, adjusting for key covariates, X, that may be associated with treatment assignment by chance alone, as well as adjusting for baseline differences in the outcomes of interest. Let the subscript *i* denote household/target child/female, *j* be the cluster (community site) and *t* the time of measurement. Our extended parametric specification is the following:

$$Y_{ijt} = \beta_0 + \beta_1 T1_j + \beta_2 T2_j + \beta_3 T3_j + \beta_4 T4_j + \Gamma + \delta X_{ij} + \varepsilon_{ijt} \qquad (1)$$

where Y_{ij2} is the outcome of interest at endline (t=2, second follow-up), $T1 - T4$ are indicators for village/cluster assignment to the different treatment arms, Γ is a vector of block-level randomization strata used in the study (region and age). The coefficients $\beta_1 - \beta_4$ provide the intention to treat effects, that is the impact of living in a village *j* that was offered each program variant ($T1$ to $T4$) on the outcome of interest. Standard errors for the parametric estimates are adjusted for village level clustering to account for the design effect in the study.

We present results that include a set of baseline or time invariant outcomes X_{ij}. The main results do not account for baseline value Y_{ij} (ANCOVA) given that the youngest cohort A (pregnant women -6,0 months) did not have anthropometric and child development outcomes by design.

Estimation of Heterogeneity Treatment Effects

Heterogeneous treatment effects were estimated by a full set of interactions between the treatment status with the variable of interest. The first dimension of heterogeneity was the age of the target child (dichotomized below and above the median values at endline): the age cohort is important to be able to fully account for the duration of exposure to the intervention, but also programmatically to target interventions. The second dimension of heterogeneity explored in the analysis was the educational attainment of the primary caregiver [below secondary (low) vs. above secondary (high)], which is important for distributional issues: as poverty is an important risk factor for developmental delays, the objective was to test whether the intervention had differential returns between low and high socio-economic status, as proxied by the primary caregiver education. Finally, we tested for differential effects given the gender of the target child.

Results

Balance and attrition

A total of 3738 women were identified and randomly allocated into intervention or control groups (**Table A1**). Treatment groups were well balanced on all measured baseline child characteristics (age, length, weight, cognitive development), maternal characteristics (education, height, age, cognitive performance), and household variables (size and composition, asset index, access to safe water) (**Table A2**). Children were 4-29 months (median=16, IQR= 12, 20) at the first follow-up and 8-42 months (median=30, IQR= 25, 34) at the second follow-up.

Loss to follow-up occurred due to still birth (n=33, 0.9%), miscarriages (n=57, 1.5%) and maternal death (n=4, 0.1%). death after first follow-up (n=92, 2.5%) and cumulatively before final assessment (n=41, 2.1%). Losses to follow-up were balanced across groups (**Table A2**). T3 has a slightly poorer sample (lower wealth index, younger maternal age, and slightly lower ASQ for the target children). We controlled for imbalance on these baseline characteristics by adding them as regressors in the main outcome regressions. The same pattern was preserved post-replacement at midline and endline (**Table A3**) after accounting for losses to follow-up and for replacement households. The composition of households pre-and post-replacement does not vary across treatment arms (**Table A4**).

Main effects on primary outcomes and secondary outcomes

There were no main effects of any of the treatment arms on any measure of anthropometry (Table 1, panel A) or on measures of the child development outcomes (Table 1, panel B). We were unable to detect any significant effect of integrated layers of intensive nutrition counselling alone, or coupled with LNS supplementation or with home visit for early stimulation, either separately compared to the control group, nor jointly.

At midline, there were benefits of being enrolled in T2 and T3 compared with the other groups in terms of hemoglobin (0.26-0.28 mg/dL), or equivalently a 12-13 percent **lower odds of being anaemic** if exposed to LNS during the age of potential supplementation (**Table 2, panels A & B**). These results on haemoglobin and anaemia did not persist to endline at the time when children had stopped being supplemented for all age combined. When combining data across survey rounds, the difference in anaemia was greatest between the ages of approximately 8-20 m (Graph 4).

The biochemical sample collected in a subset of accessible communities confirms that the pathway is through **a reduction in iron deficiency anemia**. In the subsample of specialized data collection, children in youngest cohort of children who were 18-24 m old at endline had stopped supplementation of LNS in T2 and T3 one month before the survey. **Table 3** presents the results from the biochemical sample on micronutrient status. Both T2 and T3 increased haemoglobin (T2 0.44 and T3 0.32 g/DL) and improved ferritin (an indicator of storage of iron reserves) and reduced early signal of iron deficiency (as measured by sTFR). There is no detectable difference in vitamin A status (as measured by the retinol binding protein RBP) or in acute or chronic inflammation (as measured by the two indicators of C-reactive protein (CRP) and alpha-1-acid glycoprotein (AGP)). The hemoglobin results in the subsample are larger than the results in the main sample (**Table 2**), mainly due to the fact that the biochemical sample includes a narrow age group, with full exposure to the supplementation at endline, and the shorter time elapsed since last supplementation. The effects on the continuous measures are mirrored by a reduction in anemia by 40% in the biochemical sample (compared to a 20% reduction in the full sample in Table 2), which is driven by a reduction in iron deficiency anemia (prevalence of low ferritin). In addition, the biochemical results provide indirect evidence of the fidelity of the supplementation: the LNS was indeed delivered to the target children, unlikely to have been shared with siblings or other household members.

When looking at behavioural responses, there were, however, important program effects on increasing protein intake in the previous 24 hours, and on increasing dairy intake during the same time period (**Table 4, panel A**). This is in line with the key messaging of the ACDN on the importance of proteins and animal source food for nutrition and child development: Graph 6 provides descriptive statistics of the topic covered during the home visit across treatment arms from survey data. Both ACNs and ACDNs in T1-T4 communities were much more likely to have covered topics revolving around food diversity and hygiene. ACDNs were also more likely to have talked about food security compared to ACNs.[17] The increase of protein intake is sizeable (9 percentage points gain against a control mean intake of 23%), and an even larger effect on dairy intake (2-3 percentage points gain against a negligible average dairy intake of 1.3% in the control group).

The improvements in animal source food intake, however, did not translate into improved food diversity or on an indicator of consuming at least 4 food groups. The consumption of vitamin A rich foods has a negative coefficient but is not statistically significant. There is no main effect of the any intervention on morbidity, though T3 experienced a reduction in the incidence of morbidity of 15% that is statistically different from T1 and T2 (**Table 4, panel A**).

Heterogeneity analysis

The main results mask important heterogeneity in impact depending on the age of the target child. **There were significant effects of LNS supplementation on height-for-age z-score (HAZ) and on the prevalence of stunting for children in the younger cohorts who started LNS supplementation at the age of 6 months**. When results are disaggregated by the median age of the target child at endline, there were important and significant effects of the LNS supplementation on improving the height for age z-scores in the younger group [T2 0.210 SD (95% CI -0.003, 0.424)] and T3 0.216 (95% CI 0.042,0.388)], whose age at endline was below the median age. Mirroring these results, the youngest group showed also showed significant effects on decreasing stunting T2 -8.2% (95% CI: -16.84, -1.16), T3 -8.9% (95% CI: -15.65, -0.7)].

Heterogeneity effects by maternal education (Graph 3) and gender were inconclusive, and are reported in the Table A12.

Take-up and implementation, and mechanisms

The results discussed so far present the impact of the program on primary and secondary outcomes, but do not account for compliance to the intervention. Less than perfect compliance could arise from the difficulties of carrying out home visits for the ACDNs, due to distance or security, time availability or interest of the receiving households. In this section we will present self-reported participation rates from the survey as well as administrative data descriptive statistics on the number of visits carried out.

Table A5 shows results from self-reported data from the household/female survey questionnaire on the probability of receiving a home visit (and the number of home visits) across the different treatment arms in 2015 and 2016, fully interacted with the distance (in km) between the ACN/ACDN location and the household. Data is obtained for both the ACN, who carries out home visits as part of the CORAL (3

[17] ACDNs in T4 had a larger frequency of contact with households with the ECD early stimulation, and this is reflected in the main topic discussed by the ACDN in the previous home visit.

home visits for children who faltered during the group growth monitoring), and by the ACDN (with a recall period of 3 months in T1-T3 and 30 days in T4). .

The results (column 1) show that the ACNs in T1-T4 did not reduce the number of home visits as a result of the presence of the ACDN counseling activities. Columns (2) show the take-up rates of T1-T3: 77-71% of households received a home visit in T1-T3 in the prior 3 months in 2015. Participation/home visits in 2016 were slightly less frequent with 62-70% of households receiving a home visit in T1-T3, and an average of 1.5/1.6 home visits received.

Households in T4 were significantly more likely to receive a home visit in the prior 30 days (83% in 2015 and 77% in 2016, with an average number of 1.8-1.9 home visits.

The heterogeneity of participation/home visits with remoteness (distance) was important – the ACDN in T1 were less likely to have visited more remote/isolated households, and more significantly so for ACDNs in T4, who had a much larger workload of home visits. The ACNs in T1-T4, on the other hand, marginally increased the home visits for more distant households in treatment communities.

Quality ACN-ACDN and turnover

The original ACNs were older, less likely to be single with more children, and had slightly less education and wealth on average than the newly hired ACDN (**Table A6**). However, perhaps due to their greater age and experience, they had a higher receptive vocabulary score; knowledge of nutrition, hygiene practices and child development score; and expressed significantly greater motivation across all the motivation sub-domains than the ACDN. This higher motivation may be reflected in the finding that the ACN were also less likely than the ACDN to be replaced in T2, T3 and T4 between the baseline and endline of the study (**Table A7**). Importantly, the highest turnover was in T4 for the ACDN with the highest burden of home visits and knowledge content to deliver to families, including both nutrition and early stimulation information. The replacement ACDN were less educated but wealthier than the former ACDN, and their overall motivation was lower (**Table A8**).

We constructed an index of ACN/ACDN competence by combining her education level, vocabulary score, knowledge about nutrition and hygiene and motivation scores, and used it to check whether impact varied by the ACDN competence level (below and above the median). Results (not reported) show no statistical difference between the competence index and either take-up or impact on intermediate/final outcomes. Previous evidence from the long-term evaluation of the community nutrition program and international evidence [ADD] point out to a critical role of the quality of the frontline workers in affecting the impact of complex nutrition and early stimulation packages. More work is needed in the future to better understand the relative role played by skills, motivation and teamwork and task allocation across integrated interventions.

Mediation analysis

As a complement to the main intention to treat analysis of the MAHAY intervention, we conducted a mediation analysis to explore the mechanisms through which the intervention impacted nutrition and cognitive outcomes in affected sub-samples. We focused on various dimensions of parental investment including feeding and hygiene behaviors, as well as early stimulation practices. We believe that understanding how the intensive counseling, nutrition and home stimulation interventions tested in MAHAY changed parental behavior is important to not only better understand how the program impacted outcomes, but also to improve design for more sustainable, scalable interventions. We examined mechanisms for impact in the sub-samples where we found treatment effects of the MAHAY program.

For anthropometrics outcomes, the analysis focused on the subsample of the youngest cohort, which we defined as being below the median age at endline, and for whom we detected significant impact of the LNS supplementation. The objective was to test how much of the impact of the LNS arms on anthropometric outcomes was accounted (enhanced or diminished) by changes in nutrition/hygiene practices or changes in knowledge. The cognition pathway will be explored in for future research.

We used a Monte Carlo method for assessing mediation (MCMAM), following the approach used in Campos et al (2017)[18]. The mediation framework follows closely Attanasio et al (2018)[19] The method is straightforward multi-step process.

First, we re-run equation (1) on the main impact of the intervention arms on a number of intermediate outcomes (mediators) related to parental investment and behaviors (A pathway ADD figure), with two differences: (i) we combine T2 and T3 in a single dummy, as there was no statistically different effect between the two arms and (ii) we run the regression on the subsample of the young cohorts. We use the following model:

$$M_{ijt} = \alpha_0 + \alpha_1 T1_j + \alpha_2 T23_j + \alpha_4 T4_j + \Gamma + \delta X_{ij} + \varepsilon_{ijt} \qquad (2)$$

where M_{ijt} is the intermediate outcome for target child *i* in community *j* at time *t*, where *t={1,2}* represents midline or endline follow up survey round. T1, T23, and T4 are indicators for village/cluster assignment to the different treatment arms, combining the nutrition supplementation arms (T2 and T3). Γ_s is a vector of block-level randomization strata used in the study design (region and age), and X_{ij} is a vector of time-invariant covariates for target child *i* in cluster *j*. The coefficients $\alpha_1 - \alpha_3$ provide the intention to treat effects on the intermediate outcomes. For the nutrition pathway, we are interested in α_2 The standard errors ϵ_{ijt} are adjusted for village-level clustering.

Second, we estimate intention to treat effects of the intervention on outcomes of interest (C pathway) using the following model:

$$Y_{ijt} = \beta_0 + \beta_1 T1_j + \beta_2 T23_j + \beta_4 T4_j + \Gamma + \delta X_{ij} + \varepsilon_{ijt} \qquad (3)$$

Finally, we add the intermediate indicators (one at a time and then jointly) to test how much of the intermediate outcome accounts for the effect of the program on the outcome of interest (B pathway):

$$Y_{ijt} = \tilde{\beta}_0 + \tilde{\beta}_1 T1_j + \tilde{\beta}_2 T23_j + \tilde{\beta}_4 T4_j + \sum_1^k \rho_m M_{m,ijt} + \Gamma + \tilde{\delta} X_{ij} + \varepsilon_{ijt} \quad (4)$$

We use the unstandardized regression coefficient of the treatment dummy from equation (2) (α_2 for nutrition outcomes) and the unstandardized regression coefficient of the respective mediating variable from equation (4) ρ as well as their squared standard errors to compute the 95% Monte Carlo

[18] Francisco Campos, Michael Frese, Markus Goldstein, Leonardo Iacovone, Hillary Johnson, David McKenzie, Mona Mensmann (2017) "Teaching personal initiative beats traditional training in boosting small business in West Africa". Science 357.6357: 1287–1290.

[19] Orazio Attanasio, Helen Baker-Henningham, Raquel Bernal, Costas Meghir, Diana Pineda, Marta Rubio-Codina (2018). "Early Stimulation and Nutrition: The Impacts of a Scalable Intervention". National Bureau of Economic Research Working Paper No. 25059.

confidence interval based on 20,000 repetitions (Preacher and Selig 2012)[20]. An interval that does not include zero indicates a significant indirect effect of the treatment on the outcome through the respective mediator.

The results are presented in **Table A9**. We find significant effects of T2 + T3 on various intermediate outcomes at both midline and endline for young children. At midline, the intensive counseling and nutrition supplementation treatment had a positive effect on grains consumption, parental knowledge of child nutrition and health risk factors, and hygiene practices. At endline, the treatment had a positive effect on grains, dairy, meat and vitamin A-rich foods consumption, as well as hand-washing practices.

The outcomes that were impacted by treatment (T2 + T3) at the two survey rounds were height-for-age z-score (HAZ) (and weight-for-age z-score (WAZ), not shown). The intermediate outcomes, however, explain a very small percentage of the treatment effects: ranging from 3% of the treatment effect on HAZ explained by dairy consumption at endline, to 9% of the treatment effect on WAZ explained by meat and eggs consumption at midline. We cannot reject the null hypothesis that there are no indirect effects of the treatment on HAZ or WAZ in either survey round. In other words, the results suggest that the T2 and T3 effects on anthropometric outcomes are a result of a *direct* effect of the supplementation. The changes in feeding practice or knowledge, if any are additive, but by themselves do not account for the impact observed in T2 and T3. The results also confirm that the changes in practices did not crowded out the main effect of the LNS supplementation.

[20] Kristopher J Preacher and James P Selig. (2012) "Advantages of Monte Carlo confidence intervals for indirect effects". Communication Methods and Measures, 6.2: 77–98.

Costing and Cost Effectiveness

A key research and operational question of the Mahay study was to test the cost-effectiveness of different variants of the integrated package of enhanced community-based services, in their ability to address chronic malnutrition and poor child development, with an eye on scalability. It is important to recall that this study aims at measuring the d*ifferential effects and costs of each incremental layer/add on to the existing program (the control group or U-PNNC)*.

Benefits: In the earlier sections, we show that the T2 and T3 interventions were successful at delivering gains in linear length (height-for-age z-score) and a reduction in the prevalence of stunting among the younger cohorts, with age below the median age at endline. Neither T1 nor T4 led to improvements in nutritional status or child development. We use the estimated gains from T2-T3 to be compared to their cost to assess the cost-effectiveness of these two arms. We use the estimated gains for the younger cohorts for T2 and T3 (as reported in Table 2 and Table A12). The average impact on stunting is of about 8-9 pp (vs 67 pp in the control group) or about 12% reduction in the prevalence of stunting among the eligible population.

Costs: for each arm, we collected detailed arm level data throughout the intervention on all fixed and variable costs associated with each intervention (Table A10). As operating costs, we included the monthly salary of the ACDNs, materials used for the home visits and supervision, all costs related to refresher training (per diems, lodging and travel cost of all staff involved in the training), as well as the direct cost of coaching the ACDNs in the field. In this first calculation we are not accounting for the opportunity cost of time for participation in the treatment arms. For T2 and T3, we include the variable costs of procuring and distributing the LNS to the different treatment clusters (cost LNS 95%, transport 3%, customs, local transport 2%) in addition to the variable costs of the nutritional counseling (T1).

Methodology: Note that our analysis focuses on ITT, that is the estimated impact of the program is expressed in terms of the net present value of averting stunting at the village level. The costs are calculated at the per-capita level (as in done in Hoddinott et al 2013). Benefits of averting stunting is valued in terms of the net present value of the long-term income gains in terms of improved schooling, height and cognition, drawing from a body of experimental and programmatic work summarized in systematic reviews and meta-analyses. The methodology and estimates of the value of improved nutrition are in line with a larger literature that estimates the economic benefits of addressing undernutrition (Hoddinott et al 2013, Alderman et al 2016)[21] We rely on the parameter estimates for computing the internal rates of returns and benefit/cost ratio as in Galasso and Wagstaff (2018)[22].

Our results show that a single intervention like the supplementation of LNS to children during the window of 6-18 months of age is cost-effective, with an internal rate of return for T2 from averting

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[21] Hoddinott, J., H. Alderman, J. R. Behrman, L. Haddad and S. Horton (2013). The economic rationale for investing in stunting reduction. Matern Child Nutr 9 Suppl 2: 69-82.

Alderman, H., J. R. Behrman and C. Puett (2017). Big Numbers about Small Children: Estimating the Economic Benefits of Addressing Undernutrition. World Bank Research Observer 32(1): 107 - 125.

[22] Galasso, E., A. Wagstaff, S. Naudeau and M. Shekar (2017). The Economic Costs of Stunting and How to Reduce Them. Policy Research Note No. 5. Washington, D.C. . and its technical background paper Galasso, E. and A. Wagstaff (2018) The Aggregate Income Losses from Childhood Stunting and the Returns to a Nutrition Intervention Aimed at Reducing Stunting. World Bank Policy Research Working Paper No. 8536

stunting of 10.7% and a benefit/cost ratio of 3:1. As a reference, the full package of 10 interventions included in the Bhutta et al (2013) Lancet paper[23] would result in an internal rate of return of 17%, with a benefit/cost ratio of 15:1. Some key micro and macro nutrients included in the LNS are also listed in a subset of supplementation interventions listed the Bhutta package, although provided in small quantities on a preventive basis.

Even halving the benefits, the intervention is still cost effective and with a positive rate of return.

The results presented above do not show a statistically different impact of the T2 and T3. The hypothesis that a longer supplementation from pregnancy to 18 months of age would result in a larger impact on stunting is not supported by the data. As a consequence, T3 (longer duration and higher unit average cost) is not as cost effective and dominated by T2 in terms of cost-effectiveness.

Conclusions

In this cluster randomized trial in Madagascar, we found that there were no main effects of nutrition supplementation and parenting support on any measure of anthropometry or child development across all age cohorts at endline. When disaggregated by children's median age, those exposed to lipid-based supplementation from 6-18 months of age (with or without earlier LNS starting during pregnancy and lactation) experienced an increase of 0.21 SD in height-for-age and a 8.9-8.2 percentage point reduction of stunting during supplementation, as well as improvements in hemoglobin concentration and reduction in anemia. All intervention arms resulted in an increase in animal source food consumption in the 24 hours prior to the survey interview, and in an increase in meal frequency, but no effect on child diet diversity or morbidity. There is suggestive evidence that vitamin A rich food was reduced, especially among low socio-economic status households (low maternal education), although the effect is not statistically significant. Finally, we did not find any significant impact of integrating home visiting support on either the quality of the home environment, or on child development outcomes.

Given the high prevalence of stunting, and particularly severe stunting in Madagascar, the rationale for this intervention was strong, particularly because it was combined with an improved behavior change intervention in the form of individualized intensive counselling.[24] The quantities of LNS were preventative, so they were less likely to be shared with household members other than the targeted

[23] Bhutta, Z. A., J. K. Das, A. Rizvi, M. F. Gaffey, N. Walker, S. Horton, P. Webb, A. Lartey, R. E. Black, G. Lancet Nutrition Interventions Review, Maternal and G. Child Nutrition Study (2013). "Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost?" Lancet 382(9890): 452-477.

The interventions included in the Bhutta et al package are: (i) salt iodization (ii) multiple micronutrient supplementation in pregnancy including iron-folate (iii) calcium supplementation in pregnancy (iv) energy-protein supplementation in pregnancy (v) vitamin A supplementation in childhood (vi) zinc supplementation in (vii) breastfeeding promotion (viii) complementary feeding education (ix) complementary food supplementation and (x) severe acute malnutrition management

[24] Paul KH, Muti M, Khalfan SS, Humphrey JH, Caffarella R, Stoltzfus RJ. Beyond food insecurity: how context can improve complementary feeding interventions. *Food Nutr Bull* 2011; **32**(3): 244-53.

Ickes SB, Jilcott SB, Myhre JA, et al. Examination of facilitators and barriers to home-based supplemental feeding with ready-to-use food for underweight children in western Uganda. *Matern Child Nutr* 2012; **8**: 115-29.

child or pregnant women, avoiding dilution of the benefits due to food sharing within the household or substitution of existing food intake. The results from the biochemical sample on micronutrient status confirm that the LNS supplementation was indeed received by the target children.

Our findings suggest that the addition of intensive counselling over and above the group messaging during growth monitoring sessions may be able to shift the take-up of key nutritional messages, but it may not be sufficient alone to address severe nutritional deficiencies in settings with high food insecurity and poverty depth. Our results show that LNS supplementation can be effective in increasing linear growth and decreasing stunting, as well as in improving hemoglobin and iron status, when delivered starting at the age of 6 months of age.

Our study's results add to the emerging evidence from a number of LNS efficacy trials in Africa and Asia that suggest mixed results when examining effects of LNS on child growth and development. For example, a recent systematic review of four LNS trials among pregnant women in Bangladesh, Burkina Faso, Ghana and Malawi concluded that there was evidence of a small positive effect on birth weight (mean difference: 53.3 g; 95% CI: 28.2, 78.3) and length (0.24 cm; 95% CI: 0.11, 0.36) and a lower risk of small for gestational age (RR: 0.94; 95% CI: 0.89, 0.99) and newborn stunting (RR: 0.82; 95% CI: 0.71, 0.94).17 Studies of preventive LNS supplementation among 6-24 mo old children in Kenya, Bangladesh, Burkina Faso, Malawi, Zimbabwe, Mali, and Haiti generally also have noted positive, albeit modest effects on linear growth.

Thus far, few studies in addition to ours have examined developmental outcomes after LNS supplementation and the data available are conflicting. In Malawi, children supplemented from 6-18 months of age with LNS had no difference in age of achievement of motor or language developmental milestones, or other child development measures. In a recent study evaluating prenatal and postnatal LNS and micronutrient powders, LNS had positive effects on motor and language development, but no effects on personal social behavior or executive function in Bangladesh. Similarly, a trial in Burkina Faso also reported a significant benefits of LNS on children's motor, language, and personal-social development, and two other trials in Ghana found significant beneficial effects of LNS on children's development.

Our results do not support the hypothesis that there is an additional value of supplementation of pregnant and lactating women over and above supplementation of children during a critical age window of 6-18 months of age. The existing data and evidence relating to LNS interventions suggest that lipid-based supplements have the potential to improve size at birth and other birth outcomes, but we were not able to measure those outcomes in this programmatic trial.

Our findings are inconsistent with existing studies that have found benefits of parenting programs, even at scale. For example, an at-scale home visiting program in Pakistan utilized community health workers and demonstrated improved child development outcomes.[25] A recent scaled-up program in several Caribbean islands delivered parenting support messages within primary care clinics and showed benefits to child development. A study in Colombia utilized the existing structure of the country's CCT to deliver

[25] Yousafzai AK, Rasheed MA, Rizvi A, Armstrong R, Bhutta ZA. Effect of integrated responsive stimulation and nutrition interventions in the Lady Health Worker programme in Pakistan on child development, growth, and health outcomes: a cluster-randomised factorial effectiveness trial. *Lancet* 2014; **384**(9950): 1282-93.

a home-visiting program, and showed positive effects on child development in the short term,26 that faded out two years after the program had ended.[26]

A major strength of our study was integrating new intervention strategies into an existing community-based program that is implemented by the government, is a key component of the country's nutrition and food security strategy, and is already operating at scale, covering ~6,500 communities across Madagascar. There are undeniable benefits to building on the large-scale infrastructure of service delivery of the existing program, including a strong sense of ownership by government administrators, local CHW and community members, as well as the dedication of many people inside and outside of Madagascar to making the program work.

Another strength of the study is that it fills a knowledge gap of the feasibility and effectiveness of large scale programs to integrate health and nutrition with the promotion of child development.[27] Existing studies consist primarily of small, efficacy trials, and have shown little evidence of synergistic interaction between nutrition and stimulation on child development.[28] To our knowledge, no existing evaluations have added child stimulation to government-run health and nutrition services operating on a national scale. There are clear benefits to integrating these interventions, because health and nutrition sectors are often the only services reaching children under three years. Thus, delivering support for child development through these mechanisms may be a key way to reach young children, particularly those at risk of poor development. It is also possible that integration can provide additive benefits for children at a lower cost than for a stand-alone program.

A key weakness in our study is that while the study was powered for each arm for the whole sample, we may have been underpowered to detect small effects for any given age group. Another weakness is that loss to follow-up at midline and endline, mostly due to temporary migration due to weather shocks and economic constraints, might have also limited exposure, especially in the T4 group that was administered only to the study sample.

In addition to these issues, the MAHAY program implementation itself may have failed to achieve sizeable gains for child growth and development for several reasons. First, the time spent for home visits by CHWs may have been insufficient given the large geographic dispersion of households and generally low population density in the communities in rural Madagascar. Second, program eligibility was based on child age and did not target vulnerable families with the greatest need for services. Program effectiveness may have been greater with targeting based on vulnerability. Third, there may have been limited responsivity of mothers due to either low take-up (e.g., from lack of time, willingness to engage with CHWs and/or interest in topics covered) or inability to act on suggestions made by CHWs (e.g., from lack of money to purchase food or toys or lack of time/materials to prepare special complementary

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[26] Andrew A, Attanasio O, Fitzsimons E, Grantham-McGregor SM, Meghir C, Rubio-Codina M. Impacts 2 years after a scalable early childhood development intervention to increase psychosocial stimulation in the home: A follow-up of a cluster randomised controlled trial in Colombia. *Plos Medicine* 2018

[27] Engle PE, Fernald LCH, Alderman H, et al. Strategies for reducing inequalities and improving developmental outcomes for young children in low and middle income countries. *The Lancet* 2011; **378**(9799): 1339-53

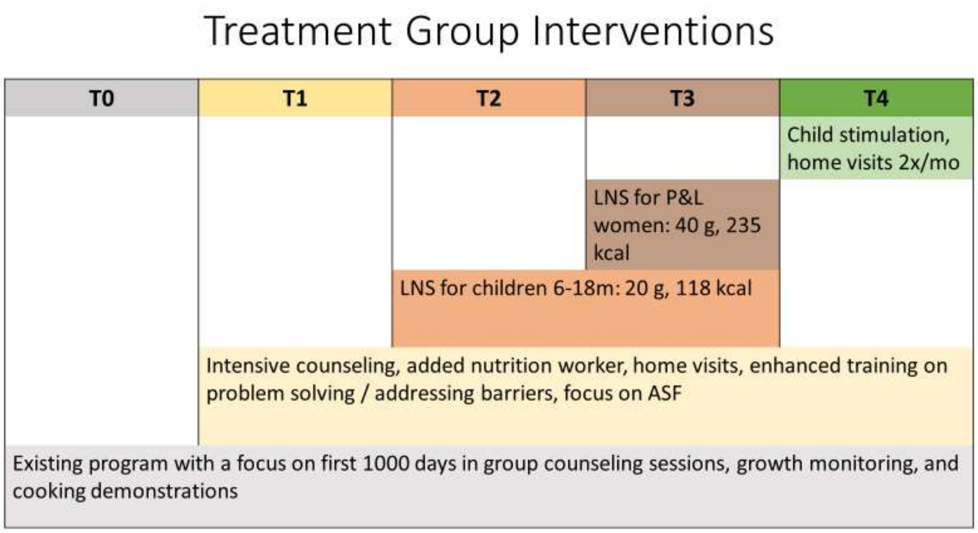
[28] Grantham-McGregor SM, Fernald LC, Kagawa RM, Walker S. Effects of integrated child development and nutrition interventions on child development and nutritional status. *Ann N Y Acad Sci* 2014; **1308**: 11-32.

foods or to make toys). Toys and books may be critical to sustain mothers' interest in stimulation activities in T4. However, in the MAHAY study, the materials were not available to keep or to borrow.

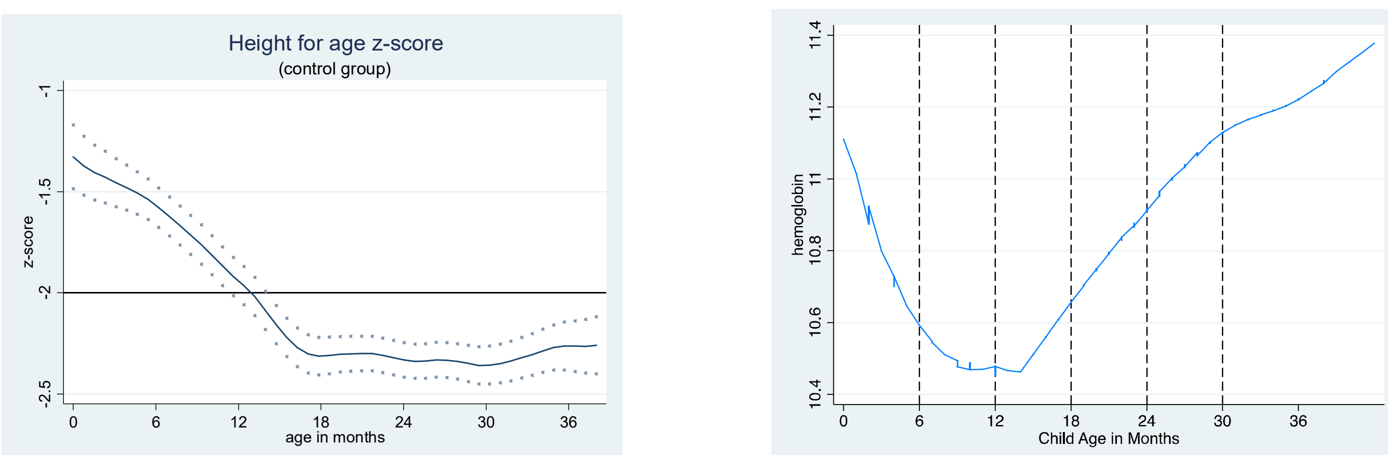
Despite the lack of a statistically significant effect of the stimulation arm, reports from various actors (CHW, parents, T4 coaches, and test administrators) suggested that T4 children were more engaged and dynamic during activities and development assessments. Current work is ongoing to improve our understanding of the pathways through which the stimulation arm may or may not have impacted developmental outcomes for children, including possibly fade out of program benefits from midline to endline. As in many African countries, children in Madagascar are frequently cared for by older siblings when they switch to complementary feeding, become mobile, or when a younger sibling is born. Thus the caregiver who participated in the program may not have been the person spending the most time with the child in their second year of life. In the future, we plan to evaluate program design variations on the stimulation component in Madagascar to fill in the knowledge gap on the role of key design features of integrating child stimulation with health and nutrition programs.

Graphs and Tables

Figure 1: Treatment Group Interventions

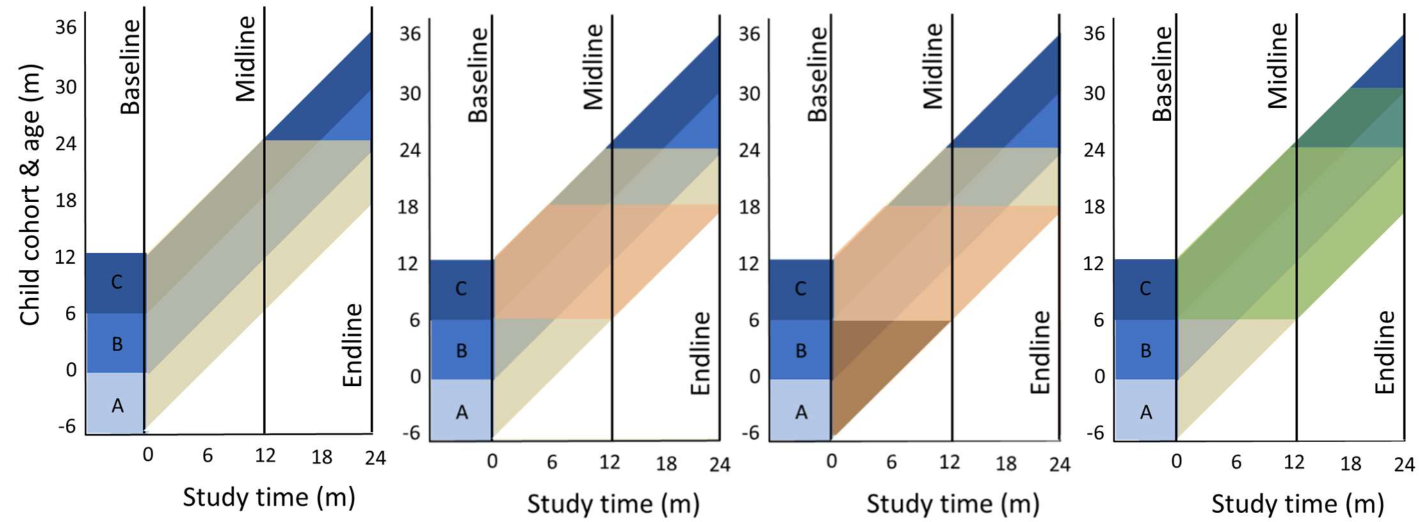


Graph 1: age profile height-for-age z-score and hemoglobin



Note: age profile of the height for age z-score (left) and of hemoglobin (right), baseline, midline and endline combined. Control group T0 only

Figure 2: Duration of exposure and eligibility by cohort, age and treatment arm (T1, T2, T3, and T4)



T0	T1: Intensive couns aeling	T2: LNS children	T3: LNS pregnant/ lactating women	T4: Child stimulation
				Eligibility: 6 to 30 m
			Eligibility: -6 to 6 m	
		Eligibility: 6 to 18 m		
	Eligibility: -6 to 24 m			
Eligibility: - 6 to 24 m				

Note: Figure 2 above describes the overlap between age at measurement for the different cohorts at midline and endline, and years of potential exposure to the different treatment arms. Cohorts A (-6,0) , B (0,5) and C(6,12) are the age group that were used to stratify the sample at baseline. The younger cohorts A and B have full exposure to the LNS supplementation for children (T2), whereas only cohort A has full exposure to the LNS supplementation to pregnant and lactating women (T3). As for T3, given that home visits for early stimulation start at age 6, age cohort C has the longest potential exposure to T4.

Table 1: Primary Outcomes: Main effects (Intention to Treat)

Panel A:	**Anthropometric Outcomes**				
	1	2	3	4	5
	Height for age z-score	*Stunted*	*Severely stunted*	*Weight for age z-score*	*Weight for length z-score*
	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]
T1 = T0 + intensive nutritional counseling	-0.053	0.037	-0.022	-0.049	-0.037
	[-0.211,0.104]	[-0.023,0.096]	[-0.078,0.035]	[-0.196,0.097]	[-0.178,0.105]
T2 = T1 + child 6-18 months LNS	0.044	-0.009	-0.005	-0.035	-0.1
	[-0.132,0.220]	[-0.077,0.059]	[-0.067,0.058]	[-0.191,0.120]	[-0.247,0.048]
T3 = T1 + child and mother LNS	0.097	-0.04	-0.037	0.022	-0.065
	[-0.049,0.244]	[-0.101,0.020]	[-0.098,0.023]	[-0.095,0.139]	[-0.183,0.053]
T4 = T1 + early child development	-0.026	0.005	-0.023	-0.074	-0.098
	[-0.192,0.139]	[-0.052,0.062]	[-0.083,0.037]	[-0.194,0.047]	[-0.219,0.024]
Adjusted R-squared	0.031	0.019	0.014	0.044	0.043
Observations (N)	3545	3545	3545	3569	3552
Control mean†	*-2.350*	*0.635*	*0.259*	*-1.537*	*-0.322*
Control SD	*1.064*	*0.482*	*0.439*	*0.927*	*0.905*
Joint F-test p-value	0.317	0.192	0.750	0.519	0.517
F-test T2 vs. T3 p-value	0.532	0.373	0.315	0.447	0.630
F-test T1 vs. T2 p-value	0.279	0.189	0.582	0.877	0.450
F-test T1 vs. T3 p-value	0.051	0.015	0.597	0.324	0.681
F-test T1 vs. T4 p-value	0.749	0.277	0.957	0.738	0.384

*** p<0.01, ** p<0.05, * p<0.1
All models adjusted for child gender, child age, region, mother's education, mother's age, household wealth, and child's birth order.
†proportion for binary outcomes: Stunted, Severely stunted

Panel B:	**Child Development Outcomes (age standardized)**					
	6	7	8	9	10	11
	Gross Motor	*Fine Motor*	*Problem Solving*	*Socio-emotional development*	*Communication Skills*	*Total ASQ*
	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]
T1 = T0 + intensive nutritional counseling	0.084	0.104	0.175	0.153	0.100	0.153
	[-0.240,0.409]	[-0.183,0.391]	[-0.137,0.486]	[-0.119,0.425]	[-0.166,0.366]	[-0.166,0.473]
T2 = T1 + child 6-18 months LNS	0.271	0.234	0.159	0.107	0.136	0.221
	[-0.066,0.608]	[-0.079,0.547]	[-0.182,0.499]	[-0.197,0.412]	[-0.127,0.399]	[-0.132,0.573]
T3 = T1 + child and mother LNS	0.033	0.045	0.074	-0.083	-0.089	-0.01
	[-0.288,0.353]	[-0.261,0.351]	[-0.275,0.423]	[-0.379,0.214]	[-0.337,0.158]	[-0.354,0.333]
T4 = T1 + early child development	0.199	0.163	0.157	0.085	0.122	0.178
	[-0.135,0.533]	[-0.153,0.479]	[-0.177,0.490]	[-0.198,0.369]	[-0.133,0.376]	[-0.165,0.520]
Adjusted R-squared	0.063	0.06	0.086	0.095	0.063	0.087
Observations (N)	3552	3552	3552	3552	3552	3552
Control mean†	*-0.110*	*-0.089*	*-0.098*	*-0.043*	*-0.042*	*-0.093*
Control SD	*1.017*	*1.023*	*1.051*	*0.990*	*0.990*	*1.005*
Joint F-test p-value	0.442	0.606	0.812	0.523	0.302	0.571
F-test T2 vs. T3 p-value	0.141	0.239	0.633	0.238	0.070	0.197
F-test T1 vs. T2 p-value	0.254	0.386	0.918	0.758	0.780	0.683
F-test T1 vs. T3 p-value	0.738	0.690	0.534	0.104	0.130	0.310
F-test T1 vs. T4 p-value	0.474	0.693	0.903	0.619	0.862	0.876

*** p<0.01, ** p<0.05, * p<0.1
All models adjusted for child gender, child age, region, mother's education, mother's age, household wealth, and child's birth order.

Table 2: Program Effects on Hemoglobin and Anemia (ITT)

Panel A: continuous outcome	*Hemoglobin (g/DL)*			
	midline		*endline*	
	comparison vs T0 Coef. [95% CI]	comparison vs T0 T1 T4 Coef. [95% CI]	comparison vs T0 Coef. [95% CI]	comparison vs T0 T1 T4 Coef. [95% CI]
T1 = T0 + intensive nutritional counseling	0.01		0.06	
	[-0.34, 0.36]		[-0.13, 0.26]	
T2 = T1 + child 6-18 months LNS	0.24	0.28*	-0.04	-0.04
	[-0.12, 0.60]	[-0.004, 0.56]	[-0.26, 0.19]	[-0.24, 0.16]
T3 = T1 + child and mother LNS	0.22	0.26**	-0.06	-0.07
	[-0.13, 0.57]	[0.01, 0.51]	[-0.26, 0.13]	[-0.23, 0.10]
T4 = T1 + early child development	-0.14		-0.05	
	[-0.48, 0.21]		[-0.30, 0.21]	
Observations (N)	568	1118	1417	2847
Control mean	*10.40*	*10.34*	*11.11*	*11.11*
Control SD	*1.64*	*1.54*	*1.26*	*1.23*

Panel B: binary outcome	*Anemia*			
	midline		*endline*	
	comparison vs T0 Odds ratio [95% CI]	comparison vs T0 T1 T4 Odds ratio [95% CI]	comparison vs T0 Odds ratio [95% CI]	comparison vs T0 T1 T4 Odds ratio [95% CI]
T1 = T0 + intensive nutritional counseling	1.01		0.96	
	[0.88, 1.15]		[0.81, 1.14]	
T2 = T1 + child 6-18 months LNS	0.89	0.87**	1.06	1.06
	[0.76, 1.03]	[0.77, 0.98]	[0.89, 1.28]	[0.90, 1.24]
T3 = T1 + child and mother LNS	0.90	0.88**	1.06	1.05
	[0.77, 1.05]	[0.77, 0.99]	[0.89, 1.26]	[0.91, 1.22]
T4 = T1 + early child development	1.06		1.06	
	[0.93, 1.21]		[0.88, 1.28]	
Observations (N)	568	1118	1417	2847
Prevalence	65.4	67.1	41.7	42.1

Note: Robust standard errors in parentheses, clustered at the village/site level
*** p<0.01, ** p<0.05, * p<0.1
All models adjusted for child age, region, mother's education, mother's age, household wealth, and child's birth order.

Table 3: Secondary Outcomes: biomarkers, sub-sample (youngest cohort A 18-24 at endline)

Panel A: continuous unadjusted	Hemoglobin (g/DL)	RBP (µmol/L)	Ferritin (µg/L)†	sTFR (mg/L)†	AGP (g/L)†	CRP (mg/L)†
	Difference [95% CI]	Difference [95% CI]	% difference [95% CI]	% difference [95% CI]	% difference [95% CI]	% difference [95% CI]
T2 = T1 + child 6-18 months LNS	0.44** [0.08, 0.80]	0.03 [-0.03, 0.09]	32.5*** [9.7, 60.2]	-13.3** [-22.3, -3.2]	10.9 [-6.3, 31.2]	-0.5 [-37.2, 57.6]
T3 = T1 + child and mother LNS	0.32** [0.05, 0.59]	0.06* [-0.01, 0.14]	45.9*** [10.3, 93.0]	-12.6*** [-21.0, -3.3]	-3.0 [-17.8, 14.6]	-3.5 [-36.1, 45.6]
T4 = T1 + early child development	0.18 [-0.09, 0.44]	0.88 [-0.08, 0.06]	7.1 [-18.8, 41.3]	-6.0 [-15.3, 4.3]	-7.7 [-22.0, 9.3]	-29.9 [-54.3, 7.4]
Observations (N)	189	189	189	189	189	189
Control median	11.3	0.93	21.9	8.8	0.83	1.31
Control IQR	(10.55, 11.75)	(0.79, 1.12)	(12.75, 35.35)	(7.38, 12.96)	(0.67, 1.50)	(0.58, 2.99)

Panel A: binary unadjusted	Anemia (Hb<11 g/DL)	vitamin A deficiency (RBP<0.83 µmol/L)	Low Ferritin (FER<12 µg/L)	High sTFR (sTFR>8.3 mg/L)	High AGP (AGP>1 g/L)	High CRP (CRP>5 mg/L)
	Prevalence Ratio [95%CI]	Prevalence Ratio [95%CI]	Prevalence Ratio [95%CI]	Prevalence Ratio [95%CI]	Prevalence Ratio [95%CI]	Prevalence Ratio [95%CI]
T2 = T1 + child 8-18 months LNS	0.58*** [0.39, 0.87]	1.14 [0.79, 1.64]	0.25*** [0.10, 0.64]	0.84 [0.63, 1.12]	1.28 [0.96, 1.71]	0.69 [0.35, 1.38]
T3 = T1 + child and mother LNS	0.60*** [0.45, 0.80]	0.82 [0.54, 1.26]	0.39** [0.17, 0.90]	0.81 [0.60, 1.09]	1.05 [0.78, 1.42]	1.09 [0.62, 1.92]
T4 = T1 + early child development	0.97 [0.72, 1.31]	1.28 [0.82, 1.99]	0.80 [0.43. 1.46]	1.03 [0.80, 1.31]	0.96 [0.70, 1.32]	0.71 [0.36, 1.38]
Observations (N)	189	189	189	189	189	189
Prevalence	40.0	31.6	22.1	56.8	38.9	20.0

Note: Robust standard errors in parentheses, clustered at the village/site level, † Log transformed for analysis. All models adjusted for child age, region, mother's education, mother's age, household wealth, and child's birth order. *** p<0.01, ** p<0.05, * p<0.1

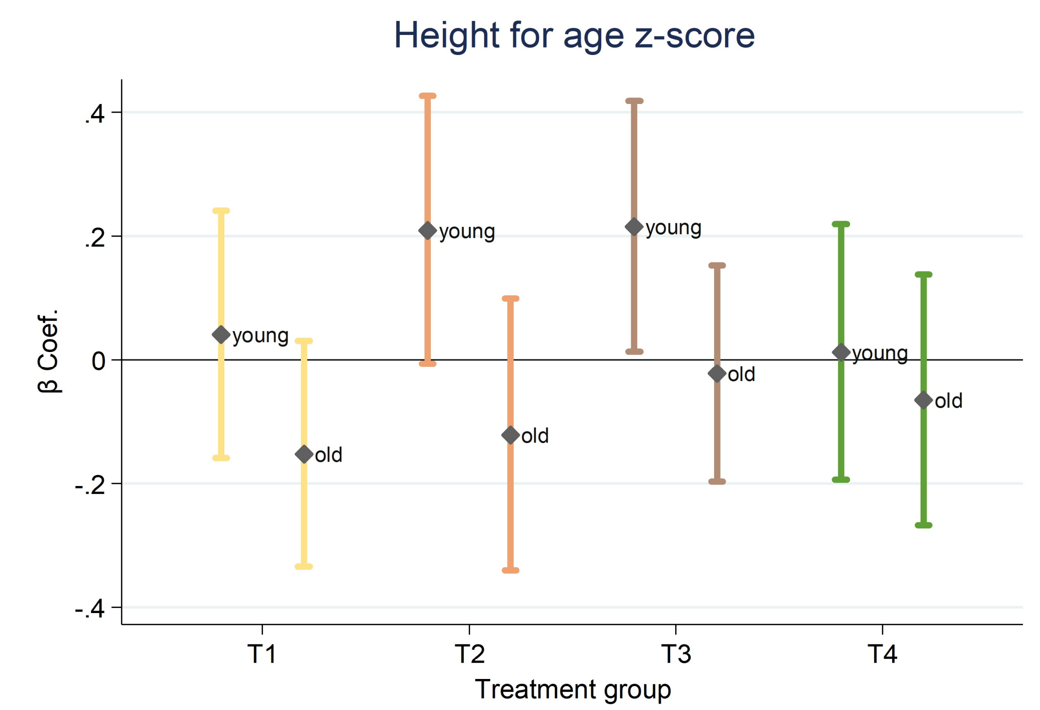
Table 4: Secondary Outcomes: Main effects (Intention to Treat)

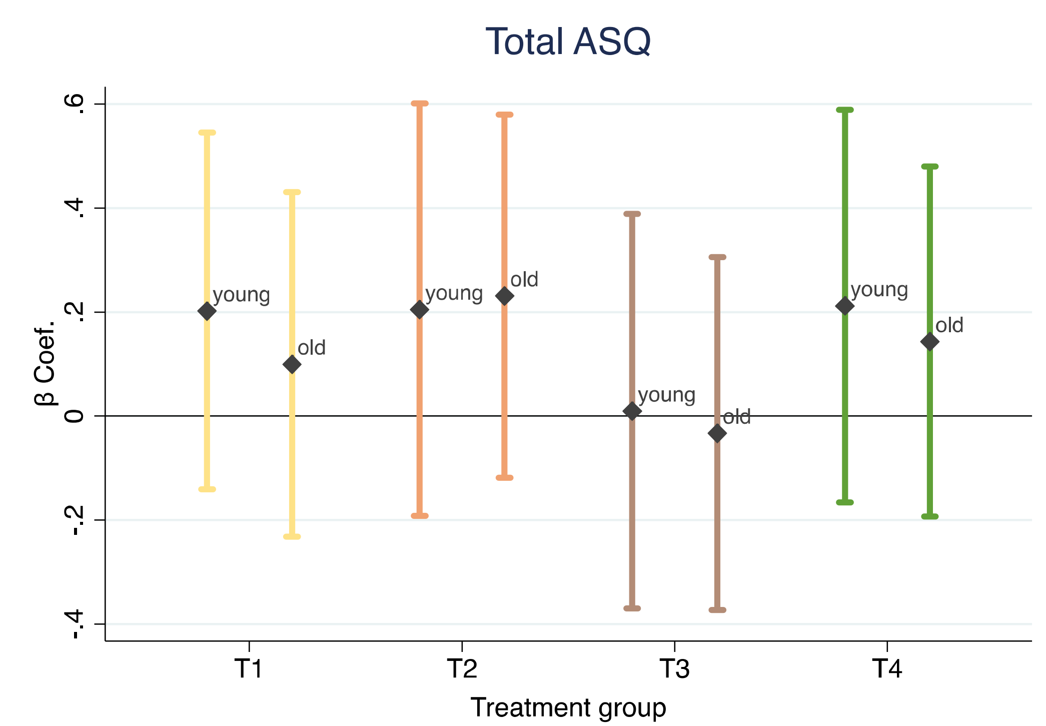
Panel A:	**Child level**						
	1	2	3	4	5	6	7
	Dairy intake past 24hr	*Protein intake past 24hr*	*Vitamin A rich foods past 24hr*	*Dietary diversity score past 24 hr*	*At least 4 food groups past 24hr*	*Meal frequency past 24 h*	*7 day morbidity*
	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]
T1 = T0 + intensive nutritional counseling	0.018	0.092**	-0.135	0.025	0.054	0.134	0.048
	[-0.002,0.038]	[0.031,0.152]	[-0.275,0.005]	[-0.149,0.199]	[-0.004,0.112]	[-0.002,0.270]	[-0.139,0.236]
T2 = T1 + child 6-18 months LNS	0.036	0.096**	-0.14	0.054	0.021	0.187**	-0.029
	[-0.002,0.073]	[0.039,0.153]	[-0.282,0.002]	[-0.116,0.223]	[-0.039,0.081]	[0.046,0.328]	[-0.200,0.142]
T3 = T1 + child and mother LNS	0.023*	0.090**	-0.102	0.079	0.044	0.022	-0.154
	[0.004,0.041]	[0.023,0.157]	[-0.235,0.030]	[-0.064,0.221]	[-0.005,0.092]	[-0.116,0.160]	[-0.316,0.008]
T4 = T1 + early child development	0.035*	0.061	-0.126	-0.046	0.01	0.165**	-0.055
	[0.006,0.063]	[-0.006,0.128]	[-0.263,0.011]	[-0.206,0.114]	[-0.053,0.072]	[0.040,0.289]	[-0.238,0.128]
Adjusted R-squared	0.058	0.139	0.053	0.283	0.126	0.168	0.036
Observations (N)	3577	3581	3581	3581	3581	3577	3581
Control mean†	*0.013*	*0.231*	*0.496*	*2.748*	*0.199*	2.978	*0.641*
Control SD	*0.111*	*0.422*	*0.500*	*0.953*	*0.400*	0.668	*1.171*
Joint F-test p-value	0.016**	0.005***	0.299	0.527	0.279	0.019**	0.142
F-test T2 vs. T3 p-value	0.499	0.874	0.525	0.753	0.439	0.038**	0.099*
F-test T1 vs. T2 p-value	0.399	0.895	0.934	0.762	0.327	0.498	0.398
F-test T1 vs. T3 p-value	0.697	0.969	0.574	0.514	0.723	0.147	0.021**
F-test T1 vs. T4 p-value	0.327	0.405	0.885	0.431	0.209	0.665	0.280

Robust standard errors in parentheses, clustered at the village/site level
*** p<0.01, ** p<0.05, * p<0.1
All models adjusted for child gender, child age, child's birth order, region, mother's education, mother's age, and household wealth.
†control mean is expressed as a proportion for binary outcomes

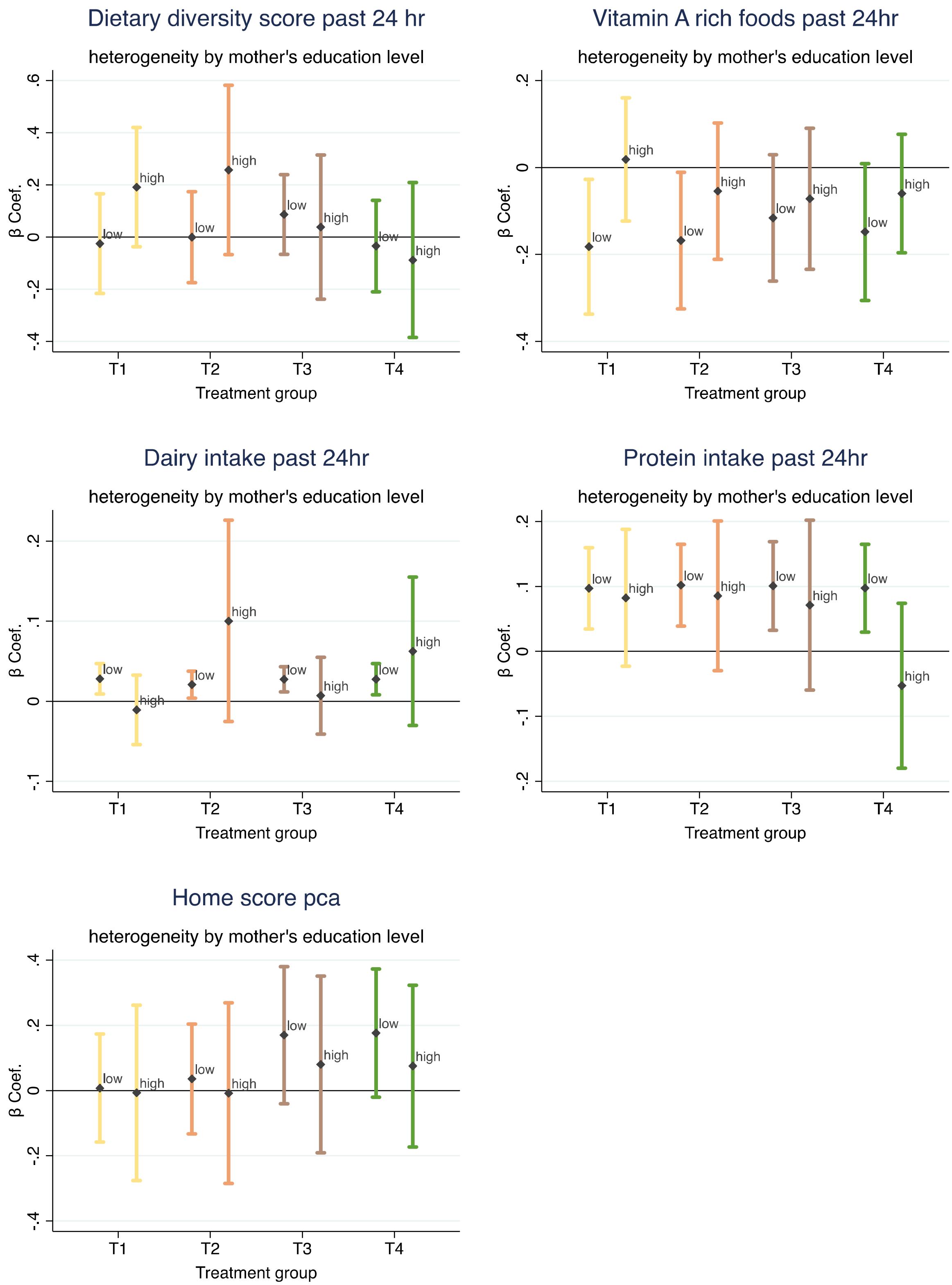
Panel B:	**Mother level**					
	8	9	10	11	12	13
	Hygiene practices score	*Meal preparation*	*ECD knowledge score*	*Maternal Dietary diversity score 24 hr*	*Food security*	*HOME/FCI score*
	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]	Coef. [95% CI]
T1 = T0 + intensive nutritional counseling	-0.240 [-0.604,0.124]	0.000 [-0.275,0.276]	-0.274* [-0.544,-0.003]	0.126 [-0.113,0.366]	0.186 [-0.189,0.561]	0.004 [-0.152,0.160]
T2 = T1 + child 6-18 months LNS	-0.144 [-0.508,0.220]	0.143 [-0.144,0.429]	-0.145 [-0.429,0.139]	0.076 [-0.168,0.320]	0.009 [-0.351,0.369]	0.026 [-0.139,0.190]
T3 = T1 + child and mother LNS	0.108 [-0.277,0.493]	0.199 [-0.080,0.478]	0.251 [-0.063,0.565]	0.032 [-0.207,0.272]	0.195 [-0.209,0.599]	0.147 [-0.052,0.345]
T4 = T1 + early child development	-0.050 [-0.425,0.324]	0.127 [-0.179,0.433]	-0.047 [-0.379,0.285]	-0.102 [-0.376,0.173]	0.020 [-0.359,0.400]	0.152 [-0.030,0.334]
Adjusted R-squared	0.122	0.118	0.104	0.193	0.254	0.284
Observations (N)	3581	3581	3581	3581	3581	3,581
Control mean†	*0.073*	*2.653*	*0.052*	*2.952*	*2.184*	*0.303*
Control SD	*1.173*	*1.139*	*1.320*	*1.366*	*1.458*	*1.029*
Joint F-test p-value	0.364	0.518	0.002***	0.533	0.718	0.136
F-test T2 vs. T3 p-value	0.168	0.695	0.005***	0.720	0.339	0.146
F-test T1 vs. T2 p-value	0.575	0.311	0.250	0.681	0.325	0.703
F-test T1 vs. T3 p-value	0.057*	0.152	0.0001***	0.434	0.964	0.074*
F-test T1 vs. T4 p-value	0.282	0.401	0.108	0.098*	0.388	0.037**

Graph 2: Heterogeneity impact on height-for-age and ASQ-I by age

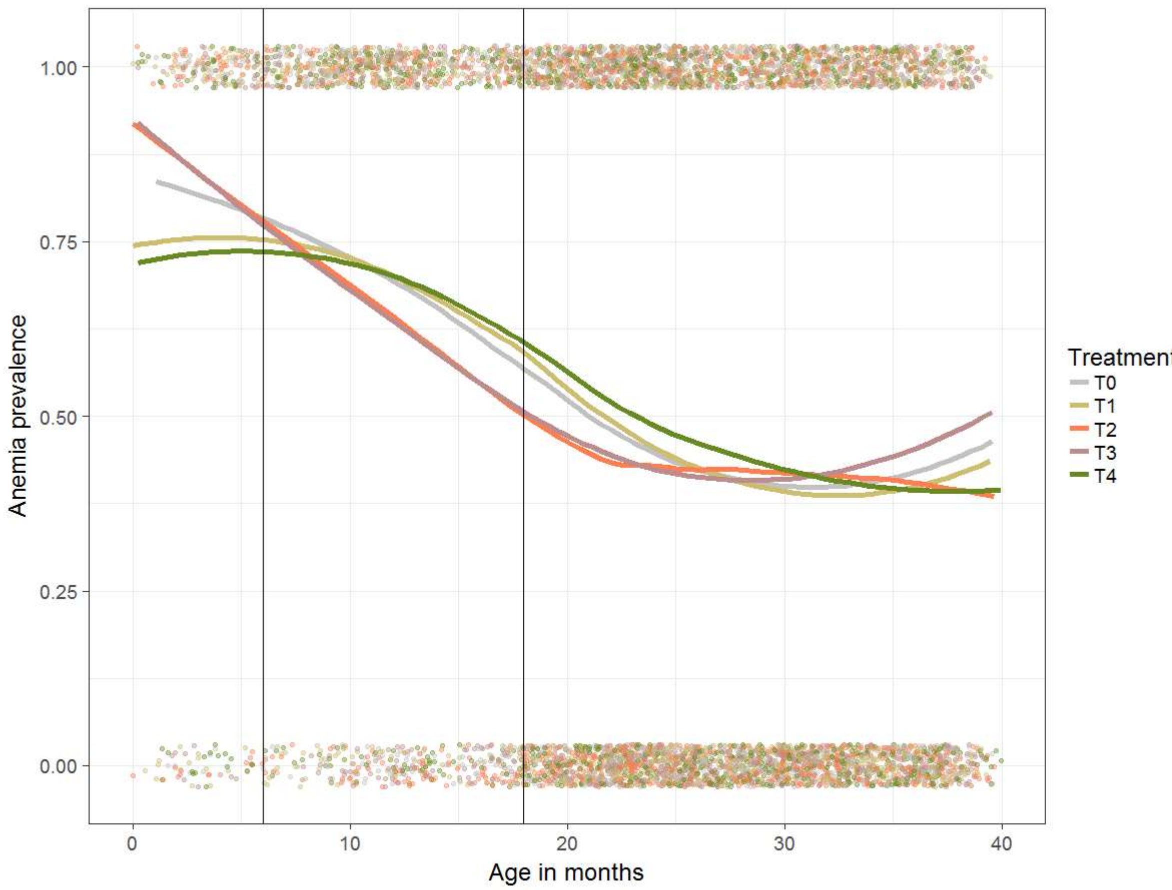




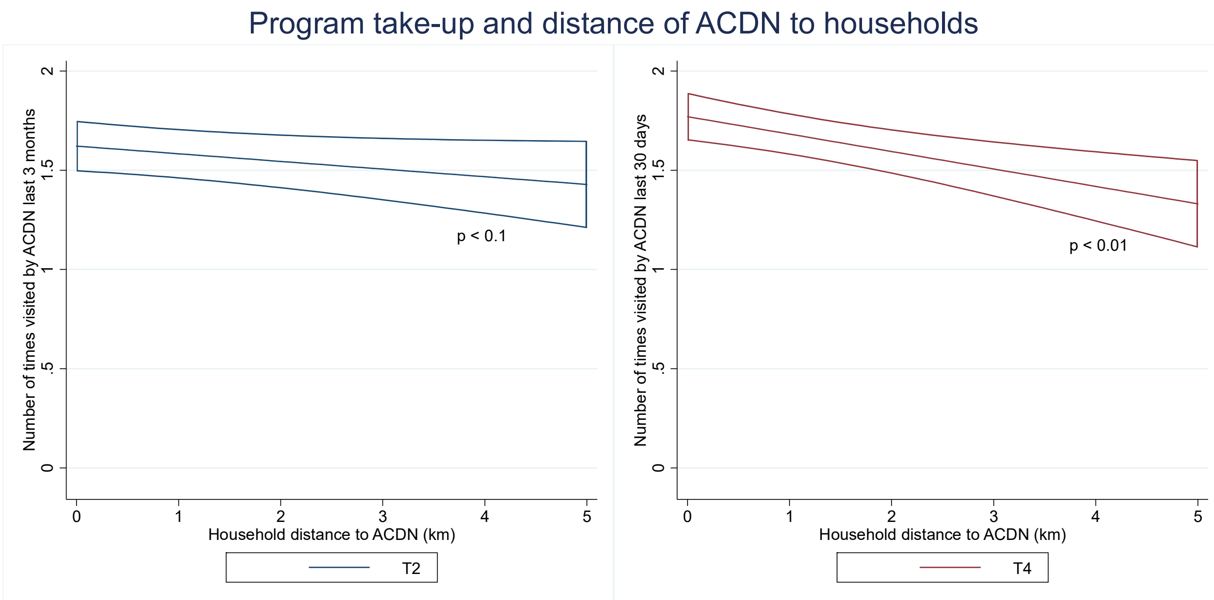
Graph 3 key intermediate outcomes by maternal education



Graph 4: impact on anemia prevalence, biochemical sample

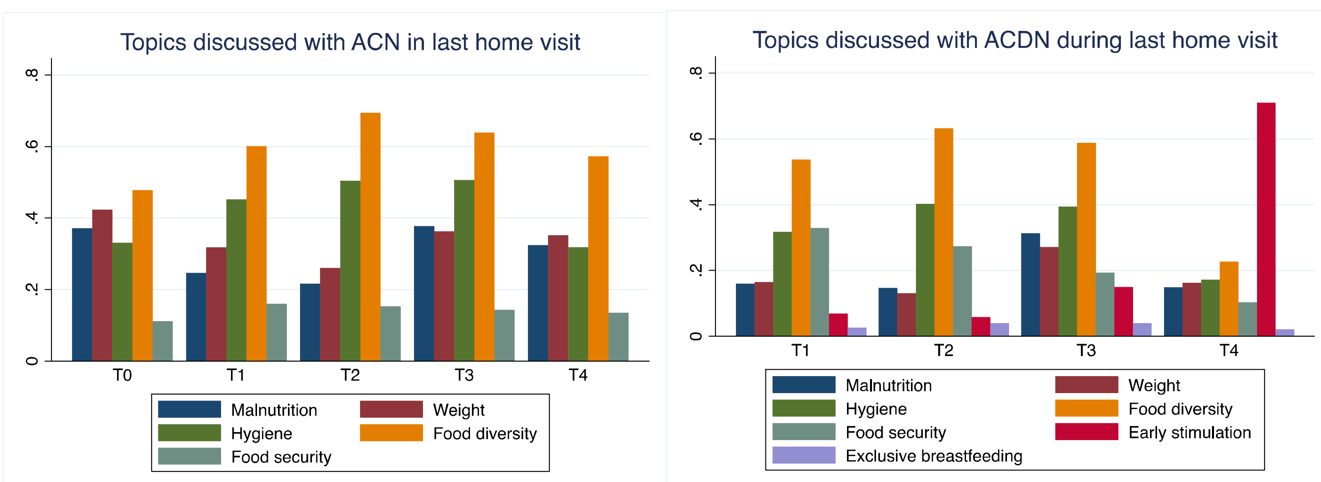


Graph 5: Program take-up and remoteness



Note: marginal effect of an extra km distance from the household to the ACDN and program take-up (probability of receiving a home visit by the ACDN in 2016). Estimates from table A5.

Graph 6: Topics discussed during the last home visit 2016



Note: Descriptive statistics on topics covered during the last home visits (ACNs, left panel; ACDN right panel). Endline survey 2016.

APPENDIX

Table A1. Consort table

Baseline survey: 3738 households surveyed at baseline and randomly assigned to treatment groups

T0	T1	T2	T3	T4
T0: 747 households	T1: 750 households	T2: 744 households	T3: 747 households	T4: 750 households
Midline survey				
T0: 710 households	T1: 727 households	T2: 710 households	T3: 707 households	T4: 692 households
Tracked from baseline: 615	Tracked from baseline: 618	Tracked from baseline: 582	Tracked from baseline: 620	Tracked from baseline: 569
Replacements: 95	Replacements: 109	Replacements: 128	Replacements: 87	Replacements: 123
Loss to follow up: 132	Loss to follow up: 132	Loss to follow up: 162	Loss to follow up: 127	Loss to follow up: 181
*20 infant deaths	*15 infant deaths	*19 infant deaths	*16 infant deaths	*22 infant deaths
*8 stillbirths	*3 stillbirths	*10 stillbirths	*6 stillbirths	*6 stillbirths
*8 miscarriages	*5 miscarriages	*10 miscarriages	*15 miscarriages	*19 miscarriages
*1 mother death	*1 mother death	*1 mother death		*1 mother death
*95 moved	*105 moved	*122 moved	*87 moved	*133 moved
	*3 unknown		*3 unknown	
Endline survey				
T0: 719 households	T1: 736 households	T2: 734 households	T3: 726 households	T4: 732 households
Tracked from baseline: 560	Tracked from baseline: 551	Tracked from baseline: 518	Tracked from baseline: 569	Tracked from baseline: 513
Tracked from midline replacement: 88	Tracked from midline replacement: 87	Tracked from midline replacement: 113	Tracked from midline replacement: 71	Tracked from midline replacement: 102
Tracked from midline loss to follow up: 17	Tracked from midline loss to follow up: 21	Tracked from midline loss to follow up: 34	Tracked from midline loss to follow up: 29	Tracked from midline loss to follow up: 45
Replacements: 54	Replacements: 77	Replacements: 69	Replacements: 57	Replacements: 72
Loss to follow up (from baseline): 115	Loss to follow up (from baseline): 111	Loss to follow up (from baseline): 128	Loss to follow up (from baseline): 98	Loss to follow up (from baseline): 136
Loss to follow up (from midline replacements): 7	Loss to follow up (from midline replacements): 22	Loss to follow up (from midline replacements): 15	Loss to follow up (from midline replacements): 16	Loss to follow up (from midline replacements): 21
*2 infant deaths	*2 infant deaths	*4 infant deaths	*2 infant deaths	
*4 moved	*19 moved	*11 moved	*13 moved	*20 moved
*1 unknown	*1 unknown		*1 unknown	*1 unknown
Loss to follow up (from midline): 55	Loss to follow up (from midline): 67	Loss to follow up (from midline): 64	Loss to follow up (from midline): 51	Loss to follow up (from midline): 56
*5 infant deaths	*9 infant deaths	*5 infant deaths	*7 infant deaths	*5 infant deaths
*44 moved	*50 moved	*54 moved	*39 moved	*45 moved
*6 unknown	*8 unknown	*5 unknown	*5 unknown	*6 unknown

Table A2: Balance table. Baseline

		Regression coefficients on treatment indicators Mean [SE]				*P-value of F-test*
	Control	T1	T2	T3	T4	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Household characteristics at baseline	*Mean (SD)*					
Household size	*5.65*	5.70	5.88	5.61	5.77	0.730
	(2.50)	[0.21]	[0.21]	[0.14]	[0.14]	
Number of household members						
0-1 years old	*0.72*	0.78	0.78	0.77	0.80	0.001***
	(0.51)	[0.02]	[0.02]	[0.01]	[0.01]	
2-5 years old	*0.82*	0.90	0.93	0.87	0.90	0.531
	(0.85)	[0.07]	[0.06]	[0.05]	[0.05]	
6-18 years old	*1.92*	1.87	1.99	1.84	1.91	0.788
	(1.75)	[0.11]	[0.13]	[0.08]	[0.08]	
19-60 years old	*2.10*	2.07	2.12	2.08	2.10	0.934
	(0.88)	[0.06]	[0.05]	[0.06]	[0.05]	
Asset index:						
Quintile 1	*0.21*	0.19	0.18	0.26	0.16	0.068*
	(0.41)	[0.05]	[0.05]	[0.05]	[0.04]	
Quintile 2	*0.19*	0.18	0.21	0.21	0.22	0.599
	(0.39)	[0.03]	[0.03]	[0.02]	[0.03]	
Quintile 3	*0.20*	0.18	0.20	0.22	0.20	0.623
	(0.40)	[0.03]	[0.03]	[0.02]	[0.03]	
Quintile 4	*0.21*	0.20	0.23	0.19	0.18	0.710
	(0.40)	[0.03]	[0.03]	[0.02]	[0.02]	
Quintile 5	*0.20*	0.25	0.19	0.11	0.24	0.003***
	(0.40)	[0.05]	[0.05]	[0.03]	[0.06]	
Household access to safe drinking water	*0.33*	0.23	0.25	0.25	0.33	0.657
	(0.47)	[0.06]	[0.06]	[0.07]	[0.07]	
Mother education: Did not attend school						
	0.23	0.29	0.28	0.25	0.26	0.447
	(0.42)	[0.05]	[0.04]	[0.04]	[0.04]	
Primary or less	*0.51*	0.49	0.53	0.56	0.51	0.202
	(0.50)	[0.03]	[0.04]	[0.03]	[0.03]	
Secondary or higher	*0.26*	0.23	0.19	0.20	0.24	0.366
	(0.44)	[0.03]	[0.03]	[0.02]	[0.04]	
Maternal height (cm)	*152.63*	151.82	151.92	152.54	152.35	0.174
	(5.75)	[0.45]	[0.50]	[0.49]	[0.47]	
Mother/caregiver age (years)	*26.26*	26.83	26.13	25.49	25.68	0.026**
	(7.67)	[0.34]	[0.29]	[0.38]	[0.31]	
Maternal vocabulary (PPVT) raw score†	*20.59*	19.85	19.56	19.61	21.47	0.447
	(11.41)	[1.67]	[1.57]	[1.27]	[1.50]	
Panel B: Child characteristics at baseline†						
Child birth order†	*2.63*	2.66	2.67	2.61	2.68	0.923
	(1.27)	[0.07]	[0.05]	[0.07]	[0.07]	
Length for age z-score†	*-1.53*	-1.64	-1.61	-1.67	-1.61	0.562
	(1.24)	[0.08]	[0.10]	[0.07]	[0.09]	
Weight for age z-score†	*-1.01*	-1.12	-1.07	-1.19	-0.98	0.284

	(1.18)	[0.08]	[0.08]	[0.08]	[0.09]	
Weight for length z-score†	*0.07*	0.02	0.09	-0.08	0.18	0.388
	(1.20)	[0.10]	[0.09]	[0.10]	[0.08]	
ASQ-I child development z-score†	*-0.09*	0.04	0.13	-0.12	0.04	0.071*
	(0.99)	[0.09]	[0.07]	[0.11]	[0.09]	
Panel C: Family characteristics at baseline						
Maternal knowledge index score	*-0.18*	-0.07	-0.05	0.13	0.15	0.542
	(1.11)	[0.20]	[0.18]	[0.16]	[0.28]	
Material diet diversity score index (MDDW)						
	2.90	2.98	3.00	2.86	2.75	0.399
	(1.26)	[0.11]	[0.10]	[0.14]	[0.13]	
Learning opportunities: # of activities with any adult†	*2.01*	2.33	2.41	2.04	2.32	0.118
	(1.51)	[0.16]	[0.21]	[0.20]	[0.21]	
Total books, general plus children's books†						
	3.60	3.36	3.57	3.33	3.73	0.848
	(4.96)	[0.36]	[0.39]	[0.36]	[0.41]	
Play objects and materials†	*1.61*	1.67	1.72	1.63	1.72	0.386
	(1.39)	[0.06]	[0.08]	[0.08]	[0.10]	
Family care indicators (FCI) PCA score †	*-0.95*	*-0.81*	*-0.74*	*-0.91*	*-0.69*	*0.123*
	[0.12]	*[0.12]*	*[0.14]*	*[0.13]*	*[0.15]*	
Child food diversity score: 24-hour recall †						
	1.00	1.02	1.19	0.92	0.92	0.000***
	(1.15)	[0.06]	[0.06]	[0.06]	[0.09]	

Note: Column (1) reports mean values for the control group, with standard deviations in parenthesis. Columns 2 to 5 report the coefficients (and standard errors) from separate regressions in which a dependent variable is regressed on the full set of treatment indicators and strata dummies. Column (6) reports the p-values of F-tests of whether the treatment coefficients are jointly equal to zero. Robust standard errors clustered at the community level.

Asterisks indicate coefficient statistical significance level (2-tailed): * P < 0.10; ** P < 0.05; *** P < 0.01.

Table A3: Balance check post-replacement

	Control	T1	T2	T3	T4	P-*value of F-test*
	(1)	(2)	(3)	(4)	(5)	(6)
Household and child characteristics	Mean (SD)	Mean [SE]	Mean [SE]	Mean [SE]	Mean [SE]	
Household size	6.47	6.61	6.76	6.53	6.61	0.847
	(2.61)	[0.20]	[0.25]	[0.16]	[0.14]	
Number of household members aged:						
0-1 years old	0.40	0.46	0.43	0.41	0.4	0.303
	(0.53)	[0.03]	[0.03]	[0.03]	[0.03]	
2-5 years old	1.29	1.33	1.35	1.36	1.37	0.479
	(0.69)	[0.05]	[0.05]	[0.04]	[0.04]	
6-18 years old	1.89	1.97	1.94	1.76	1.91	0.401
	(1.77)	[0.09]	[0.11]	[0.11]	[0.08]	
19-60 years old	2.15	2.07	2.13	2.12	2.10	0.747
	(0.87)	[0.05]	[0.05]	[0.05]	[0.03]	
Asset index (housing, assets and livestock): Quintile 1	0.22	0.20	0.18	0.22	0.18	0.838
	(0.41)	[0.04]	[0.04]	[0.04]	[0.04]	
Quintile 2	0.20	0.19	0.19	0.23	0.18	0.291
	(0.40)	[0.02]	[0.02]	[0.02]	[0.02]	
Quintile 3	0.20	0.17	0.21	0.23	0.19	0.295
	0.40	[0.02]	[0.02]	[0.02]	[0.02]	
Quintile 4	0.17	0.20	0.24	0.18	0.20	0.243
	(0.38)	[0.02]	[0.03]	[0.02]	[0.03]	
Quintile 5	0.20	0.24	0.18	0.13	0.25	0.022**
	(0.40)	[0.05]	[0.04]	[0.02]	[0.05]	
Household has access to safe drinking water source	0.28	0.26	0.23	0.27	0.33	0.885
	(0.45)	[0.07]	[0.06]	[0.07]	[0.07]	
Mother education:						
Did not attend school	0.22	0.28	0.26	0.24	0.26	0.517
	(0.42)	[0.05]	[0.04]	[0.04]	[0.04]	
Primary or less	0.51	0.50	0.55	0.57	0.52	0.074*
	(0.50)	[0.03]	[0.03]	[0.03]	[0.03]	
Secondary or higher	0.26	0.22	0.19	0.19	0.23	0.177
	(0.44)	[0.03]	[0.03]	[0.02]	[0.03]	
Maternal height in cm	152.66	151.99	151.91	152.74	152.46	0.226
	(5.68)	[0.41]	[0.54]	[0.51]	[0.45]	
Mother/caregiver age in years	28.6	29.50	28.86	28.51	28.54	0.247
	(8.12)	[0.44]	[0.40]	[0.31]	[0.32]	
Maternal vocabulary (PPVT) raw score	22.67	20.69	20.8	20.6	22.48	0.156
	(9.88)	[1.44]	[1.32]	[1.00]	[1.26]	
Child birth order†	2.56	2.72	2.68	2.65	2.66	0.414
	(1.28)	[0.06]	[0.06]	[0.08]	[0.07]	

Note: Column (1) reports mean values for the control group, with standard deviations in parenthesis. Columns 2 to 5 report the coefficients (and standard errors) from separate regressions in which a dependent variable is regressed on the full set of treatment indicators and strata dummies. Column (6) reports the p-values of F-tests of whether the treatment coefficients are jointly equal to zero. Robust standard errors clustered at the community level. Asterisks indicate coefficient statistical significance level (2-tailed): * P < 0.10; ** P < 0.05; *** P < 0.01.

Table A4: Comparison attrited and replacement households

	N	attrited	Replacement	P-value
Panel A: Treatment status		(1)	(2)	(3)
T1: intensive counseling	1,125	0.16	0.21	0.19
		(0.37)	(0.41)	
T2: LNS children 6-18	1,125	0.27	0.23	0.87
		(0.44)	(0.42)	
T3: LNS pregnant/lactating and children	1,125	0.15	0.16	0.65
		(0.36)	(0.37)	
T4: nutrition and early stimulation	1,125	0.26	0.22	0.18
		(0.44)	(0.41)	
Program (T1-T4 vs T0)	1,125	0.84	0.82	0.62
		(0.37)	(0.38)	
Panel B: Household and child characteristics				
Household size	1,337	5.46	5.85	0.81
		(2.66)	(2.54)	
No. household members aged 0-1 years old	1,337	0.70	0.53	*0.00*
		(0.58)	(0.56)	
2-5 years old	1,337	0.88	1.20	*0.00*
		(0.87)	(0.73)	
6-18 years old	1,337	1.75	1.71	0.63
		(1.75)	(1.76)	
19-60 years old	1,337	2.05	2.05	0.41
		(0.96)	(0.83)	
Asset index (housing, assets and livestock)	1,336	-0.01	-0.01	0.74
		(1.06)	(0.94)	
Household has access to safe water	1,337	0.28	0.32	0.35
		(0.45)	(0.47)	
Mother education: Did not attend school	1,337	0.26	0.23	0.20
		(0.44)	(0.42)	
Primary or less	1,337	0.50	0.50	0.43
		(0.50)	(0.50)	
Secondary or higher	1,337	0.24	0.23	0.52
		(0.43)	(0.42)	
Maternal height in cm	1,102	*151.60*	*152.40*	*0.08*
		(5.80)	(5.75)	
Maternal vocabulary (PPVT) raw score	1,048	19.02	21.32	*0.02*
		(11.17)	(10.33)	
Child birth order†	1,095	2.48	2.50	0.74
		(1.23)	(1.25)	
Intermediate outcomes				
Maternal knowledge index score	1,336	-0.03	-0.06	0.44
		(1.55)	(1.29)	
Material diet diversity score index (MDDW)	1,337	2.95	2.94	0.52
		(1.19)	(1.49)	

Note: (1) reports mean values for the control group, with standard deviations in parenthesis of the sample of households that attrited at midline or at endline. (2) reports mean values for the control group, with standard deviations in parenthesis of the sample of households that were sampled as replacement households at midline or at endline. (3) reports the p-value of an indicator of being a replacement household from a regression in which a dependent variable is regressed on a replacement household indicator and strata dummies. Robust standard errors clustered at the community level. Asterisks indicate coefficient statistical significance level (2-tailed): * P < 0.10; ** P < 0.05; *** P < 0.01.

Table A5: Take-up and household distance from ACN-ACDN

	(1)		(2)			(3)			
	ACN		**ACDN**						
	Received home visit ACN past 3m		Received any home visit T1-T3 past 3m		# visits T1-T3 past 3m	Received any home visit T4 past 30days		# visits T4 past 30 days	
	2015	2016	2015	2016	2016	2015	2016	2015	2016
T1: intensive counseling	0.043	-0.123	0.772***	_0.627***_	1.577***				
	(0.057)	(0.068)	(0.052)	_(0.063)_	(0.129)				
T2: LNS children 6-18	-0.023	-0.061	0.741***	_0.700***_	1.617***				
	(0.070)	(0.060)	(0.057)	_(0.046)_	(0.072)				
T3: LNS pregnant /lactating and children	0.034	-0.086	0.712***	_0.671***_	1.658***				
	(0.057)	(0.067)	(0.062)	_(0.058)_	(0.116)				
T4: nutrition & early stimulation	0.004	-0.154				0.829***	_0.770***_	1.893***	1.756***
	(0.060)	(0.084)				(0.042)	_(0.057)_	(0.098)	(0.063)
Distance (km) to ACN/ACDN	-0.043*	-0.072	0.007	0.005	0.005	0.004	0.002	0.01	-0.010
	(0.021)	(0.037)	(0.01)	(0.007)	(0.01)	(0.005)	(0.005)	(0.01)	(0.009)
T1*distance	0.035	0.082*	-0.066*	-0.037*	0.018				
	(0.029)	(0.039)	(0.028)	(0.015)	(0.039)				
T2*distance	0.063**	0.065	-0.021	-0.011	-0.043				
	(0.024)	(0.039)	(0.021)	(0.019)	(0.025)				
T3*distance	0.049†	0.062	0.036	-0.045	-0.066				
	(0.031)	(0.043)	(0.027)	(0.034)	(0.070)				
T4*distance	0.044†	0.077				-0.027	-0.029	-0.150***	-0.077**
	(0.029)	(0.047)				(0.019)	(0.017)	(0.038)	(0.025)
Mean in T0									
(SD in T0)									
Observations	2,753	3,116	2,221	2,512	1,817	1,102	1,238	995	1,079
R-squared	0.073	0.036	0.443	0.331	0.631	0.684	0.605	0.810	

Robust standard errors clustered at the community level.

Asterisks indicate coefficient statistical significance level (2-tailed): † P< 0.15; * P < 0.10; ** P < 0.05; *** P < 0.01.

Table A6: Comparison ACN ACDN characteristics at endline

	ACN	ACDN	difference (ACN-ACDN)	p-value
Age	42.73	32.13	10.6***	<0.001
Marital Status	2.790	2.460	0.328**	0.002
Single	0.080	0.233		
Civil marriage	0.334	0.230		
Customary marriage	0.361	0.374		
Separated/Divorced	0.158	0.133		
widowed	0.067	0.030		
Number of kids	3.85	2.90	0.95***	<0.001
Has other economic activity	0.760	0.820	-0.056	0.138
Educational level	2.100	2.220	-0.116*	0.018
Primary or less				
Secondary or higher				
Total vocabulary score	36.65	34.46	2.182*	0.012
Wealth index	-0.210	0.260	-0.463***	<0.001
Knowledge score	0.150	-0.050	0.202*	0.026
Hygiene score	0.090	-0.060	0.151	0.121
Motivation score (index)	0.090	-0.150	0.243**	0.006
External motivation	9.50	9.09	0.41*	0.017
Introject motivation	9.29	8.88	0.41*	0.037
Intrinsic motivation	9.60	9.02	0.58***	0.001
Identifying motivation	6.31	5.78	0.52***	<0.001
Social motivation	4.93	4.70	0.23*	0.038
Sum of Motivation score	39.59	37.69	1.89**	0.002

* p<0.05, ** p<0.01, *** p<0.001

Table A7: ACN-ACDN turnover between baseline and endline

	ACN turnover N. of ACNs / %		ACDN turnover N. of ACDNs / %	
T0	1	4%	n/a	
T1	2	8%	1	4%
T2	3	12%	4	16%
T3	1	4%	3	12%
T4	0	0%	5	20%
total	7	5.6%	13	12.8%

Table A8: comparison ACDN characteristics: replaced and new

	Original ACDN	New ACDN	p-value difference
Age	33.09	30.36	0.510
Marital Status	2.636	2.273	0.371
Number of kids	3	3	1
Has other economic activity	1.091	1.091	1
Educational level	2.636	2.091	0.082*
Total Vocabulary Score	35.30	37.60	0.575
Wealth Index	-0.107	0.530	0.041*
Knowledge score	-0.0934	-0.354	0.611
Hygiene score	-0.383	0.355	0.400
Motivation score (index)	0.219	-0.644	0.028*
External motivation	8.583	7.833	0.545
Introject motivation	9.333	7.583	0.171
Intrinsic motivation	9.167	7.583	0.159
Identifying motivation	5.917	5.333	0.461
Social motivation	4.667	4	0.322
Sum of Motivation score	41.09	32	0.005*

Table A9: Mediation analysis. Effects on height-for-age z score outcomes, subsample of young cohorts

	Height for age z-score, young cohorts										
	Main ITT		+ dairy past 24h		+ meat/eggs past 24h		+vitA food past 24h		+ knowledge score		+ all joint
	Midline 2015	Endline 2016	Midline 2015	Endline 2016	Midline 2015	Endline 2016	Midline 2015	Endline 2016	Midline 2015	Endline 2016	2016
T1	0.058	0.042	0.051	0.031	0.052	0.031	0.058	0.045	0.055	0.051	0.034
	(0.093)	(0.103)	(0.093)	(0.104)	(0.091)	(0.103)	(0.093)	(0.102)	(0.093)	(0.101)	(0.099)
T2+T3 combined	0.204**	0.209**	0.202**	0.202**	0.202**	0.193**	0.204**	0.213**	0.192**	0.208**	0.192**
	(0.089)	(0.094)	(0.089)	(0.093)	(0.088)	(0.093)	(0.089)	(0.092)	(0.088)	(0.092)	(0.089)
T4	-0.040	0.009	-0.039	-0.004	-0.049	0.000	-0.039	0.013	-0.047	0.008	-0.007
	(0.113)	(0.107)	(0.113)	(0.105)	(0.111)	(0.106)	(0.113)	(0.106)	(0.113)	(0.105)	(0.103)
Dairy past 24h			0.145	0.272**							0.227*
			(0.178)	(0.129)							(0.134)
meat/egg past 24h					0.113	0.142***					0.124**
					(0.074)	(0.054)					(0.055)
vit A rich food past 24h							0.008	0.024			0.016
							(0.061)	(0.057)			(0.057)
Knowledge score									0.036*	0.032	0.028
									(0.020)	(0.022)	(0.021)
N	1509	1762	1495	1758	1509	1762	1509	1762	1509	1762	1758
R-sq	0.060	0.055	0.060	0.057	0.062	0.058	0.060	0.055	0.062	0.056	0.061
Rmse	1.035	1.054	1.037	1.052	1.035	1.053	1.036	1.054	1.035	1.054	1.051
A path [impact T2-T3 on mediator]				0.026**		0.111***		-0.168***	0.342**		
				(0.011)		(0.037)		(0.064)	(0.159)		
A*B path [impact T2-T3 on HAZ				0.007		0.027		-0.004	0.012		
% of treatment explained by mediator(s)				3%		8%		-2%	6%		

Note: sample restricted to youngest cohorts (defined as age target child below the median age at endline). Robust standard errors clustered at the community level.

Asterisks indicate statistical significance level (2-tailed): † P< 0.15; * P < 0.10; ** P < 0.05; *** P < 0.01.

Table A10: intervention costs

	eligible children (or woman)/site[(a)]	annual cost/site [(b)]	annual average cost/eligible child (or woman)	annual cost per capita[(c)]
T1	117	$373	$3.20	$0.20
T2: LNS kids kids only	57	$2,485	$44	$1.7
T2: T1+LNS kids	117			$1.90
T3: LNS pregnant & lactating women only	33	$2,845	$87	$1.9
T3: LNS (kids&women)	90	$5,330	$59*	$3.6
T2: T1+LNS kids&women	117			$3.80
T4: ECD home visits in T4	30	$995	$33	
T4: ECD home visits in T4 excl. coaching		$297	$10	

Note: average exchange rate 2015: 1USD/MGA 2,700
[(a)] eligible population from program administrative data.
[(b)] all unit costs refer to the year 2015, where all the program sites were operational for all 12 months. Unit cost for T1: 82% salary ACDN, 1% materials, 14% refresher training
unit cost for T2 LNS only: 95% supplement, 3% international transport, 2% customs and domestic transport. Coaching costs for T4
* weighted average cost LNS kids and LNS pregnant and lactating women weighted by their population share in the community
[(c)] per capita calculations are performed by dividing the cost by the village population size (on average 1,500 individuals). Population is obtained from program administrative data obtained from village censuses carried out annually by the ACN

Table A11: Cost-benefit analysis: T2-T3

	Benefit/cost ratio	Internal rate of return
T2 kids	**3:1**	**10.7%**
T2 (halving estimates benefits)	2:1	7.4%
T3: kids and pregnant and lactating women	**2:1**	**7.9%**
T3 (halving estimates benefits)	1:1	4.7%

Note: Benefits from averting stunted are computed from Galasso, Wagstaff (2018), including the net present value from averted stunted in terms of schooling, adult height and cognition. Unit costs are obtained from Table A9.

Table A12: Secondary outcomes, heterogeneous effects by age, maternal education and gender

<u>Panel A: Heterogeneity by child age - below (young) or above (old) the median age at endline</u>

	Dairy intake past 24hr			*Protein intake past 24hr*			*Vitamin A rich foods past 24hr*			*Dietary diversity score past 24hr*			*Meal frequency past 24hr*			*Home/FCI score*		
	Young	old	*p*	Young	old	*p*	Young	Old	p	Young	Old	p	Young	Old	p	Young	old	p
	Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.	
	(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)	
T1	0.036	0.0005z	0.10	0.075	0.110	0.43	-0.136	-0.133	0.97	0.072	-0.020	0.39	0.165	0.105	0.39	0.078	-0.072	0.08
	(0.018)	(0.011)		(0.039)	(0.036)		(0.078)	(0.073)		(0.106)	(0.100)		(0.089)	(0.064)		(0.085)	(0.093)	
T2	0.032	0.039	0.65	0.103	0.091	0.80	-0.178	-0.102	0.16	0.035	0.072	0.68	0.247	0.130	0.27	0.025	0.024	0.99
	(0.023)	(0.017)		(0.044)	(0.030)		(0.076)	(0.078)		(0.087)	(0.107)		(0.110)	(0.063)		(0.090)	(0.100)	
T3	0.021	0.024	0.85	0.122	0.061	0.19	-0.162	-0.043	0.02	0.097	0.062	0.69	0.071	-0.028	0.16	0.118	0.173	0.55
	(0.010)	(0.012)		(0.043)	(0.039)		(0.075)	(0.067)		(0.084)	(0.084)		(0.095)	(0.056)		(0.111)	(0.110)	
T4	0.048	0.021	0.09	0.065	0.057	0.85	-0.165	-0.085	0.12	-0.058	-0.034	0.78	0.259	0.065	0.01	0.193	0.110	0.29
	(0.016)	(0.017)		(0.043)	(0.039)		(0.077)	(0.071)		(0.090)	(0.094)		(0.057)	(0.085)		(0.104)	(0.096)	

Panel B: heterogeneity by primary caregiver education -below secondary (low) or above secondary (high)

	Dairy intake past 24hr			*Protein intake past 24hr*			*Vitamin A rich foods past 24hr*			*Dietary diversity score past 24hr*			*Meal frequency past 24hr*			*Home/FCI score*		
	Low	High	*p*	Low	High	*p*	Low	High	p	Low	High	p	Low	High	p	Low	High	p
	Coef. (SE)	Coef. (SE)		Coef. (SE)	Coef. (SE)		Coef. (SE)	Coef. (SE)		Coef. (SE)	Coef. (SE)		Coef. (SE)	Coef. (SE)		Coef. (SE)	Coef. (SE)	
T1	0.028	-0.011	0.06	0.097	0.082	0.79	-0.182	0.018	0.01	-0.025	0.191	0.08	0.130	0.148	0.85	0.007	-0.007	0.92
	(0.010)	(0.022)		(0.053)	(0.032)		(0.071)	(0.078)		(0.096)	(0.116)		(0.109)	(0.067)		(0.083)	(0.136)	
T2	0.021	0.100	0.17	0.102	0.086	0.80	-0.168	-0.055	0.17	0.0004	0.257	0.12	0.222	0.051	0.07	0.036	-0.008	0.74
	(0.009)	(0.064)		(0.032)	(0.058)		(0.080)	(0.079)		(0.088)	(0.164)		(0.076)	(0.095)		(0.085)	(0.140)	
T3	0.027	0.007	0.39	0.101	0.071	0.66	-0.116	-0.072	0.59	0.087	0.039	0.74	0.063	-0.136	0.03	0.170	0.080	0.47
	(0.008)	(0.024)		(0.034)	(0.066)		(0.074)	(0.082)		(0.077)	(0.140)		(0.088)	(0.076)		(0.137)	(0.106)	
T4	0.027	0.062	0.45	0.098	-0.053	0.02	-0.148	-0.060	0.27	-0.035	-0.088	0.74	0.157	0.191	0.73	0.176	0.075	0.42
	(0.010)	(0.047)		(0.064)	(0.034)		(0.069)	(0.080)		(0.150)	(0.089)		(0.063)	(0.106)		(0.125)	(0.099)	

Panel C: heterogeneity by gender

	Dairy intake past 24hr			*Protein intake past 24hr*			*Vitamin A rich foods past 24hr*			*Dietary diversity score past 24hr*			*Meal frequency past 24hr*			*Home/FCI score*		
	Female	Male	*p*	Female	Male	*p*	Female	Male	p	Female	Male	p	Female	Male	p	Female	Male	p
	Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.		Coef.	Coef.	
	(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)		(SE)	(SE)	
T1	0.008	0.029	0.13	0.096	0.088	0.86	-0.114	-0.157	0.36	-0.008	0.060	0.40	0.162*	0.106	0.34	0.007	0.002	0.95
	(0.011)	(0.014)		(0.039)	(0.036)		(0.078)	(0.070)		(0.098)	(0.096)		(0.073)	(0.076)		(0.099)	(0.080)	
T2	0.032	0.04*	0.66	0.087	0.106	0.61	-0.152	-0.127	0.62	-0.015	0.126	0.09	0.268*	0.103	0.09	0.044	0.007	0.71
	(0.027)	(0.014)		(0.036)	(0.034)		(0.071)	(0.081)		(0.097)	(0.093)		(0.061)	(0.103)		(0.100)	(0.090)	
T3	0.024	0.022	0.88	0.110	0.072	0.38	-0.069	-0.134	0.16	0.115	0.046	0.44	0.102	-0.056	0.05	0.216*	0.080	0.12
	(0.014)	(0.011)		(0.041)	(0.039)		(0.076)	(0.065)		(0.074)	(0.093)		(0.099)	(0.057)		(0.112)	(0.106)	
T4	0.039	0.030	0.73	0.060	0.063	0.95	-0.107	-0.145	0.43	-0.084	-0.009	0.38	0.168	0.159	0.87	0.157	0.145	0.88
	(0.020)	(0.017)		(0.045)	(0.036)		(0.079)	(0.068)		(0.096)	(0.086)		(0.066)	(0.071)		(0.110)	(0.092)	

APPENDIX B

Sampling frame and stratification[29]

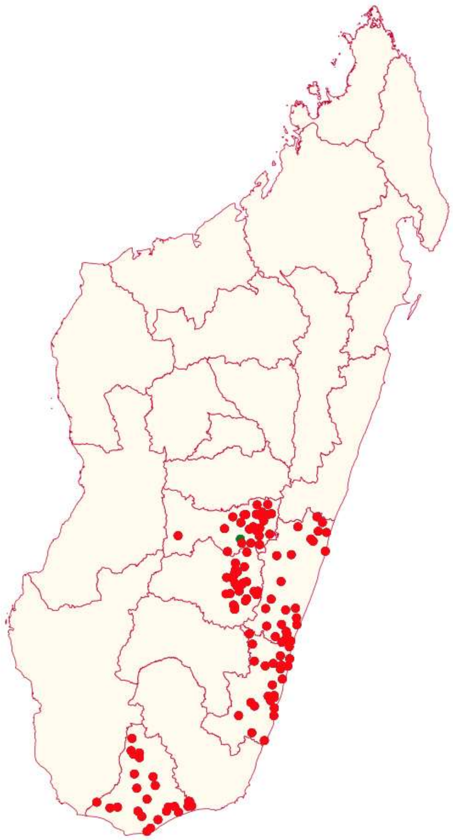
Our randomization is at the site/village level, and it was stratified in two stages, first at the region level and then by age of the target child to reduce the ex-ante probability of imbalance.

Site/villages**:** Site selection and randomization to intervention arm was carried out by the research team using January 2014 governmental administrative data of active program sites, which indicated the existence of 2000 operating sites in the five targeted regions. Newly opened sites were excluded from the randomization process, reducing the sampling frame of eligible study sites to 1476.
First, to minimize contamination by NGO supervisor, we randomly sampled one site per supervisor, such that each person supervised at most one intervention type, reducing the number of sites to 261. Second, in order to reduce the logistical constraints of working with a large number of NGOs, we randomly sampled 13 NGOs per region, for a total of 65 NGOs. Finally, in the third stage, we assigned sites to a trial arm by performing a stratified random sample of 5 sites per intervention arm per region for a total of 125 sites (25 sites per region). The final sample was balanced across trial arms along average underweight prevalence and average size of the target population, based on program monitoring data. Local Malagasy government officials were notified of the site selection and program assignment after the above process was completed by the research team.

The geographic location of the sample sites is available in Figure B1 below:

[29] This section draws from the study protocol paper Fernald, L. C. H., E. Galasso, J. Qamruddin, C. Ranaivoson, L. Ratsifandrihamanana, C. P. Stewart and A. M. Weber (2016). "A cluster-randomized, controlled trial of nutritional supplementation and promotion of responsive parenting in Madagascar: the MAHAY study design and rationale." BMC Public Health **16**: 466.

Figure B1 Geographic location study sites



Households/Children: The initial sampling frame of survey participants within selected community sites was based on a census performed by the local community nutrition workers in November/December 2013. These same nutrition workers provided updates to the census in April 2014 for all sites and up to a week before the team's arrival for each individual site. Upon the team's arrival for the baseline data collection, the list received a final update with the help of the nutrition worker to add newborns and newly pregnant women, update that status of pregnant women who had given birth, and remove those who were traveling, had migrated or died. In the case where we had an insufficient number of pregnant women or children in the updated list, then the catchment area was extended to villages within 5 km of the site that do not currently participate in the government program, but are eligible to participate.

Power calculations

The number of communities was selected based on testing the null hypothesis that the treatment effect for any pair-wise comparison of treatment arms is equal to zero at a conventional 95% confidence level (alpha=0.05) to achieve a statistical power of 80%.

An effect size of 0.25 to 0.30 SD for the supplementation arms is expected to be seen based on the review on lipid-based complementary feeding interventions in developing countries[30] and was chosen for the mid-point of the sample size calculation.

The intra-cluster correlation was drawn from the 2011 Anthropometrics Survey (ADE)[31] for height-for-age z-scores (HAZ). With an effect size of 0.30 SD and an estimated intra-cluster correlation of 0.10, the number of communities to be included in each pair-wise comparison of treatment arms should be 50 communities (25 per treatment arm) with 30 children sampled from within each community.

Tracking protocols and replacements

Our sample of interest is the cohort of children (and their households) sampled at baseline and followed longitudinally at midline and at endline survey. The sample was drawn from the census of children enrolled in the community-based intervention in December 2013 and updated in May 2014 in preparation for the baseline fieldwork. A sample of 3,738 households with either pregnant women or with children aged 0-11 months old was selected at baseline. At midline and endline tracking protocols were put in place with the objective to minimize attrition and preserve a sample that reflected the target population of children in the program site. The following tracking criteria were followed:

* if the pregnant woman had a miscarriage or died, or if the target child had died, the household was considered as lost

* if the target child had temporarily moved within the catchment area of the program sites, the child should be located and interviewed;

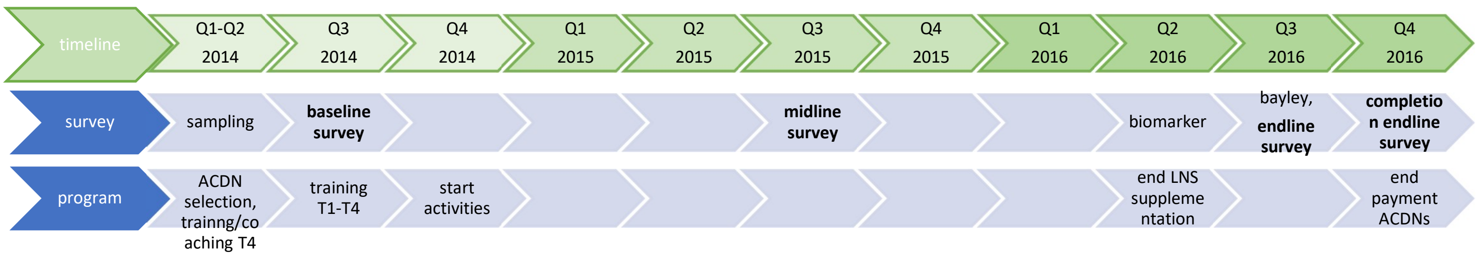
* If the target child has moved outside the catchment area (and therefore not eligible to receive the services), the household would be replaced with a household randomly chosen from within the same age group;

* if the target child returned to the original household after their temporary migration at endline, both the original household and its replacement household at midline were interviewed at endline.

[30] Dewey, K. G. and S. Adu-Afarwuah (2008). "Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries." Maternal and Child Nutrition **4**: 24-85.

[31] http://microdata.worldbank.org/index.php/catalog/2219 Madagascar - Enquête Anthropométrique et Développement de l'Enfant 2011.

Project Timeline



Data by survey round

The table below provides the description of the key outcomes collected in each round used in the analysis

Outcome		*Timing of data collection:*		
		Baseline	Midline	Endline
Nutritional and child development outcomes				
Anthropometrics (height, weight, MUAC)	Target child	√	√	√
	Younger siblings below age 42 months		√	√
	Primary caregiver	√		√
Anemia/Hemoglobin	Target child	√ (1/3 sample)	√(1/3 sample)	√
Mid upper arm circumference (MUAC)	Target child	√	√	√
Biochemical measures (RBP, Ferritin, sTFR, AGP, CRP)	Target child (18-24 months old)			√ Subsample
Language and cognitive and socio-emotional development: - Ages and Stages Questionnaire : Inventory (Bricker and Squires 1999)	Target child	√	√	√

- Bayley Scale[32]	Target child (28-34 months old)			√ subsample
Intermediate *indicators*				
Household Food Insecurity Experience Scale, FAO)		√	√	√
Maternal knowledge on nutrition and child development	Primary caregiver	√	√	√
Food diversity, maternal and child diet (FANTA, FAO, WHO)	Primary caregiver and target child	√	√	√
Appetite and responsive feeding	target child	√	√	√
Child morbidity (endline)	Primary caregiver			√
Maternal child stimulation (Family Care indicator)[33]	Primary caregiver	√	√	√
Maternal time use and time spent with child	Primary caregiver	√	√	√
Maternal receptive vocabulary (Peabody Picture Vocabulary Test (PPVT)[34]	Primary caregiver	√		√
Maternal depression (Adaptation Center for Epidemiologic Studies Depression Scale[35]	Primary caregiver	√	√	√
Caregiver-Perceived role of parents and perceived nutrition and child development ladder	Primary caregiver			√

[32] Bayley, N. (2006). Bayley scales of infant and toddler development-Third edition. San Antonio, TX, Harcourt Assessment, Inc

[33] Hamadani, J.D. et al (2010). Use of Family Care Indicators and Their Relationship with Child Development in Bangladesh. J Health Population and Nutrition, 28(10: 23-33.

[34] Dunn, L. N. (1965). Peabody Picture Vocabulary Test. Nashville, Tennessee, American Guidance Service.

[35] Radloff, L. S. (1977). "The CES-D scale: A self-report depression scale for research in the general population." Applied Psychological Measurement **1**(3): 385–401.

Questionnaire content

The Mahay study is composed of the following data sources:

The household questionnaire includes detailed sections on demographics, housing/water and sanitation, education, household expenditures, food security, and shocks. The household questionnaire was administered to the household head, or in his/her absence to the most informed household member. Data on food security status was collected using the Household Food Insecurity Access Scale (HFIAS) developed by and dietary diversity using the Household Dietary Diversity core (HDDS).

The female and child questionnaire were administered to all primary caregivers of the target children. At baseline, all primary caregivers were asked about fertility. Mothers were administered sections on knowledge about nutrition and child development, as well as a module on child appetite and responsive feeding. A child questionnaire was administered to all primary caregivers include delivery information, breastfeeding history and status, timing introduction of complementary feeding, morbidity, and a 24 hour dietary recall. Child weight, height, and mid upper-arm circumference were measured at baseline in duplicate using techniques described for the WHO Multicenter Growth Reference Study. Child development was assessed using The Ages and Stages Questionnaire Inventory (ASQI), which is a comprehensive self-report maternal assessment of child development. ASQ-I is a continuous version of child development and progress as opposed to the more widely used ASQ-3 screening tool. The subscales measure skills in Communication, Gross Motor, Fine Motor, Personal-Social and Problem-Solving domains. In addition, pregnant women and primary caregivers were also administered a module on depression, using the Center for Epidemiological Studies Depression Scale (CESD) and administered a test on receptive vocabulary, using the Peabody Picture Vocabulary Test (PPVT) already adapted for Madagascar.

A community health worker questionnaire was administered to both the community nutrition worker (ACN) and the added community nutrition worker (ACDN, if already identified at baseline). The questionnaire includes demographics and socio-economic information about the community worker (education, occupation, household assets), a Motivation Scale. The community workers were administered the same test of receptive vocabulary, using the Peabody Picture Vocabulary Test (PPVT) administered to the primary caregiver. In addition, the questionnaire has specific sections about how the site characteristics, the characteristics and composition of a volunteer support group, the referral to a health center and the training received.

A community questionnaire: was administered to a group of informed leaders about the size and population of the village (Fokontany), accessibility and availability of local infrastructure, the presence of associations in the village, the occurrence of weather shocks and production shocks.

Questionnaires are structured as follows:

Household questionnaire
A: Identification
B: Household Roster
B1: Education > 3
B1: Education 3-24
B2: Occupation
D: Dwelling
E: Assets
F: Shocks past 12 months
G: Food Security
Female questionnaire
FA: Reproduction
FB: Pregnancy Antenatal Care (target child and youngest sibling)
FC: Birth/Delivery, Breastfeeding
FD: Infant/Child Feeding, child food diversity
FE: Responsive Feeding
FM: Child morbidity (endline)
FH : Knowledge/practices about hygiene
FK : Maternal knowledge about child feeding and child development
FX: Maternal Food Diversity
L: Time Use previous 24h PR: Participation to T1-T4 activities [midline and endline] MA: Anthropometric and hemoglobin measurements

Infant questionnaire
FL: Primary Caregiver, Family Care Indicators
FP: Ages and Stages Questionnaire Inventory
FP: Questionnaire Ages and Stages - Communication
FP: Questionnaire Ages and Stages – Gross Motor
FP: Questionnaire Ages and Stages – Fine Motor
FP: Questionnaire Ages and Stages – Problem Solving
FP: Questionnaire Ages and Stages - Socialization
FG: Depression (CESD) scale
V: Vocabulary mother/primary caregiver
FR: Perception on the role of parents and subjective perception of child nutrition, child development (endline)

Community Health Worker questionnaire
CA: Demographics
E: Assets
CB: Site Characteristics

CC: Occupation
CD: Support Group
CH: Training
CM: Local health center
CN: Motivation Scale
FK: Knowledge (Nutrition, Development)
FH: Skills and practical knowledge of hygiene
CV: Receptive Vocabulary (PPVT) [baseline, endline]

Village (Fokontany)
VB: Population and Households of Fokontany
VC: Physical, Administrative and Socio-Economic Infrastructures
VD: Organizational structures of the Fokontany
VF: Food security [prices at midline/endline]
VG: Production Risks and Shocks

Administrative data

Program site registry records: activities community based nutrition program activities carried out by the community nutrition worker (ACN) are recorded in paper registries in all project sites, with extensive detailed information about the census of eligible children and pregnant women updated every year, monthly caregiver/child information about attendance to the nutrition education sessions and cooking demonstrations, referral to health services and receipt of home visits and a record of the measured anthropometric status. The child level information is on paper. We will rely on a summary set of average indicators at the site level set of indicators drawn from the program registries (such as the number of children and pregnant women enrolled and attending the nutrition activities) are sent by the ACNs monthly by SMS to be consolidated at the NGO, regional and national level. These indicators are used for activity monitoring and decision making.

Mahay monitoring forms: As part of the Mahay study, arm-specific registry forms were developed to track activities. Each ACDN was required to collect information about the number of home visits administered (total and by topics covered) for nutrition counseling (T1-T4). Program sites with LNS supplementation (T2 and T3) had also to record stocks of the supplements, as well the number of sachets distributed by week. In T4, each child in the study sample eligible for the early stimulation home visits had a record of the home visits received, and a child level short assessment of the child growth across different developmental domain. Support and supervision for the completion of the data collection of the treatment forms was overall weak, except for the T4 treatment, where the record of the home visits was used for program planning and closely monitored by the ECD coaches.

Table B1: Nutrient composition of the maternal and child lipid based nutrient supplement

Nutrient	WHO/FAO RNIs for children 1-3 y[a]	IOM RDAs for pregnant women[b]	LNS Child (*Kalina Zaza*)		LNS Pregnant/Lactating Women (*Kalina Reny*)	
			Content	**%RNI**	**Content**	**%RDA**
Daily dose, g			20		40	
Energy, kcal			118		235	
Fat, g			9.9		19.7	
Protein, g			2.6		5.2	
Vitamins						
Vitamin A, µg	400	750	400	100%	800	107%
Vitamin D[c], µg	10	15	10	100%	15	100%
Vitamin E, mg	5	15	6	120%	20	133%
Vitamin K, µg	15	90	30	200%	45	50%
Vitamin C, mg	30	85	30	100%	100	118%
Folic acid[d], µg	150	400	150	100%	400	100%
Thiamine (B1), mg	0.5	1.4	0.5	100%	2.8	200%
Riboflavin (B2), mg	0.5	1.4	0.5	100%	2.8	200%
Niacin, mg	6	18	6	100%	36	200%
Pantothenic acid (B5), mg	2	6	2	100%	7	117%
Vitamin B6, mg	0.5	1.9	0.5	100%	3.8	200%
Vitamin B12, µg	0.9	2.6	0.9	100%	5.2	200%
Minerals						
Calcium, mg	500	1000	280	56%	500	50%
Copper, mg	0.56	1	0.34	61%	4	400%
Iodine, µg	90	220	90	100%	250	114%
Iron[d], mg	11.6	60	6	52%	30	50%
Magnesium, mg	60	360	40	67%	150	42%
Manganese, mg	1.2	11	1.2	100%	2.6	24%
Phosphorous, mg	460	700	190	41%	400	57%
Potassium, mg	700	4700	200	29%	1000	21%
Selenium, µg	17	400	20	118%	130	33%
Zinc, mg	8.3	11	8	96%	30	273%

a. RNI for infants and young children 1-3 years. Values from the WHO/FAO Vitamin and Mineral Requirements in Human Nutrition.

b. RDA values for pregnant women from IOM DRIs in 2006

c. Vitamin D recommendations are based on IOM RDA for pregnant women and AI for 6-12 mo old infants established in 2010.

d. Iron and folic acid recommendations for pregnant women are based on WHO recommendations in areas where anemia prevalence is high