

NUTRITION



BEST INVESTMENTS FOR THE SDGs

EXCELLENT BENEFIT COST RATIO: 18

Investment

Complementary feeding promotion for mothers with children 6–23 months.
Multi-micronutrients and calcium supplements to the 40% of pregnant women, that currently take iron and folic acid supplementation.

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Investing in nutrition – a global best investment case¹

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Summary

Undernutrition and micronutrient deficiencies are key drivers of infant and child mortality and are causes of impaired human potential for hundreds of millions of children every year. Investing in nutrition in the first 1,000 days from conception not only supports individual lifetime health, education, and productivity, but is also key to breaking the intergenerational cycle of malnutrition and enhance equitable development pathways for low- and middle-income countries.

A decade ago, Bhutta et al (2013) presented a comprehensive update of a package of evidence-based interventions to address undernutrition and micronutrient deficiencies in women and children. The package consisted of ten interventions. Four are for pregnant women and six are for children: periconceptual folic acid supplementation or fortification, maternal balanced energy protein supplementation, maternal calcium (Ca) supplementation, multiple micronutrient (MMN) supplementation in pregnancy, promotion of breastfeeding, appropriate complementary feeding, vitamin A and preventive zinc supplementation in children 6–59 months of age, management of severe acute malnutrition (SAM), and management of moderate acute malnutrition (MAM).

Since then, Keats et al (2021) presented a new update of the evidence of effective interventions, including strengthened evidence on the effectiveness of MMN supplementation. The update also reviews the evidence of some emerging interventions, such as preventive small-quantity lipid-based nutrient supplements (SQ-LNS) for children 6-23 months.

In light of the emerging evidence on the effectiveness of preventive SQ-LNS and strengthened evidence on MMN supplementation over the last decade, this paper provides a cost-benefit analysis of preventive SQ-LNS, the more traditional complementary feeding promotion (CFP), and two supplement interventions for pregnant women. Specifically, benefits and costs of three nutrition interventions are assessed in this paper:

- 1) Provision of preventive small-quantity lipid-based nutrient supplements (SQ-LNS) to children 6–23 months of age.

- 2) Complementary Feeding Promotion (CFP) for children 6–23 months of age.
- 3) Provision of MMN and Ca supplements to pregnant women.

The two first interventions target the cohort of children born in the 40 low- and lower middle-income (LI-LMI) countries with the highest prevalence of stunting among children under five years of age.

Within these countries the preventive SQ-LNS intervention targets the children in the three lowest quintiles of socio-economic status (SES), as for instance defined in Demographic and Health Surveys (DHS). This group has disproportionately high stunting prevalence rates and limited resources to provide adequate complementary food to their children.

The CFP intervention targets the same group of 40 LI-LMI countries. Within these countries we model the intervention for two groups: i) children in the same group as the preventive SQ-LNS, but with a cash transfer to make adequate complementary feeding affordable; ii) children in the two highest quintiles of SES, but without a cash transfer because households in this group have far more resources than in the three lowest quintiles of SES. We are not assessing provision of preventive SQ-LNS to children in the two highest quintiles of SES because a large share of these children is at low risk of becoming stunted

Quantified benefits of these two interventions are reduced prevalence of stunting and reduced mortality.

The third intervention replaces iron and folic acid (IFA) with MMN and additionally provides Ca supplements. The intervention targets 40% of pregnant women annually in low- and lower middle-income countries. This is the percentage of pregnant women that currently take IFA supplementation (36 million women) mainly delivered through antenatal care (ANC) services. Quantified benefits are reductions in still births, low birth weight (LBW) births, premature births (PB), and maternal mortality.

MMN supplementation for pregnant women replacing IFA, as well as MMN and Ca combined, have the highest benefit-cost ratios (BCRs). The BCRs for CFP for children in the two highest SES quintiles and SQ-LNS for children in the three lowest SES quintiles are fairly similar

at 16 and 14, respectively. The lowest BCR is for CFP for children in the three lowest SES quintiles due to the high cost of accomplishing behavioral change for improved complementary feeding in resource poor households.

Table S1: Annual benefits and costs of nutrition interventions

	Benefit	Cost	BCR
Preventive SQ-LNS for children 6–23 months in the three lowest SES quintiles	44,515	3,248	13.7
CFP for children 6–23 months in the three lowest SES quintiles	27,988	3,748	7.5
CFP for children 6–23 months of age in the two highest SES quintiles	12,160	765	15.9
MMN for pregnant women (replacing IFA)	3,162	84	37.5
Adding Ca for pregnant women (w/o maternal mortality reduction)	2,426	216	11.2
Adding Ca for pregnant women (w/ maternal mortality reduction)	4,009	216	18.6
MMN <i>and</i> Ca for pregnant women (w/o maternal mortality reduction)	5,588	300	18.6
MMN <i>and</i> Ca for pregnant women (w/ maternal mortality reduction)	7,171	300	23.9

Note: Base case BCRs with 8% discount rate.

Introduction

Undernutrition, including stunting, wasting, and micronutrient deficiencies, is prevalent among infants and young children in low- and middle-income countries (LMICs) and is associated with increased morbidity and mortality and delayed psychomotor and neurocognitive development (Black et al. 2013). Among children under five years of age globally, 22% (149 million) were stunted and 6.7% (45 million) were wasted in 2021 (WHO, 2021). With high rates of stunting, and associated infant mortality, LMICs, especially Sub-Saharan Africa and South Asia bear the largest burden (UNICEF, 2021; see Figure 1).

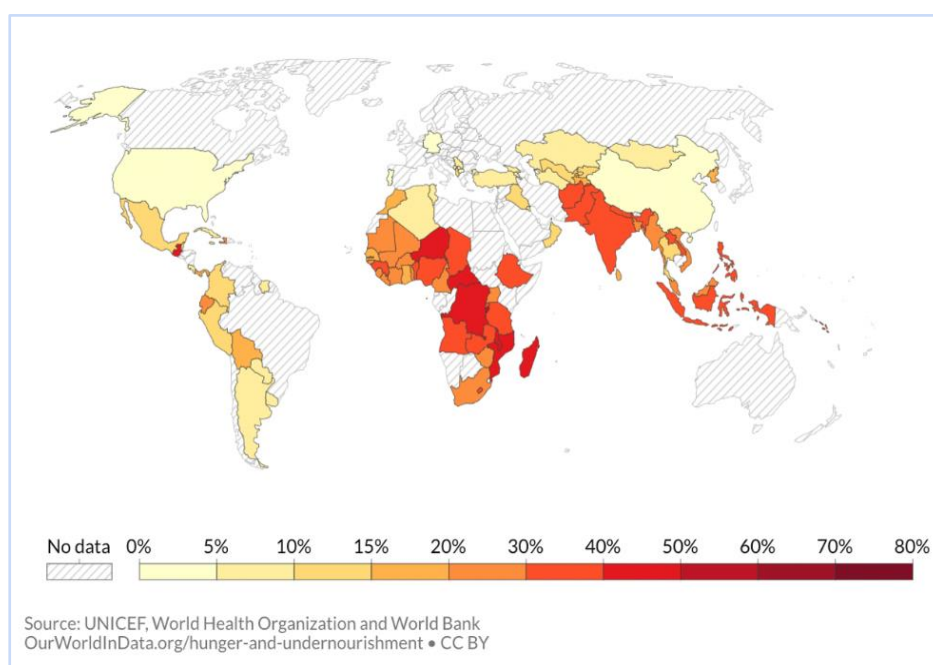


Figure 1: Percentage of children under five years of age being stunted: 2020

The 2012 World Health Assembly tackled the crucial issue of undernutrition by aiming “to reduce the number of stunted children under five by 40% by 2025”. This commitment was reinforced by the global Sustainable Development Goal 2, target 2, the objective of which is to, “By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under five years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons” (United Nations 2015). However, there has not been sufficient progress in reducing the rates of stunting

and wasting across the world, and the progress has been hampered even more with the disruptions due to the COVID-19 pandemic.

The consequences for childhood stunting—being short for one’s age—has life-long impacts not just for health but also for human capital and economic growth at the individual, household and national levels. Being stunted in early childhood is associated with slower cognitive development and lower IQ scores, and reduced schooling attainment by one year (Martorell et al. 2010), and lowers adult income by 5% to 53% (Hoddinott et al. 2008, 2011). Consequently, reductions in stunting prevalence can increase economic productivity by 4% to 11% in Africa and Asia (Horton and Steckel 2013).

While the etiology of stunting and wasting is complex and could be due to a multitude of factors, inadequate nutrition and poor dietary intake plays a crucial role, particularly in a child’s first 1,000 days. This includes the period just before conception up to two years of age (Dewey et al. 2022). Early childhood, therefore, is a critical window during which the nutrition of the mother and the early life nutrition of the child have a substantial impact on the child’s future physical and mental health. Undernutrition during this period is related to poor outcomes in overall health, neurobehavioral and cognitive development, and educational and economic attainment later in life (Victora et al. 2008).

Maternal and child nutrition research has had a rapid development over the last decade with large scale effectiveness studies and developments in innovations and improved nutritional commodities. Evidence on the effectiveness of antenatal multiple micronutrient (MMN) supplementation in reducing the risk of stillbirth, low birthweight, and babies born small-for-gestational age (SGA) has strengthened. Evidence continues to support the provision of supplementary food in food-insecure settings and community-based approaches with the use of locally produced supplementary and therapeutic food to manage children with acute malnutrition. Some emerging interventions, such as preventive small-quantity lipid-based nutrient supplements (SQ-LNS) for children aged 6–23 months, have also shown positive effects on child growth (Keats et al. 2021).

Interventions to improve complementary feeding practices include education and promotion or provision of food for children aged 6–24 months. The interventions have been found to improve various nutrition indicators (Lassi et al. 2020, Keats et al. 2021; Abdurahman et al., 2019; Imdad, Yakoob and Bhutta 2011). Updated evidence supports the use of maternal MMN supplementation to improve birth and child health outcomes in LMICs, when compared with iron and folic acid (IFA) alone. Benefits include reduced risk of stillbirth, low birthweight, preterm birth, and babies born SGA (Oh, Keats and Bhutta 2020). In addition, there was a greater effect on low birthweight with the use of the UN International Multiple Micronutrient Antenatal Preparation (UNIMMAP) with 15 micronutrients compared with MMN formulations that comprised only three to four micronutrients.

Preventive SQ-LNS have been extensively evaluated in the past fifteen years. Experimental studies showed that when SQ-LNS is used as daily point-of-use fortification for complementary foods, it consistently reduces severe and moderate wasting, underweight, stunting, anemia and mortality for the complementary feeding age group. The evidence from LMICs suggests that SQ-LNS provided during complementary feeding to children aged 6–24 months, compared with no intervention, reduces the prevalence of severe and moderate stunting, moderate wasting and moderate underweight (Das et al. 2019). A separate meta-analysis of thirteen trials found that the risk of all-cause mortality was reduced by 27% (11–41) among children taking SQ-LNS (Stewart et al. 2020).

This paper assesses the costs and benefits of three nutrition interventions:

- 1) Provision of preventive SQ-LNS to children 6–23 months of age.
- 2) Complementary Feeding Promotion (CFP) for children 6–23 months of age.
- 3) Provision of MMN and Ca supplements to pregnant women.

The target group for the first two interventions are children in the 40 low- and lower middle-income countries (LI-LMIs) with the highest rates of stunting prevalence. These countries, while accounting for only 37% of the world's population, are home to 75% of stunted children globally.

Within these countries, the SQ-LNS intervention is targeting children in the 60% of the population with the lowest socio-economic status (SES) while the CFP intervention is modeled for both targeting the children in the three lowest SES quintiles and the children in the two highest SES quintiles.

The third intervention replaces iron and folic acid (IFA) with MMN and additionally provides Ca supplements. The intervention targets 40% of pregnant women annually in LI-LMI countries. This is the percentage of pregnant women that currently take IFA supplementation (36 million women) mainly delivered through antenatal care (ANC) services.

Intervention 1: provision of preventive SQ-LNS to children 6–23 months of age

This intervention targets children in the 60% of the population with the lowest SES in each of the 40 LI-LMIs with the highest rates of stunting prevalence. Thus SQ-LNS would be provided preventively to the cohort of 41 million children annually for 18 months once they are six months of age. Preventive SQ-LNS consists of 100-120 kcal per child per day and multiple micronutrients and proteins. The stunting prevalence rate among children under five years of age in the target group was 41% in 2020 compared to 30% in all LMICs.²

Intervention cost

The cost of preventive SQ-LNS, including cost of delivery to mothers and caretakers of the children, is estimated at US\$ 4.37 per child per month (Adams et al. 2022). This amounts to US\$ 79 per child over a duration of 18 months, or US\$ 3.25 billion per annual birth cohort for the target group.

Intervention benefits

The benefits to young children of preventive SQ-LNS include reduced risk of mortality, anemia, developmental disability, and stunting and wasting (Das et al. 2019; Stewart et al. 2020;

² The stunting prevalence rate in the target group is calculated from the rate in the 40 LI-LMIs with the highest stunting rates and from stunting rates across the five population wealth quintiles as reported by Demographic and Health Surveys (DHS) in 51 LI-LMIs.

Keats et al. 2021; Dewey et al. 2021a; Adams et al. 2022). A recent cost-effectiveness analysis of preventive SQ-LNS found that reduction in anemia and developmental disability constituted less than 6% of total disability adjusted life years (DALYs) averted with reduction in mortality accounting for over 94% (Adams et al. 2022).³ We therefore assessed the benefits of preventive SQ-LNS in terms of reduced risk of stunting and mortality. We did not include reduced risk of wasting to avoid any potential double counting.⁴ Our estimate of benefits may therefore be considered conservative.

A review of available studies found that preventive SQ-LNS for children 6–23 months of age reduces the prevalence of moderate stunting by 7% and severe stunting by 15% compared with no intervention (Das et al. 2019). Dewey et al. (2021b) found an overall reduction in moderate and severe stunting of 12%. Dewey et al. (2022) found a reduction in severe stunting of 17%. We apply the effect sizes from Das et al because Dewey et al (2021b) do not report separate effect size for moderate and severe stunting separately and Dewey et al (2022) do not report effect size for moderate stunting. Using Das et al, gives an overall reduction in moderate and severe stunting of 9.1% from 41% to 37% prevalence in the intervention target group. Provision of preventive SQ-LNS is therefore expected to reduce stunting among children in the target group by 1.55 million cases. The reduction would be 1.64 million if the reduction in severe stunting is 17%.

The effect of preventive SQ-LNS on mortality is assessed by two methods. The first method ('indirect mortality effect') estimates mortality reduction from the effect of stunting reduction from SQ-LNS on mortality using relative risks of mortality from stunting reported by Olofin et al (2013) (see Table 1). The second method ('direct mortality effect') applies the findings from a meta-analysis of randomized controlled trails on the effect of SQ-LNS on all-

³ Reduction in stunting and wasting was not included in the estimation of DALYs averted as there were no measure of DALY available (Adams et al. 2022).

⁴ Global prevalence of stunting among children under five years of age is more than three times higher than the prevalence of wasting (WHO 2021). We therefore chose to focus the benefit of SQ-LNS in terms of stunting.

cause mortality in children 6–24 months of age. The meta-analysis found an 18% to 27% reduction in all-cause mortality (Stewart et al. 2020).

Table 1: Relative risk of mortality from stunting in children under five years of age

	Severe	Moderate	Mild	None
All-cause mortality	5.48	2.28	1.46	1.00
Diarrhea	6.33	2.38	1.67	1.00
Acute lower-respiratory infections (ALRI)	6.39	2.18	1.55	1.00
Measles	6.01	2.79	1.25	1.00
Malaria	1.92	1.06	0.74	1.00
Other infectious diseases	3.01	1.86	0.95	1.00

Note: ALRI is acute lower-respiratory infections. Other infectious diseases included here are tuberculosis and meningitis. Severe stunting refers to a HAZ less than -3 . Moderate stunting refers to a HAZ between -2 and -3 . Mild stunting refers to a HAZ between -1 and -2 . Relative risks are in relation to stunting according to the WHO Child Growth Standards. Source: Olofin et. al. (2013).

Baseline mortality among children 6-23 months in the 40 LI-LMI countries is from the Global Burden of Disease (GBD) 2019. These mortality figures are adjusted by the difference in mortality rates across SES quintiles from DHS surveys in the target countries in order to arrive at baseline mortality among children in the three lowest and two highest SES quintiles.

The indirect method following Olofin et al. (2013) indicates that 15,000–27,000 deaths can be averted annually by the provision of SQ-LNS to children 6–23 months of age, while the direct method following Stewart et al. (2020) indicates that 104,000–155,000 thousand deaths can be averted (see Table 2).

We consider the estimates of averted deaths by the direct method more likely than the estimates by the indirect method for two reasons: One, the direct method is based on studies specifically assessing SQ-LNS and mortality risk reduction. Two, mortality risk reduction from SQ-LNS likely extends beyond mortality risk among stunted children considered by the indirect method. The monetized benefit-cost analysis that follows is based on the mortality reduction benefits estimated by the direct method.

Table 2: Estimated annual deaths averted from SQ-LNS provision to children 6–23 months of age: 2023

Indirect method (infectious disease mortality reduction)	15,166
Indirect method (all-cause mortality reduction)	27,398
Direct method (18% all-cause mortality reduction)	103,676
Direct method (27% all-cause mortality reduction)	155,514

Source: Estimates by the authors.

Averted cases of stunting are valued by a 30% increase in lifetime income relative to a person who became stunted in early childhood. Lifetime income is estimated separately for individuals from the three lowest SES quintiles (see Annex). Averted cases of deaths are valued using a 'value of statistical life year' (VSLY) at 1.55 times GDP per capita in 2022 and rising to 2.9 times GDP per capita in 2090 (see Annex).

Total annual benefits of providing SQ-LNS to the target group of children are US\$ 1.0-11.8 billion for averted stunting and US\$ 26.5-39.8 billion for averted mortality. We choose the 27% reduction in all-cause mortality as base case. Total annual benefits in the base case are US\$ 44.5 billion with 8% discount rate. Nearly 90% of the benefits are from mortality reduction and 10% from lifetime productivity gains (see Table 3).

Table 3: Estimated annual benefits of SQ-LNS provision to children 6–23 months of age: 2023

	US\$ million per year
Benefit of averted stunting (lifetime income gain)	
Discount rate 5%	11,826
Discount rate 8%	4,666
Discount rate 14%	1,035
Benefit of averted mortality	
Direct method (18% all-cause mortality reduction)	26,556
Direct method (27% all-cause mortality reduction)	39,848

Note: No discounting of mortality benefits is undertaken because averted deaths would have occurred in the same or subsequent year of SQ-LNS provision. Source: Estimates by the authors.

Benefit-cost ratios

The total cost of SQ-LNS provision to 60% of children 6–23 months of age in the 40 LI-LMI countries with the highest prevalence rates of stunting amounts to US\$ 3.2 billion per year. Total benefits in the base case with 27% all-cause mortality reduction are US\$ 41-52 billion per year depending on the discount rate applied to lifetime income gains from averted stunting. The BCR for the base case and 8% discount rate is 13.7, in other words, the benefits are over over thirteen times the cost (see Table 4).

Table 4: Total annual benefits and costs of SQ-LNS provision to children 6–23 months of age: 2023

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	51,674	3,248	15.9
8%	44,515	3,248	13.7
14%	40,884	3,248	12.6

Source: Estimates by the authors.

Intervention 2: Complementary Feeding Promotion for children 6–23 months of age

Assessment of benefits and costs is undertaken for Complementary Feeding Promotion (CFP) interventions targeting two distinct groups:

- i) CFP with a cash transfer component to mothers and caretakers in the 60% of the population with the lowest SES in each of the 40 LI-LMI countries with the highest rates of stunting prevalence.
- ii) CFP without a cash transfer to mothers and caretakers in the 40% of the population with the highest SES in the 40 LI-LMI countries.

The rationale for the cash transfer component for the lowest SES population is that their households are often resource poor and cannot readily afford nutritious food in adequate quantity and appropriate dietary diversity for their children, and/or they may have other intra-household resource allocation priorities. CFP with a cash transfer component may therefore also be able to spur improvements in complementary feeding at least in some food insecure households. A cash transfer allows households flexibility to obtain the necessary dietary diversity and quantity of each food item and has been found to be more effective for prevention of stunting than a standard food package (Ahmed et al. 2019).

Nearly 30% of stunted children in the 40 targeted LI-LMI countries live in households in the 40% of the population with the highest SES according to our analysis of recent DHS surveys. These children therefore also constitute an important group for nutrition interventions. The income in the two richest quintiles of the population in LI-LMI countries are on average three times higher than average income in the three poorest quintiles according to our analysis of data from the World Bank (World Bank, 2022). A cash transfer component is therefore not

included for this target group because they are in a much better position to improve complementary feeding than the 60% poorer households.

The CFP intervention modeled here consists of interpersonal complementary feeding education and counseling to mothers and caretakers of children over an 18-months period from the age of 6 to 23 months. Mothers and caregivers who respond positively to the intervention increase the quantity and dietary diversity of complementary food that they provide to their children to partially or fully bridge the gap between pre-intervention and recommended complementary feeding.

The average incremental complementary food provided by the mothers and caretakers who respond positively to the intervention is assumed to be 250 kcal of nutrient adequate food per child per day. This quantity of kcal is similar to the incremental complementary feeding found by Ahmed et al (2019) as a result of a behavioral change communication (BCC) and cash transfer intervention in a resource poor setting in Bangladesh. This incremental food is provided and its cost borne by the children's household.

However, nearly half of stunted children in the 3 lowest SES quintiles are severely stunted while a little more than one-third are severely stunted in the 2 highest SES quintiles according to our analysis of recent DHS surveys in the 40 LI-LMI target countries. We therefore assume that mothers and caretakers who respond positively to the intervention provide 125 kcal of nutrient adequate food per child per day.

Intervention cost

The cost of CFP includes the promotion program cost and the time spent by mothers and caregivers on complementary feeding education sessions. The intervention does not include provision of complementary food by the promotion program. However, mothers and caretakers responding to the CFP will increase the amount and dietary diversity of complementary food they give to their children. This private cost is also included in the total cost of the intervention.

Panjwani and Heidkamp (2017) reported four studies of CFP interventions on child growth and stunting. The intervention in these studies ranged from three home visits over 30

weeks (Saleem et al. 2014) to initial group meetings, individual counseling, and five home visits over 15 months (Zhang et al. 2013) to 30 biweekly home visits over 12 months (Vazir et al. 2013). The last study involved an improvement in nutrition education at government health facilities and eight home visits over 18 months (Penny et al. 2005). Thus the range in frequency of visits is from one visit per two weeks to one visit per 2.5-3 months.

For the CFP targeting the two highest SES quintiles, with better educated mothers and caretakers and higher household income, we model the cost of one visit per two months over 18 months with one hour of healthcare worker's (HCW) time per visit. The cost of HCWs is based on estimated annual average labor income in the target countries.

For CFP targeting the three lowest SES quintiles, we rely on Ahmed et al (2019) that included a BCC intervention with complementary feeding education in a resource poor setting with one hour group sessions per week.

The cost of mothers' and caregivers' time is assumed to be 50% of average female wage rate. Female wage rate is estimated separately for the three lowest and two highest income quintiles. Cost of the CFP program, including mothers' and caregivers' time, is US\$ 61.50 and US\$ 18.65 per child over the intervention period for children in the three lowest and two highest SES quintiles, respectively (Table 5).

Table 5: Cost of CFP (US\$ per child)

	Target: 3 lowest SES quintiles	Target: 2 highest SES quintiles
CFP frequency of visits over 18 months intervention period	1 per week	1 per two months
Cost of providing complementary feeding education (promotion program)	37.50	14.05
Cost of mother's time of receiving complementary feeding education	24.00	4.60
Total cost of promotion	61.50	18.65

Source: Estimates by the authors.

The cost of an increased amount and improved nutritional value of complementary food provided by mothers and caretakers to their children is from Bai et al. (2021). Bai et al. estimated the cost of nutrient adequate food at US\$ 1.13 per day per adult woman in LI-LMI countries in 2011. Assuming a daily energy requirement of 2,300 kcal for adult women, 1,000

kcal for children 6–23 months of age, and a complementary feeding deficit of 25% (250 kcal) for children in the three lowest SES quintiles whose mothers and caretakers respond to the promotion program, the cost of incremental complementary feeding by mothers and caretakers in 2011 was US\$ 67.2 per child over 18 months. Applying the food price index by the Food and Agriculture Organization (FAO) from 2011 to 2022 brings the cost to US\$ 71 per child.⁵

As mentioned, 250 kcal is about the same as the increased amount found by Ahmed et al. (2019) as a result of BCC for improved complementary feeding with a cash transfer component in a resource poor setting. For children from the two highest SES quintiles we assume that the response is half the amount, or 125 kcal at half the cost per child, or US\$ 36 per child because the complementary feeding gap is likely to be less than among children from the lowest SES quintiles, and the share of stunted children being severely stunted is substantially less among children from the two highest SES quintiles.

While the cost per child of the CFP program is for all children in the target group, the cost of incremental complementary food is only for those children whose mothers and caregivers respond to the promotion. We assume that the response rate is the same as the stunting prevalence rate, or 41% and 26% among children in the three lowest and two highest SES quintiles, respectively. This totals 24 million children each year. Assigning the cost of program promotion and the cost of incremental and more dietary diverse complementary food to these children brings the cost to US\$ 221 and US\$ 108 per child in the three lowest and two highest SES quintiles, respectively, for the 18 months complementary feeding period.

Intervention benefits

We assess the benefits of CFP in terms of reduced risk of stunting and mortality. A recent systematic review found that Complementary Feeding Promotion for children 6–23 months increases height-for-age z-scores (HAZ) by 0.25 in food secure settings through education and counseling of mothers and caretakers (Lassi et al. 2020). A previous systematic

⁵ <https://www.fao.org/worldfoodsituation/foodpricesindex/en/>

review and meta-analysis found increased length-for-age z-scores (LAZ) of 0.22 in food secure settings from studies that used the WHO growth standard (Panjwani and Heidkamp 2017). A most recent systematic review and meta-analysis of behavioral change communication (BCC) interventions found a HAZ effect of 0.19 from 26 studies of CFP but did not distinguish between food secure and insecure settings (Mahumud et al. 2022). Ahmed et al. (2019) found a HAZ effect of 0.25 in a resource poor setting from a BCC with complementary feeding education and a cash transfer component of a size that made incremental and nutritious complementary feeding affordable.

We therefore chose to apply an effect size of 0.25 for children in the three lowest SES quintiles combined with a cash transfer, and an effect size of 0.25 for children in the two highest SES quintiles because most of the households in this group are likely to be food secure and can respond to the CFP.

Applying a z-score normal distribution, the baseline stunting prevalence rates, and a HAZ effect size of 0.25 gives an estimated reduction in stunting prevalence of 23% from 41% to 32% among children in the three lowest SES quintiles and 29% reduction from 26% to 19% among children in the two highest SES quintiles. CFP is therefore expected to reduce stunting among children by 3.9 million and 2.0 million cases in the two target groups.

The effect of CFP on mortality is assessed by two methods: an indirect effect of stunting on mortality following the approach in Olofin et al. (2013), and a direct effect of CFP on all-cause mortality following Stewart et al. (2020). The two methods give fairly similar results (Table 6). This is because the mortality reduction of 18-27% by the direct method is calculated only among children whose mothers and caretakers respond to the CFP and not the whole target groups. This may be a conservative approach. The difference in estimated mortality between the two methods was very large for SQ-LNS.

As for SQ-LNS, we chose to apply the direct effect of 18–27% reduction in all-cause mortality among children 6–23 months from the meta-analysis by Stewart et al. (2020) to CFP, with 18% reduction for children in the two highest SES quintiles (which has less severe

stunting) and 27% reduction for children in the three lowest SES quintiles (which have more severe stunting). Much of the difference in annual cases of deaths averted in the two target groups is due the large difference in baseline mortality rates.

Table 6: Estimated annual deaths averted from CFP for children 6–23 months of age: 2023

	3 lowest SES quintiles	2 highest SES quintiles
Indirect method (infectious disease mortality reduction)	37,521	10,558
Indirect method (all-cause mortality reduction)	68,123	20,133
Direct method (18% all-cause mortality reduction)	42,564	9,044
Direct method (27% all-cause mortality reduction)	63,845	13,566

Source: Estimates by the authors.

Averted cases of stunting are valued by a 30% increase in lifetime income relative to a person who became stunted in early childhood. Lifetime income is estimated separately for individuals from the three lowest and two highest SES quintiles (see Annex). Averted cases of deaths are valued using a VSLY at 1.55 times GDP per capita in 2022 and rising to 2.9 times GDP per capita in 2090 (see Annex).

Total annual benefits of averted stunting are fairly similar for the two target groups, albeit the difference in averted cases of stunting is large. The similar magnitude of benefits is due to much higher baseline income among individuals from the two highest SES quintiles. Benefits of mortality reduction is, however, much larger for the three lowest quintiles. Noteworthy is that, in the base case with 8% discount rate, productivity or income gains are about 80% of total benefits in the two highest SES quintiles while mortality benefits are nearly 60% of total benefits in the three lowest SES quintiles (Table 7).

Table 7: Estimated annual benefits of CFP for children 6–23 months of age: 2023 (US\$ million per year)

	3 lowest SES quintiles	2 highest SES quintiles
Benefit of averted stunting (lifetime income gain)		
Discount rate 5%	29,469	24,943
Discount rate 8%	11,628	9,842
Discount rate 14%	2,580	2,183
Benefit of averted mortality	16,360	2,317

Note: No discounting of mortality benefits is undertaken as averted deaths would occur in the same or subsequent year of CFP. Source: Estimates by the authors.

Benefit-cost ratios

The benefit-cost ratio (BCR) for CFP targeting children in the two highest SES quintiles is 15.9, or twice as high as the BCR for the three lowest SES quintiles. This is because the cost per child in the two highest SES quintiles is three times as high as the cost per child in the three lowest SES quintiles while benefits per child is somewhat lower. The reasons for the difference in cost are the need for a more intensive and thus costly promotion program in resource poor settings in order to spur behavioral change, and the need for more incremental complementary food.

The BCRs for CFP for children in the two highest SES quintiles and for preventive SQ-LNS for children in the three lowest SES quintiles is very similar.

Table 8: Total annual benefits and costs of CFP for children 6–23 months: 2023; 3 lowest SES quintiles

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	45,829	3,748	12.2
8%	27,988	3,748	7.5
14%	18,939	3,748	5.1

Source: Estimates by the authors.

Table 9: Total annual benefits and costs of CFP for children 6–23 months: 2023; 2 highest SES quintiles

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	27,261	765	35.6
8%	12,160	765	15.9
14%	4,501	765	5.9

Source: Estimates by the authors.

Intervention 3: provision of MMN and calcium (Ca) supplements to pregnant women

The third intervention replaces iron and folic acid (IFA) with MMN and additionally provides Ca supplements to pregnant women in LI-LMI countries. The intervention delivery platform is antenatal care (ANC) services (Heidkamp et al. 2020). We calculated from forty Demographic and Health Services (DHS) in LI-LMIs from 2013 to 2021, constituting 80% of the total population in LI-LMIs, that 56% of pregnant women had four or more antenatal care (ANC)

visits and that 40% reported to have taken iron tablets for at least 90 days during pregnancy. The target of the intervention is therefore 40% of pregnant women (36 million women) in LMIs.

Intervention cost

The MMN intervention replaces IFA supplementation and targets pregnant women who would be taking IFA. MMN contains IFA. The cost of the intervention is therefore the incremental cost of switching from IFA to MMN. The incremental cost of 180 MMN tablets of UNIMMAP formula (15 micronutrients) is reported to be in the range of US\$ 0.88 – 1.83 per pregnant woman over the course of pregnancy (Engle-Stone et al. 2019; Kashi et al. 2019). The cost of Ca is US\$ 5.96 per pregnant woman, assuming two tablets of 600 mg per day over 20 weeks (WHO 2018). In the cost-effectiveness analyses by Engle-Stone et al. (2019) and Kashi et al. (2019), incremental cost of delivery program is assumed zero because the intervention is delivered through existing ANC services with no scale-up needed to reach the 40% of women who take IFA supplements. To be conservative we include an incremental delivery cost of US\$ 0.50 - 1.45 per pregnant woman. This brings the midpoint cost of MMN to US\$ 2.33 per pregnant woman.

With a target of 36 million pregnant women annually the total cost is US\$ 84 million for MMN supplementation and, if also Ca is provided, US\$ 216 million additionally for Ca supplementation.

Intervention benefits

Four main health benefits of MMN supplementation for pregnant women are often highlighted. These are reduced risk of stillbirths, low birth weight (LBW), preterm births (PB) and being SGA (Keats et al. 2021). Three recent reviews and/or meta-analyses of evidence are presented in Table 10. They all find reduced risk of the four main health outcomes with relative risks (RRs) in the range of 0.86 to 0.98, and Oh et al. (2020) find an RR of 0.79 if the MMN supplement contains more than four micronutrients.

None of the reviews and meta-analyses find any statistically significant general effect on neonatal or infant mortality of MMN with two notable exceptions. If women adhere to the MMN regimen throughout pregnancy ($\geq 95\%$) the risk of infant mortality is reduced by 15% (RR of 0.85). MMN also seems to reduce neonatal and infant mortality among females but not males.

In order to be conservative, no potential neonatal or infant mortality benefits from MMN supplementation during pregnancy is included in the benefit-cost assessment here. Moreover, the benefit-cost assessment does not include benefits or reducing SGA to avoid any double counting of benefits from reduced risk of LBW.

Table 10: Evidence of effects of MMN supplementation versus IFA during pregnancy (Relative Risk)

	Keats et al. (2019)	Smith et al. (2017)		Oh et al. (2020)
		Random effects	Fixed effects	
Stillbirth	0.95	0.97	0.92	0.91
Low birth weight	0.88	0.86	0.88	0.79**
Preterm birth	0.95	0.93	0.92	0.96
Small-for-gestational age	0.92	0.94	0.97	0.93
Perinatal mortality				1.00
Neonatal mortality	1.00	0.99*	0.98*	
Infant mortality		0.97*	0.97*	
Infant mortality (with mother adhering to regimen $\geq 95\%$)		0.85		
Neonatal mortality (females)		0.85		
Infant mortality (females)		0.87		
Maternal anemia	1.04			1.02
Maternal mortality	1.06			1.04

* Not statistically significant at 95% confidence level. ** In studies with MMN > 4 nutrients.

Four main health benefits of Ca supplementation for pregnant women are also often highlighted. These are reduced risk of maternal pre-eclampsia/eclampsia, as well as stillbirths, LBW and PB as for MMN (Keats et al. 2021). Two recent reviews and/or meta-analyses of evidence are presented in Table 11. They all find reduced risk of the four main health outcomes with RRs in the range of 0.45 to 0.99, but no statistically significant reduction in maternal or neonatal and infant mortality.

Table 11: Evidence of effects of Ca supplementation during pregnancy (Relative Risk)

	Oh et al. (2020)	Hofmeyr et al. (2018)
Stillbirth	0.87	
Low birth weight	0.99	0.85
Preterm birth	0.84	0.76
Maternal pre-eclampsia/eclampsia	0.45	0.45
Maternal mortality		1.00

RRs applied for benefit estimation and annual averted cases of health outcomes are presented in Table 12. A joint attributable fraction formula is applied for stillbirths, LBW, and PB to estimate the incremental averted cases of adding Ca to MMN.⁶ While the RR for maternal pre-eclampsia/eclampsia is as low as 0.45, no maternal mortality effect was found by Hofmeyr et al. (2020). A range of 0–8,470 averted annual deaths is therefore presented reflecting RRs of 1.00 and 0.45.

Table 12: Effect sizes and annual cases averted from MMN and Ca supplementation during pregnancy

RRs	MMN	Ca
Stillbirth	0.93	0.87
Low birth weight	0.79	0.92
Preterm birth	0.95	0.84
Maternal pre-eclampsia/eclampsia		0.45
Annual cases averted		
Stillbirths	46,857	80,928
Low birth weight	227,952	692,973
Preterm births	1,405,702	423,049
Maternal pre-eclampsia/eclampsia (deaths)		0–8,470

Note: Baseline cases of each health outcome in LI-LMIs is from the World Bank's World Development Indicators for the most recent year available.

Annual benefits are presented in Table 13 for the provision of MMN and Ca to 36 million pregnant women annually. Averted PB and LBWs are valued using a lifetime income effect of 10% based on effects on IQ and effects of IQ on income (see Annex). Valuation of averted stillbirths is controversial. Conservatively, it is here valued at the cost of a funeral. Averted maternal deaths are valued using the VSLY (see Annex).

⁶ $AF_j = 1 - (1 - AF_M) * (1 - AF_C)$ where AF_j , AF_M , and AF_C are the joint attributable fraction, and attributable fractions for MMN and Ca, respectively.

Table 13: Total annual benefits of MMN and Ca supplementation during pregnancy: 2023 US\$ million

	MMN	Ca	MMN & Ca
Stillbirths avoided	94	162	256
Preterm births avoided	428	1,406	1,834
Low birth weight births avoided	2,640	858	3,498
Maternal deaths avoided	0	0-1,583	0-1,583
TOTAL	3,162	2,426-4,009	5,588-7,171

Note: Annual discount rate is 8%. Source: Estimates by the authors.

Benefit-cost ratios

The total cost of MMN supplementation amounts to US\$ 84 million per year. Total benefits are US\$ 0.7-8.1 billion per year depending on the discount rate applied to lifetime income gains. The BCR for the base case with 8% discount rate is 37.5, that is with benefits 37 times the cost (see Table 14). If we use the assumption of no incremental MMN delivery cost as Engle-Stone et al. (2019) and Kashi et al. (2019), the BCR is as high as 65.

The total cost of Ca supplementation amounts to US\$ 216 million per year. Total incremental benefits of adding Ca to MMN are US\$ 0.6-5.6 billion per year depending on the discount rate applied to lifetime income gains. The BCR for the base case is 10.5, that is with benefits 10 times the cost (see Table 15). Potential reduction in maternal pre-eclampsia/eclampsia mortality is assumed zero. With maternal mortality reduction the BCR is 17.8.

The base case BCR for provision of MMN *and* Ca supplements is 18.1 (Table 16). With maternal mortality reduction the BCR is 23.3.

Table 14: Total annual benefits and costs of MMN supplementation: 2023

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	8,092	84	96.0
8%	3,162	84	37.5
14%	739	84	8.8

Source: Estimates by the authors.

Table 15: Incremental annual benefits and costs of adding Ca supplementation: 2023

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	5,899	216	27.3
8%	2,426	216	11.2
14%	664	216	3.1

Source: Estimates by the authors.

Table 16: Total annual benefits and costs of MMN & Ca supplementation: 2023

Discount rate	Total benefits (US\$ million)	Total costs (US\$ million)	BCRs
5%	13,991	300	46.6
8%	5,588	300	18.6
14%	1,403	300	4.7

Source: Estimates by the authors.

Conclusion

MMN supplementation for pregnant women replacing IFA, as well as MMN and Ca combined, have the highest benefit-cost ratios (BCRs). The BCRs for CFP for children in the two highest SES quintiles and SQ-LNS for children in the three lowest SES quintiles are fairly similar at 16 and 14, respectively. The lowest BCR is for CFP for children in the three lowest SES quintiles due to the high cost of accomplishing behavioral change for improved complementary feeding in resource poor households (Table 17).

Table 17: Annual benefits and costs of the nutrition interventions

	Benefit	Cost	BCR
MMN for pregnant women (replacing IFA)	3,162	84	37.5
MMN and Ca for pregnant women (w/ maternal mortality reduction)	7,171	300	23.9
Adding Ca for pregnant women (w/ maternal mortality reduction)	4,009	216	18.6
MMN and Ca for pregnant women (w/o maternal mortality reduction)	5,588	300	18.6
CFP for children 6–23 months of age in the two highest SES quintiles	12,160	765	15.9
Preventive SQ-LNS for children 6–23 months in the three lowest SES quintiles	44,515	3,248	13.7
Adding Ca for pregnant women (w/o maternal mortality reduction)	2,426	216	11.2
CFP for children 6–23 months in the three lowest SES quintiles	27,988	3,748	7.5

Note: Base case BCRs with 8% discount rate.

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Annex: Valuation of benefits

Stunting

An averted case of stunting of a child participating in the labor force during adult life is valued as the lifetime productivity gain estimated at a 30% boost to lifetime income. The productivity gain or income effect is based on a survey of nine longitudinal studies of stunted children from LMICs which shows that avoiding stunting is associated with a 6 cm increase in height in adulthood or adolescence (Galasso et al. 2017) and a review of 13 studies that shows that 1 cm of height is associated with 5% increase in wages (4% increase in wages for men, and 6% increase in wages for women, controlling for confounding factors; McGovern et al. 2017). The productivity gain is multiplied by the projected labor force participation rate for ages 15–62 years. Thus, the estimated benefit of the intervention is conservative because individuals not participating in the labor force during adult life may also derive value from avoided stunting.

To estimate the lifetime productivity gain, annual average labor income is calculated as GDP multiplied by the labor income share of GDP taken from the PENN World Table, version 10, and divided by the total labor force. Consequently, annual average labor income is currently 1.3 times GDP per capita in the low- and lower middle-income countries as a group. This ratio gradually declines to 1.0 in 2090 as GDP per capita increases to over \$10,000. A linear decline is applied based on current observed values of GDP per capita, labor income shares and labor force participation rates in lower middle-income countries. Average labor income is adjusted by income distributions in LI-LMI countries reported by the World Bank's World Development Indicators to arrive at average labor income in the three lowest and two highest SES quintiles.

Annual average labor income among adults who were stunted in childhood is calculated based on the 30% income effect of avoiding stunting and the prevalence rate of stunting in childhood. The lifetime income gain from averted stunting is calculated based on income projections from age 15 to 62 years discounted at rates 5%, 8% and 14%, with 8% as the base case. For the base case, the lifetime income gain is US\$ 4,740 multiplied by an expected labor

force participation rate of 59% for a child avoiding stunting in 2023 and working from 2038 to 2085. For a child that will not participate in the labor force, the value of averted stunting is zero. This is obviously an understatement of the cost of stunting. Estimated benefits of averted stunting are therefore conservative.

Child mortality

Mortality benefit per death averted is monetized using a VSLY that is multiplied by remaining years of life expectancy at the age of death. The VSLY is calculated as the value of statistical life (VSL) divided by remaining years of life expectancy at average adult age. The VSL for the target group of countries is calculated using a benefit transfer method based on GDP per capita differentials between the target group of countries and the United States and an income elasticity of 1.5 (Robinson et al. 2019a, 2019b). Specifically, each averted child death at age 6–23 months saves 68 years of life, and each life year saved is valued at 1.55 times GDP per capita in 2022 and rising to 2.9 times GDP per capita in 2090. The benefit of an averted death is US\$ 212,000 in 2022 in the target countries, or 106 times GDP per capita.

Preterm birth and low birthweight

Recent meta-analyses have estimated the effects of preterm birth and LBW on income-related outcomes. Bilgin et al. (2018) found decreased likelihood of attainment of higher education (OR=0.74), lower employment rate (OR=0.83), and increased likelihood of receiving social benefits (OR=1.25). Kormos et al. (2014) found that LBW is associated with a loss of 5 IQ points after adjusting for publication bias. McBryde et al. (2020) found that preterm births are associated with significantly lower scores on reading comprehension and applied mathematical problems assessments.

The results from Kormos et al. (2014) can be combined with the literature on income effects of IQ. Salkever (1995) found a lifetime income effect per IQ point of 2.09% for males and 3.63% for females. These effects include a positive direct effect of higher IQ on income, a positive indirect effect on income through increased schooling and likelihood of high school

graduation, and a positive effect on lifetime labor-force participation and thus lifetime income. USEPA (2020) undertook a reanalysis of the effect on income using a more recent version of the dataset used by Salkever. The reanalysis found a lifetime income effect per IQ point of 1.86% for males and 3.4% for females. These estimates are fairly similar to the original estimates by Salkever and suggest an effect of well over 2.0% for the overall labor force. We therefore use an income effect of 5 IQ points * 2% income effect per IQ point = 10% lifetime income effect per LBW or preterm birth.