Effective interventions to address maternal and child malnutrition: an update of the evidence

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Malnutrition—consisting of undernutrition, overweight and obesity, and micronutrient deficiencies—continues to afflict millions of women and children, particularly in low-income and middle-income countries (LMICs). Since the 2013 *Lancet* Series on maternal and child nutrition, evidence on the ten recommended interventions has increased, along with evidence of newer interventions. Evidence on the effectiveness of antenatal multiple micronutrient supplementation in reducing the risk of stillbirths, low birthweight, and babies born small-for-gestational age 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 for children aged 6–23 months, have shown positive effects on child growth. For the prevention and management of childhood obesity, integrated interventions (eg, diet, exercise, and behavioural therapy) are most effective, although there is little evidence from LMICs. Lastly, indirect nutrition strategies, such as malaria prevention, preconception care, water, sanitation, and hygiene promotion, delivered inside and outside the health-care sector also provide important nutritional benefits. Looking forward, greater effort is required to improve intervention coverage, especially for the most vulnerable, and there is a crucial need to address the growing double burden of malnutrition (undernutrition, and overweight and obesity) in LMICs.

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Introduction

Despite a recent focus on maternal and child undernutrition, no country is ready to meet all ten of the 2025 nutrition targets set by the World Health Assembly in 2012.[1] Globally, there are 149 million children younger than 5 years whose growth is stunted, 49·5 million who are wasted, and 40·1 million who are overweight, with notable disparities between countries and regions.[1] The 2008 *Lancet* Series on maternal and child undernutrition and the 2013 *Lancet* Series on maternal and child nutrition were important publications that summarised the effect of evidence-based interventions in reducing maternal and child undernutrition.[2,3] Since, many countries and agencies have scaled up the ten core interventions outlined in these Series (preventive zinc supplementation; promotion of breastfeeding; appropriate complementary feeding; periconceptual folic acid supplementation or fortification; maternal balanced energy protein supplementation; maternal multiple micronutrient [MMN] supplementation; maternal calcium supplementation; vitamin A supplementation; management of moderate and severe acute malnutrition). However, there is a need to periodically revisit the evidence-base of these interventions with newer evidence and assess areas that need further investigation.

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 commodities. The nutrition programme community now recognises the co-occurrence of conditions (eg, stunting and overweight, or stunting and wasting, in children) and the need for double-duty or triple-duty actions.[4] There is also a growing awareness of the importance of targeting certain populations (eg, adolescents and school-aged children) that have been ignored until now. Additionally, the very nature of evidence synthesis is evolving, with emphasis being placed on good quality and effectiveness studies that assess how an intervention will fare in real life conditions that are not optimal.[5] The inappropriate inclusion of low-quality studies in systematic reviews has also been highlighted.[6]

The 2013 *Lancet* Series showed a conceptual framework that categorised nutrition actions into those that were either nutrition-specific or nutrition-sensitive, depending on the nutrition determinant they addressed.[7] This framework has triggered multisectoral planning in many countries, and has posed challenges in terms of coordination and affixing responsibility for nutrition oversight,

Key messages

- Evidence-based interventions for improving maternal and child nutrition continue to be a combination of interventions that are direct (eg, delayed cord clamping, micronutrient supplementation, breastfeeding promotion, and counselling) and indirect (eg, malaria prevention, and water, sanitation, and hygiene promotion)
- Nutritional interventions delivered within and outside the health-care sector are equally crucial for preventing and managing malnutrition
- New evidence supports the use of preventive lipid-based nutrient supplementation for reducing childhood stunting, wasting, and underweight, and the use of antenatal multiple micronutrient supplementation for preventing adverse pregnancy and birth outcomes
- Evidence gaps remain for strategies to address malnutrition among schoolchildren and adolescents
- The drivers of undernutrition are diverse, and novel evidence synthesis methods underscore the need for multisectoral action and coordination

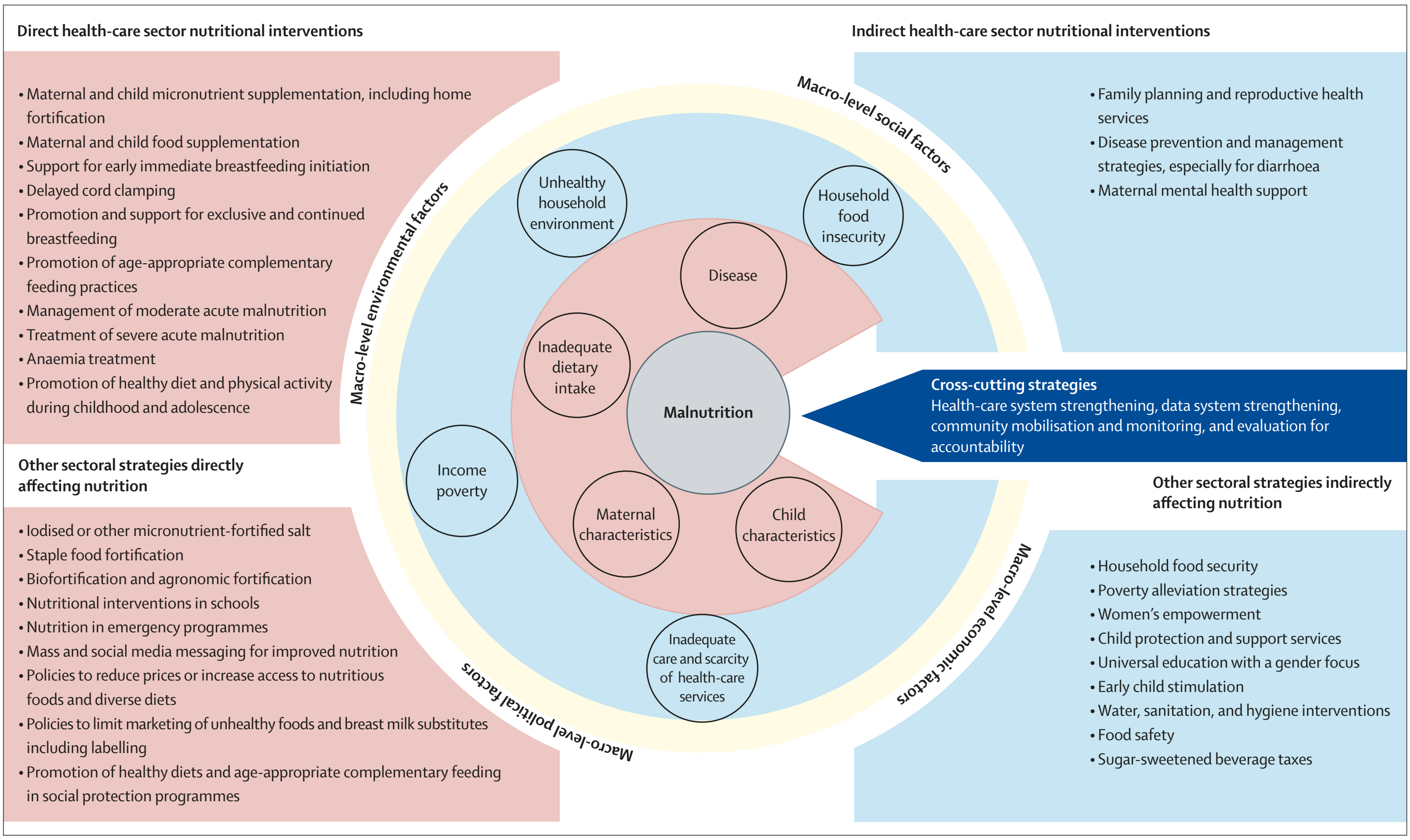

Figure 1: **Revised framework for the classification of nutrition actions**

especially for the traditional health and nutrition sectors.[8–11] We have proposed a revision of the framework, categorising nutrition actions into direct and indirect health and non-health-care sector interventions alongside cross-cutting strategies for nutrition support and integration (figure 1).[12] With the revised framework as a guide, this Review builds upon previous research through a comprehensive set of systematic reviews and review updates to provide a new overview of what works to improve undernutrition in low-income and middle-income countries (LMICs; panel 1). We also discuss potential actions that could be taken to mitigate the rising double burden of malnutrition.

Direct health-care sector nutritional interventions for women of reproductive age and during pregnancy

Proper nutrition that can support maternal health and fetal growth and development is important to maintain. This section details the evidence for micronutrient and food supplementation in the preconception period and during pregnancy (table 1; appendix pp 2–5).

See Online for appendix

Single and multiple micronutrient supplementation in the preconception period

Good nutrition in the preconception period is crucial to ensure that women with unintended or planned pregnancies have enough nutrient stores to support both fetal and maternal nutrition throughout gestation. The widespread non-adherence to dietary guidelines for iron, folate, calcium, and other micronutrient intakes during preconception has been documented.[17] Among women of reproductive age, including adolescents, who were provided weekly iron–folic acid supplements before conception and until the first trimester of pregnancy, the overall risk of anaemia was reduced by 34% (95% CI 19–47).[18] Women of reproductive age who received daily folic acid supplements before conception and until the first trimester of pregnancy had a 47% (33–59) reduction in the risk of neural tube defects.[18]

Small-quantity lipid-based nutrient supplementation (SQ-LNS) consists of MMNs delivered within a lipid-based vehicle. A multicountry trial, which provided SQ-LNS and balanced energy protein to women who were underweight, found that mean newborn length-for-age Z scores did not differ between women who were supplemented 3 months or more before conception (preconception) and those who were supplemented antenatally.[19] However, when comparing the preconception group to control (no supplementation), the number of babies born small-for-gestational age (SGA) was reduced by 22% (95% CI 12–30) and stunting at birth was reduced by 31% (2–51).[18] However, study benefits could have been

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Panel 1: Methods, search strategy, and selection criteria

We undertook a comprehensive analysis of the evidence underpinning the 2013 *Lancet* Series on maternal and child nutrition, and evaluated a set of new and promising nutritional interventions for mothers, newborn babies, children, and adolescents, including those found within WHO's Essential Nutrition Actions.[13] Although several systematic reviews have been done on the nutritional interventions discussed in this Review, our systematic reviews build on them to capture recent, high-quality, efficacy and effectiveness data from low-income and middle-income countries (LMICs), where the undernutrition burden is greatest. For new reviews (n=10), we adapted our research questions into searchable queries that followed the PICO methodology (population, intervention, comparator, outcome). For example: ((exp infant/ or exp child/ or exp child, preschool/ or exp pediatrics/ or (infant* or child* or preschool* or "pre school*" or pre-school* or under-five* or "under five*" or "under 5" or under-5).tw,kf) AND (exp powders/ or vitamins/ or minerals/ or micronutrients/ or (sprinkle* or powder* or mnp).tw,kf) AND ((point-of-use or "home fortif*" or enrich* or fortif*).tw,kf) AND [low- and middle-income countries]). A LMIC filter, available from Cochrane Consortium, was applied to search results along with date criteria (1995–2019), where applicable.

Database and grey literature searches were done by topic, and all screening, data extraction, and quality assessment were completed in duplicate. Populations varied by review, and included apparently healthy women in the preconception and periconception period, pregnant women, neonates, children younger than 5 years, school-aged children (aged 5–9 years), and adolescents (aged 10–19 years) living in LMICs. One review included unhealthy children who had moderate or severe acute malnutrition, whereas another included children and adolescents with obesity. Given the changing context of micronutrient deficiencies and nutritional risks in many parts of the world, such as with vitamin A deficiency[14] and soil-transmitted helminths,[15] we chose to review the evidence from studies published after 1995 for some interventions, and as applicable, also evaluate the evidence of time trends for effectiveness.

Eligible study designs included randomised controlled trials, randomised at the individual-level or cluster-level, and non-randomised quasi-experimental studies, such as controlled before–after studies, interrupted time series studies, natural experiments, and regression discontinuity designs. Interventions included preventive interventions for undernutrition, including micronutrient deficiencies; preventive interventions for overweight and obesity; interventions to manage acute malnutrition among children younger than 5 years; and interventions to manage child and adolescent obesity. We selected direct and indirect nutritional interventions along the continuum of care on the basis of those reviewed previously and those recommended by WHO. One review[16] specifically examined the effectiveness of community, social protection, and technology-based platforms to deliver nutritional interventions. Outcomes were review-specific, and encompassed anthropometric measures (eg, stunting and wasting), biochemical outcomes (eg, haemoglobin), morbidities (eg, diarrhoea), mortality, improved practices (eg, early initiation of breastfeeding), and coverage, in some cases. For all analyses, Review Manager (RevMan 2014) was used for the meta-analyses for two or more datapoints to pool.

Updates of existing reviews were done to complement the set of ten systematic reviews outlined above, of which a given review on a relevant direct or indirect nutritional intervention was published before January, 2018. For reviews that were done with a search date in 2018 or later, we summarised the best available evidence. Review updates were done for water, sanitation, and hygiene interventions, kangaroo mother care, and delaying cord clamping. Searches were done in MEDLINE and Cochrane, and review updates adopted the same methods as new reviews. The quality of included non-Cochrane reviews was assessed according to the AMSTAR criteria and the newly added trials were assessed with the Cochrane risk of bias assessment tool.

limited by several factors (ie, duration of supplementation and micronutrient composition),[20] all important factors when evaluating and implementing preconception programmes in LMICs. Unfortunately, relatively few programmes have evaluated medium to long term outcomes for women,[20] a major limitation of most interventions among women of reproductive age.

Single and multiple micronutrient supplementation in the antenatal period

WHO recommends a daily intake of 30–60 mg iron and 400 µg folic acid for all women throughout pregnancy.[21] Daily iron supplementation in pregnancy, compared with no iron intake, was associated with a 47% (95% CI 35–57) reduction in the risk of maternal anaemia, a 46% (26–60) reduction in the risk of iron deficiency, and a 12% (1–22) reduction in the risk of having a low birthweight baby among women in LMICs.[22] Evidence suggests that intermittent iron supplementation has a reduced benefit on anaemia but with fewer side-effects compared with daily iron supplementation.[23]

Updated evidence supports the use of maternal MMN supplementation to improve birth and child health outcomes in LMICs, when compared with iron–folic acid. The risk of stillbirth was reduced by 9% (95% CI 2–14), low birthweight by 15% (7–23), preterm birth by 4% (95% CI 9% reduction to 1% increase), and babies born SGA by 7% (95% CI 2–12).[22] Additionally, there was a greater effect on low birthweight when the dose of iron was less than 60 mg, compared with supplements with 60 mg iron, and with the use of the UN International Multiple Micronutrient Antenatal Preparation (15 micronutrients) compared with

	Location (number of studies done in each country)	Population	Evidence reviewed	Estimates of maternal outcomes	Estimates of fetal and newborn baby outcomes	Estimates of childhood outcomes	Notes
Folic acid supplementation *vs* placebo	China (2), Honduras, Cuba, Brazil	Women of reproductive age*	Systematic review of 5 RCTs and quasi-experimental studies	..	Neural tube defects (RR 0·53, 95% CI 0·41–0·67, 3 studies, GRADE: very low)	..	..
Iron folic acid supplementation *vs* placebo	Bangladesh (2), India (2), Indonesia (3), Nepal, Mali, Tanzania	Women of reproductive age*	Systematic review of 10 RCTs and quasi-experimental studies	Anaemia (RR 0·66, 95% CI 0·53–0·81, 6 studies, GRADE: very low)	..	..	..
Iron folic acid supplementation *vs* folic acid or placebo	China (3), Tanzania, The Gambia, Nepal, Iran	Healthy, pregnant women	Systematic review of 7 RCTs	Maternal anaemia (RR 0·52, 95% CI 0·41–0·66, 5 studies, GRADE: medium); haemoglobin concentration (MD 6·95 g/L, 95% CI 2·80–11·1, 7 studies); serum and plasma ferritin (MD 15·87 μg/L, 2·96–28·79, 5 studies)	Low birthweight (RR 0·88, 95% CI 0·78–0·99, 4 studies, GRADE: high)	..	..
MMN supplementation *vs* iron with or without folic acid	Ghana (2), Malawi (2), Burkina Faso, The Gambia, Guinea-Bissau, Tanzania, Zimbabwe, Niger, Indonesia (4), Vietnam (2), China (2), Bangladesh (5), Nepal (2), Pakistan (2), Peru (2), Mexico, Iran (3)	Healthy, pregnant women	Systematic review of 33 RCTs	Serum retinol (MD 0·11 μmol/L, 95% CI 0·05–0·17, 7 studies); zinc concentration (MD 0·40 μmol/L, 0·18–0·62, 5 studies); vitamin B12 concentration (MD 14·77 pmol/L, 5·13–24·42, 3 studies)	Low birthweight (RR 0·85, 95% CI 0·77–0·93, 28 studies, GRADE: high); stillbirths† (RR 0·91, 0·86–0·98, 22 studies); SGA‡ (RR 0·93, 0·88–0·98, 19 studies); preterm births§ (RR 0·96, 0·91–1·01, 29 studies)	Executive function (SMD 0·09, 95% CI 0·01–0·17, 3 studies); diarrhoea incidence (RR 0·84, 95% CI 0·76–0·92, 4 studies); retinol concentration (MD 0·06 μmol/L, 95% CI 0·02–0·09, 3 studies)	MMN defined as ≥3 micronutrients; looked at effects of MMN supplements consisting of 3–4 micronutrients compared with MMN supplements with >4 micro-nutrients (ie, UNIMMAP formulation)
Iron supplementation	China (3), Indonesia, Iran (4), Tanzania, The Gambia, Niger, Nepal	Healthy, pregnant women	Systematic review of 12 RCTs	Maternal anaemia (RR 0·53, 95% CI 0·43–0·65, 7 studies, GRADE: moderate); haemoglobin concentrations (MD 7·80 g/L, 95% CI 4·08–11·52, 11 studies); serum and plasma ferritin¶ (MD 24·14 μg/L, 10·83–37·45, 9 studies); iron deficiency‖ (RR 0·54, 95% CI 0·40–0·74, 4 studies)	Low birthweight (RR 0·88, 95% CI 0·78–0·99, 4 studies, GRADE: high)	..	Looked at supplementation with strictly iron and iron plus additional micronutrients (ie, iron–folic acid as standard of care)
Calcium supplementation *vs* placebo	Argentina, Ecuador, India, multicountry study (Peru, South Africa, Vietnam, India)	Healthy, pregnant women with low calcium intakes	Systematic review of 4 RCTs	Pre-eclampsia and eclampsia** (RR 0·45, 95% CI 0·19–1·06, 4 studies)	Low birthweight (RR 0·99, 95% CI 0·95–1·04, 3 studies, GRADE: high); stillbirths (RR 0·87, 0·70–1·07, 4 studies); preterm births (RR 0·84, 0·65–1·08, 4 studies)	..	Looked at supplementation with strictly calcium and calcium plus additional micronutrients (ie, iron–folic acid as standard of care)

(Table 1 continues on next page)

MMN formulations that comprised only three to four micronutrients. The risk of diarrhoea among children whose mothers had been supplemented with MMNs, instead of iron–folic acid, was also reduced by 16% (8–24) and executive functioning among school-aged children was improved in follow-up at age 7–14 years in three studies.[22]

The evidence from LMICs for other single micronutrient supplements in pregnancy, including calcium, vitamin A, and vitamin D, was mixed. Calcium supplementation (any dose) among healthy women with low calcium intake in LMICs improved the combined risk of maternal pre-eclampsia and eclampsia by 55% (95% CI 81% reduction to 6% increase).[22] When gathering all high dose (≥1g per day) calcium supplementation studies, including those among women at risk of hypertensive disorders of pregnancy and residing in high-income countries, several benefits were seen: a 55% (95% CI 35–69) reduced risk of pre-eclampsia,

	Location (number of studies done in each country)	Population	Evidence reviewed	Estimates of maternal outcomes	Estimates of fetal and newborn baby outcomes	Estimates of childhood outcomes	Notes
(Continued from previous page)							
Breastfeeding promotion *vs* standard of care	Egypt, Ghana (2), Jordan, Kenya (2), Nigeria, South Africa (2), Tanzania (2), Uganda (2), Uganda (3), Burkina Faso, Bangladesh (6), China, India (3), Iran (2), Malaysia, Nepal, Pakistan, Philippines, Thailand, Turkey (2), Mexico, Brazil (5)	Infants	Systematic review of 38 studies	..	Early initiation of breastfeeding (RR 1·20, 95% CI 1·12–1·28, 14 studies)	Exclusive breastfeeding at 3 months (RR 2·02, 1·88–2·17, 6 studies); exclusive breastfeeding at 6 months (RR 1·53, 1·47–1·58, 19 studies, GRADE: very low); prevalence of diarrhoea (RR 0·76, 0·67–0·85, 8 studies)	These educational interventions are effective either as facility-based, community-based, or home-based, and if the intervention is delivered by either community health workers and volunteers or health-care professionals
Complementary feeding education alone *vs* standard of care	Brazil (2), Pakistan (2), Peru, China (2), Bangladesh, India (4)	Children aged 6–24 months	Systematic review of 12 studies	..	..	Food secure population: weight-for-age (MD 0·41, 95% CI 0·07–0·75, 4 studies, GRADE: low); height-for-age (MD 0·25, 0·04–0·45, 4 studies, GRADE: moderate); food insecure population: weight-for-age (MD 0·47, 95% CI 0·35–0·59, 1 study); height-for-age (MD 0·26, 0·10–0·42, 1 study); weight-for-height (MD 0·50, 0·35–0·65, 1 study)	..
Complementary feeding provision with or without education *vs* standard of care	Burkina Faso, Zambia, India, Nigeria, Vietnam, Ghana (2), Ecuador (2), DR Congo, Bangladesh, Malawi (2), Guatemala, Colombia, Brazil, China	Children aged 6–24 months	Systematic review of 17 studies	..	..	Food secure population: stunting (RR 0·47, 95% CI 0·37–0·59, 1 study); food insecure population: height-for-age (MD 0·14, 95% CI 0·04–0·24, 12 studies, GRADE: low); stunting (RR 0·64, 95% CI 0·44–0·92, 7 studies, GRADE: low)	..
Preventive vitamin A supplementation *vs* placebo or no intervention	India (3), Mexico (2), Ghana (2), Indonesia (2), Nepal, Papua New Guinea, Ecuador, Bangladesh, Guinea-Bissau, The Gambia, China, Kenya, Peru	Children aged 1–59 months	Systematic review of 16 studies	..	..	Plasma retinol concentration (MD 0·33 μmol/L, 95% CI 0·01–0·65, 3 studies)	..
Micronutrient powders *vs* placebo or no intervention	India (4), Kenya (3), China (3), Bangladesh (2), Brazil (2), Ghana (2), Cambodia (2), Laos (2), Pakistan, Honduras, Mali, Ethiopia, Guatemala, North Korea, Nepal, Haiti, South Africa, Kyrgyzstan, Colombia, Nicaragua, Africa	Children aged 1–59 months	Systematic review of 34 RCTs	..	..	Anaemia (RR 0·76 cm, 95% CI 0·69–0·84; 21 studies), haemoglobin (MD 1·85 g/L, 1·24–2·47, 26 studies); iron deficiency (RR 0·50, 0·40–0·63, 12 studies); iron deficiency anaemia (RR 0·45, 0·32–0·58, 7 studies); diarrhoea (RR 1·30, 1·11–1·53, 4 studies)	Increased diarrhoea prevalence with micronutrient powders

(Table 1 continues on next page)

	Location (number of studies done in each country)	Population	Evidence reviewed	Estimates of maternal outcomes	Estimates of fetal and newborn baby outcomes	Estimates of childhood outcomes	Notes
(Continued from previous page)							
Preventive zinc supplementation *vs* placebo or no intervention	Indonesia (5), Bangladesh (5), India (4), Burkina Faso (3), Tanzania (2), Mexico (2), Guatemala (2), Thailand, Ethiopia, Nepal, Brazil, Uganda, Vietnam, Laos; India (2), South Africa (2), Bangladesh, Peru	Children aged 1–59 months; children aged 2–59 months	Systematic review of 31 RCTs; systematic review of 6 studies	..	..	Incidence of diarrhoea (RR 0·89, 95% CI 0·82–0·97, 11 studies); zinc deficiency (RR 0·37, 0·22–0·62, 11 studies); plasma serum zinc (MD 3·85, 2·48–5·23, 19 studies); incidence of pneumonia (RR 0·87, 95% CI 0·81–0·94, 6 studies, GRADE: low); prevalence of pneumonia (RR 0·59, 0·35–0·99, 1 study)	..
Preventive SQ-LNS *vs* no intervention	Malawi (4), Bangladesh (3), Ghana (2), Burkina Faso, Chad, Congo, Guatemala, Haiti, Honduras, Kenya, Peru	Children aged 6–23 months	Systematic review of 17 studies	..	..	Severe stunting (RR 0·83, 95% CI 0·70–0·99, 4 studies); moderate stunting (RR 0·92, 0·84–1·00, 7 studies); moderate wasting (RR 0·83, 0·73–0·95, 7 studies); moderate underweight (RR 0·88, 0·80–0·96, 7 studies)	SQ-LNS is more effective if provided to children for a longer period of time (ie, >12 months); little evidence also suggests that SQ-LNS is more effective than fortified blended foods and micronutrient powders at improving some growth outcomes

GRADE=Grading of Recommendations, Assessment, Development and Evaluations. MD=mean difference. MMN=multiple micronutrient. RCT=randomised controlled trial. RR=relative risk. SGA=small-for-gestational age. SMD=standardised mean difference. SQ-LNS=small-quantity lipid-based nutrition supplementation. UNIMMAP=UN International Multiple Micronutrient Antenatal Preparation. *Pubescent or menstruating women who received any folic acid supplementation before conception or continued using supplementation until the first trimester of pregnancy. †Subgroup difference for stillbirths between MMN supplements consisting of more than four micronutrients (average RR 0·91, 95% CI 0·85–0·98; 17 studies) and MMN with three or four micronutrients (RR 0·93, 95% CI 0·77–1·14; five studies). ‡Subgroup difference for SGA between MMN supplements consisting of more than four micronutrients (RR 0·90, 95% CI 0·85–0·96; 16 studies) and MMN supplements with three or four micronutrients (RR 1·07, 95% CI 0·98–1·16; three studies). §Subgroup difference for preterm birth between MMN supplements consisting of more than four micronutrients (RR 0·97, 95% CI 0·91–1·03; 18 studies) and MMN with three or four micronutrients (RR 0·93, 95% CI 0·84–1·02; 11 studies). ¶Subgroup difference for serum and plasma ferritin between iron alone (MD 7·09 μg/L, 95% CI 4·45–9·72; three studies) and iron combined with additional micronutrients (MD 32·87 μg/L; 95% CI 15·39–50·34; six studies). ||Subgroup difference for iron deficiency between iron alone (RR 0·34, 95% CI 0·23–0·51; two studies) and iron combined with additional micronutrients (RR 0·67, 95% CI 0·54–0·83; two studies). **Subgroup difference for pre-eclampsia and eclampsia between calcium alone (RR 0·30, 95% CI 0·17–0·52, three studies) and with additional iron–folic acid supplementation (RR 0·92, 95% CI 0·75–1·13, one study). All non-statistically significant outcomes for the interventions shown (plus additional interventions and outcomes) are available in the appendix for pregnant women (appendix pp 2–5), and infants and children younger than 5 years (appendix pp 6–10).

Table 1: **Review of priority direct health-care system nutritional interventions during preconception or pregnancy, and for children younger than 5 years**

a 35% (19–47) reduced risk of high blood pressure, a 20% (3–35) reduced risk of maternal death or serious morbidity, a 24% (3–40) reduced risk of preterm birth, and a 15% (95% CI 28% reduction to 1% increase) reduced risk of low birthweight.[24]

A 2015 Cochrane review of vitamin A supplementation (without any additional micronutrients) across all income bands that included any pregnant women (even with pre-existing conditions) revealed a 36% (95% CI 6–57) reduction in maternal anaemia, a 55% (1–80) reduction in infections, and a 21% (2–36) reduction in night blindness.[25] However, this Review could not support these findings given data limitations from LMICs, and did not show any benefits to maternal mortality or stillbirths.[22]

Vitamin D supplementation did not have any effect on rates of caesarean sections or births considered SGA, but might have reduced the risk of preterm birth by 36% (95% CI 60% reduction to 4% increase) based on studies in LMICs only.[22] However, a meta-analysis of studies across all income bands showed that maternal vitamin D supplementation reduced the risk of infants born with a low birthweight by 45% (95% CI 13–65), improved infant length at birth by 0·57 cm (95% CI 0·19–0·95), and reduced the risk of maternal pre-eclampsia by 52% (21–70).[26]

When comparing SQ-LNS with MMN supplementation, there were no benefits for any of the outcomes examined: miscarriage, perinatal mortality, SGA, preterm birth, or neonatal mortality.[22] Two studies reported that rates of maternal anaemia were higher among women who took SQ-LNS than those who took MMNs.[27,28] However, when comparing SQ-LNS with iron–folic acid, anthropometry at birth was slightly improved (birthweight increased by mean 53 g [95% CI 28–78] and birth length by mean 0·24 cm [95% CI 0·11–0·36]).[29] This improvement translated to a reduced risk of SGA by 6% (95% CI 1–11) and stunting at 6 months by 18% (6–29). There was no difference in gestational weight gain when SQ-LNS was compared with iron–folic acid or MMN intake; however, iron–folic acid was more effective than SQ-LNS in terms of reducing maternal anaemia.[29]

Food supplementation

In LMICs, balanced energy protein supplementation (ie, food supplements in which the protein accounts for less than 25% of the total caloric content) in pregnancy led to a 61% (95% CI 20–81) reduced risk of stillbirth, a 40% (14–59) reduced risk of low birthweight, and a 29% (6–46) reduction in SGA.[30] However, when data from LMICs and high-income countries were combined, the risk reduction of SGA was 21% (10–31).[31] No evidence to support an effect of balanced energy protein on maternal weight gain, morbidity, or mortality was available.

General food distribution programmes (foods being distributed without a specific focus on balanced energy protein, and with or without nutrition counselling) that reach pregnant women reduced the risk of low birthweight by 8% (95% CI 0–16), SGA by 6% (0–11), and improved both birthweight and birth length.[30] Additionally, newborn babies born to mothers who took food supplements had an 18% (6–29) lower risk of neonatal stunting and a 13% (3–22) lower risk of neonatal wasting.[30]

Direct health-care sector nutritional interventions in neonates

This section details the evidence for delayed cord clamping, vitamin K supplementation, vitamin A supplementation, kangaroo mother care, emollient use, and probiotics (appendix pp 6–7)—interventions that might improve neonatal vitamin and mineral stores, and reduce infections.

Delayed cord clamping

A 2019 Cochrane review found that delayed cord clamping (>30 s) versus early cord clamping (<30 s) reduced the risk of neonatal death by 27% (95% CI 2–46) and intraventricular haemorrhage by 17% (1–30) among preterm neonates.[32] Some studies found higher ferritin concentrations among preterm infants who received delayed cord clamping than those who received early cord clamping, although whether this effect is sustained beyond 6 weeks post partum is unclear.[33]

Among term neonates, delayed cord clamping improved iron stores and neurodevelopment at 12 months.[34,35] Although there is little evidence on infants born at term, a 2019 meta-analysis revealed an 8% (95% CI 1–13) reduced risk of anaemia, a 45% (28–57%) reduced risk of iron deficiency, and a 32% (6–51) reduced risk of iron-deficiency anaemia among term infants with delayed cord clamping versus early cord clamping.[36]

Vitamin K supplementation

For the prevention of haemorrhagic disease, WHO recommends 1 mg of intramuscular vitamin K after birth for all newborn babies.[37] This recommendation is based on reduced bleeding after circumcision and other bleeding, along with reduced risks of late vitamin K deficiency bleeding in LMICs.[38] Although late vitamin K deficiency bleeding is rare, a third of newborn babies with this condition will die or develop a disability. Taken together, the benefits associated with vitamin K prophylaxis outweigh the costs and risks of this intervention.

Neonatal vitamin A supplementation

Although trials of vitamin A supplementation on hospitalised newborn babies of very low birthweight have shown some benefits in neonatal mortality and oxygen requirements,[39] vitamin A supplementation studies in general newborn infants in community settings do not show any reduction in mortality among neonates provided vitamin A supplementation compared with the control.[40] A Cochrane review examining effects in term neonates similarly found no effect of vitamin A supplementation on infant mortality,[41] although individual patient data meta-analysis of neonatal vitamin A supplementation trials supported regional benefits in south Asia with a 13% (95% CI 2–23) reduction in mortality at age 6 months.[42]

Kangaroo mother care

Kangaroo mother care, of which early initiation and continued breastfeeding on demand are integral components, has traditionally been recommended for preterm infants, but updated evidence also suggests benefits among healthy (term or late preterm) newborn babies, with more weight gain by day 14 and 40% (95% CI 18–69) higher rates of exclusive breastfeeding at age 6 months than with standard of care (unpublished). These benefits are notable among low birthweight infants. The risk of mortality at discharge was reduced by 32% (13–47), at 6 months by 22% (4–37), and at the latest follow-up by 26% (11–39). There were also statistically significant improvements in time to breastfeeding initiation and exclusive breastfeeding at various timepoints (at discharge, 1–3 months, and 6–12 months follow-up).

Community-initiated, as opposed to facility-initiated, kangaroo mother care has been considered to improve coverage of this intervention. A large trial in Haryana, India, showed reduced mortality and substantial improvements in breastfeeding at 6 months (relative risk [RR] 8·83, 95% CI 5·0–15·6) compared with routine care.[43] Furthermore, improved infant weight-for-age Z scores (WAZ) and weight-for-height Z scores (WHZ) were noted at 90 days, along with height-for-age Z scores (HAZ) at day 28, and a 27% (11–40) reduced risk of severe wasting at day 28.[43]

Emollient use

Coconut oil is considered a potentially beneficial topical agent for the skin of preterm newborn babies because of its protective emollient and anti-infective properties, and could be absorbed transepidermally. A 2019 review noted a 65% (95% CI 33–82; two studies) lower incidence of hospital-acquired bloodstream infections, along with improved growth (three studies), although a meta-analysis for weight gain could not be done because of data limitations.[44] Evidence on the use of other topical emollients, such as ointments, creams, and vegetable oil, for reducing infections among preterm infants is conflicting,[45,46] although preterm infants massaged with vegetable oil had higher rates of weight gain (mean difference [MD] 2·55 g/kg per day, 95% CI 1·76–3·34; six studies), height gain (MD 1·22 mm per week, 1·01–1·44; six studies), and head circumference growth (MD 0·45 mm per week, 0·19–0·70; five studies) compared with usual care.[45] A review of seven studies also reported a mean difference in weight of 98 g and excess weight gain of 1·6 g/kg per day for infants who were provided emollient therapy compared with those without emollient therapy.[46]

Probiotics

Probiotics, a recently identified intervention from the last 20 years, containing potentially beneficial bacteria or yeast that are provided enterally, have been associated with a 20% (95% CI 4–34) lower risk of all-cause neonatal mortality, a 54% (41–65) reduced risk of necrotising enterocolitis, and a 22% (14–30) reduced risk of neonatal sepsis.[40] However, there was clinically significant heterogeneity in terms of strains of probiotics used, combination of probiotics with prebiotics (synbiotics), dose, duration, and mode of delivery (along with breastfeeding, formula feeding, or both). Also, most of the included studies in the review by Imdad and colleagues[40] were done in neonatal intensive care unit settings, not generalisable to community setting in LMICs. Further, large, well controlled studies in representative settings are needed to assess their efficacy.

Direct health-care sector nutritional interventions in infants and children younger than 5 years

This section (table 1; appendix pp 8–10) details the evidence for breastfeeding and complementary feeding promotion, single and multiple micronutrient, and food supplementation interventions that promote optimal micronutrient intakes and diets among infants and children younger than 5 years. We also summarise the evidence on interventions to manage malnutrition.

Breastfeeding and complementary feeding promotion

Optimal infant and young child feeding practices, including breastfeeding and complementary feeding, are the cornerstone for ensuring good long-term child nutrition, yet global coverage remains low. Evidence from LMICs suggests that education strategies for breastfeeding could lead to a 20% (95% CI 12–28) increase in rates of early initiation of breastfeeding, a 102% (88–117) increase in exclusive breastfeeding at 3 months, and a 53% (47–58) increase in exclusive breastfeeding at 6 months.[47] These interventions had no effect on the prevalence of child stunting and wasting, but did lead to a 24% (15–33) decrease in diarrhoeal diseases. Educational strategies were effective when delivered in all settings, including in facilities, communities, and homes, although the strategies were more effective when done by health-care professionals and tailored to a specific context. For notable effects, prenatal education should continue after birth, as ongoing scheduled visits can ensure continuous support that is tailored to the setting and the needs of the population group.[47,48] There is a still a dearth of evidence for effective strategies to support breastfeeding among working women, especially in underprivileged settings.

Interventions to improve complementary feeding practices include education and provision of food for children aged 6–24 months. In food secure populations within LMICs, complementary feeding education alone improved WAZ (MD 0·41; 95% CI 0·07–0·75) and HAZ (MD 0·25; 0·04–0·45), and reduced stunting by 52% (95% CI 20–71).[47] In food-insecure populations, complementary feeding education alone showed some benefits, although only one study contributed to this analysis.[46] Complementary feeding provision and education in food insecure populations improved HAZ (MD 0·14; 95% CI 0·04–0·23) and reduced stunting by 36% (95% CI 8–56).[47]

Single and multiple micronutrient supplementation

A review of 47 studies of vitamin A supplementation in children aged 6–59 months from all countries showed a 12% reduction (95% CI 7–17) in all-cause mortality, a 12% reduction (2–21) in diarrhoea-specific mortality, and a 15% reduction (13–18) in diarrhoea incidence, but no effect on mortality due to measles, respiratory disease, and meningitis.[49] Another review of vitamin A supplementation in children aged 1–59 months living in LMICs showed a 10% reduction (95% CI 20% decrease to 2% increase) in all-cause mortality,[50] but this review only included studies published from 1995 onwards. A sensitivity analysis (appendix p 11) that includes eligible studies published before 1995 showed that the pooled effect estimate for mortality once again became highly significant (20% reduction; 95% CI 8–30), underscoring a changing context of vitamin A deficiency that could have implications for vitamin A supplementation regimens moving forward.[51]

The evidence from 45 studies on preventive zinc supplementation in apparently healthy children aged 1–59 months from LMICs showed a reduction in the incidence of diarrhoea by 11% (95% CI 3–18) but showed no effect on the risk of anaemia, stunting, wasting, and all-cause mortality.[50] A previous review that included studies that specifically recruited children who were undernourished, stunted, anaemic, or born with a low birthweight or SGA noted positive effects on linear growth (standardised mean difference [SMD] 0·13, 95% CI 0·04–0·23).[52] Therefore, we did a sensitivity analysis to assess the height among apparently healthy children and children with nutrition disorders at baseline, and found that linear growth improved among the deficient group (SMD 0·21, 95% CI 0·04 to 0·38 *vs* SMD 0·03, –0·03 to 0·09; appendix p 12). A third review shows that zinc supplementation in children aged 2–59 months might reduce the incidence of pneumonia by 13% (95% CI 6–19) and the prevalence of pneumonia by 41% (1–65).[53] Zinc supplementation for the treatment of diarrhoea in children older than 6 months might shorten the average duration of diarrhoea by close to half a day, and probably reduces the number of children whose diarrhoea persists until day seven (RR 0·73, 95% CI 0·61–0·88; six studies).[54] This effect is greater in malnourished children[55] and mainly seen in populations with high rates of zinc deficiency.[55]

Iron supplementation, when provided to children aged 1–59 months in LMICs, leads to a reduced risk of anaemia by 45% (95% CI 30–56) with no improvements in stunting or wasting.[50] Evidence, albeit scarce, also suggests that iron supplementation benefits cognitive and motor development. However, concerns remain about iron supplementation increasing the risk of malaria-related morbidity and mortality in malaria-endemic areas, hence WHO's recommendation to provide iron with antimalarial interventions in these settings.

MMN supplementation, when provided to children aged 1–59 months in LMICs, was associated with a 31% (95% CI 15–44) reduction in anaemia and an increase in height, and the effect was greater with daily versus intermittent supplementation.[50] Micronutrient powders, which contain iron and MMNs, are used in some community nutrition programmes. Evidence from LMICs suggests that micronutrient powder supplementation among children aged 1–59 months is associated with a 24% (16–31) lower risk of anaemia, but has no effect on stunting, underweight, and wasting.[50] Micronutrient powder supplementation is associated with a 30% (11–53) increased risk of diarrhoea, which is a disadvantage in settings with high rates of malnutrition.[50]

Preventive SQ-LNS have been extensively evaluated in the past 15 years. 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 stunting by 17% (95% CI 1–30), moderate stunting by 8% (0–16), moderate wasting by 17% (5–27), and moderate underweight by 12% (4–20).[56] In comparison with micronutrient powders, SQ-LNS reduces the prevalence of moderate underweight by 12% (1–22) and anaemia by 62% (32–79), although there were no differences in moderate stunting and moderate wasting.[56] A separate meta-analysis of 13 trials found that the risk of all-cause mortality was reduced by 27% (11–41) among children taking lipid-based nutrient supplements when compared with no lipid-based nutrient supplement intervention.[57]

Supplementary feeding programmes

A systematic review of seven trials looking at the effects of supplementary feeding programmes for children younger than 2 years in LMICs found no effect on stunting, wasting, HAZ, or WAZ.[47] However, there was a significant effect on WHZ (MD 0·15, 95% CI 0·08–0·22) and a 39% (95% CI 3–62) reduced risk of infant mortality when pooling data from two trials that provided ready-to-use supplementary and therapeutic food to children.[47] A Cochrane review of 32 studies among socioeconomically disadvantaged children globally noted a positive effect on growth (0·12 kg weight gain and 0·27 cm height gain over 6 months), along with improvements in HAZ and WAZ, but not WHZ.[58] Another systematic review of reviews on community-based supplementary feeding for food insecure populations noted that effects were generally notable for younger (<2 years) and poorer, less nourished children.[59]

Management of moderate, severe, and acute malnutrition

Although preventing malnutrition through the various interventions described in this Review is crucial, managing children who are malnourished is equally important and can be undertaken in community settings.[3] A recent review assessed the evidence for the management of severe acute malnutrition and moderate acute malnutrition, according to the WHO guidelines for both facility-based and community-based strategies, and included the effectiveness of ready-to-use therapeutic food, ready-to-use supplementary food, prophylactic antibiotics, and vitamin A supplementation.[60] Evidence, albeit scarce, suggests that integrated community-based screening, identification, and management of severe acute malnutrition and moderate acute malnutrition, when compared with standard treatment, further improves recovery rates by 4% from 79% to 83%,[60] whereas facility-based screening and management of uncomplicated severe acute malnutrition has no additional effect on recovery and mortality when compared with outpatient and community-based management. This strategy of triage and community-based management with a range of commodities, has enabled more than 90% of severely malnourished children without signs of infection or other complications to be treated at low cost.[61]

The types of commodities can vary. Comparison of various supplementation strategies also suggests that, for moderate acute malnutrition, local foods are similar to standard ready-to-use supplementary food for recovery rates and weight gain, whereas standard ready-to-use supplementary food has additional benefits compared with corn soy blend.[60] Community-based management of children with uncomplicated severe acute malnutrition as outpatients shows no difference in recovery rate, weight gain, and mortality when standard ready-to-use therapeutic food was compared with other formulations.

Direct health-care sector nutritional interventions in school-aged children and adolescents

Although adolescence is a crucial period to maintain proper nutrition to support growth and development, large-scale nutrition programmes targeting this subgroup in LMICs are scarce, despite global guidance by WHO to provide additional micronutrients to adolescents in the preconception period in some contexts—eg, when the prevalence of anaemia is between 20–39%, intermittent iron–folic acid supplementation for adolescent girls who are menstruating is recommended.[62] Of existing trials in LMICs targeting adolescent girls (aged 10–19 years) specifically, none assessed the effect of nutritional counselling and education or macronutrient supplementation interventions in this age group.[63] Evidence for micronutrient supplementation interventions exist, but is of low quality and calls into question the certainty of results for several interventions and outcomes examined among adolescents. Iron supplementation with or without folic acid might improve haemoglobin concentration by 0·42 g/L (95% CI 0·13–0·71) and supplementation with calcium and vitamin D might improve serum 25-hydroxyvitamin D concentrations (SMD 2·85, 95% CI 0·89–4·82).[63] However, the effect of other micronutrient supplementation interventions (calcium plus vitamin D, zinc, MMN supplementation) on anaemia, zinc concentration, body-mass index (BMI), total body bone mineral density, and developmental outcomes showed no additional benefits compared with control. Another review assessing micronutrient supplementation in low-income, middle-income, and high-income countries showed a 31% reduction in anaemia with iron with or without folic acid supplementation alone or in combination with other micronutrients. The delivery strategy in most of these studies was school-based.[64]

Examining the pregnant adolescent population revealed an increase in mean birthweight, a 30% (95% CI 16–43) reduced risk of low birthweight, and a 27% (5–43) reduced risk of preterm birth when pooling studies that provided antenatal micronutrient supplementation (eg, calcium and zinc) in addition to routine iron–folic acid and nutritional counselling.[64]

The escalating double burden of malnutrition requires interventions that have the capacity to prevent and manage both undernutrition and overweight and obesity in the same population. Based on an understanding of common drivers of malnutrition, preliminary evidence has shown that these double-duty actions might include: promotion of exclusive breastfeeding and appropriate complementary feeding; antenatal care programmes; school food policies and programmes; and regulations around marketing for unhealthy foods and breast milk substitutes.[65] Together, these strategies work across the continuum of care to ensure adequate nutrition among mothers, infants, school-aged children, and adolescents.

Poor oral health can be a manifestation of poor nutrition and also lead to further worsening of nutritional status. Children are susceptible to dental caries, made substantially worse by low intake of fluoride in their diets.[66] Dental caries can be obviated by judicious uptake of fluoride in drinking water or through commodities such as toothpaste. Dental caries are also commonly seen among school-aged children and adolescents in LMICs,[67] often triggered by excessive uptake of sugar-containing drinks and fast foods as these become more readily available in these countries.

Considering the increasing burden of overweight and obesity, various lifestyle, pharmacological, and surgical interventions, delivered both inside and outside of the health-care sector, have been suggested to prevent and manage these conditions in school-aged children and adolescents. Schools tend to be an ideal location for lifestyle modification interventions because they provide easy access to this particular age group over a long period; schools also offer time slots, facilities, and equipment to encourage adequate physical activity. Reviews have supported this notion, suggesting that education on healthy diets and physical activity at school is a key strategy for preventing obesity in school-aged children.[68]

A review assessed the effect of lifestyle interventions to prevent and manage childhood and adolescent obesity, summarising findings from 656 included studies of which 81% were from high-income countries.[69] Evidence suggests that a combination of diet and exercise interventions might reduce BMI by 0·41 kg/m² (95% CI –0·60 to –0·21), BMI Z score by 0·12 SDs (95% CI –0·18 to –0·06), and bodyweight by 1·59 kg (95% CI –2·95 to –0·23). Behavioural therapy alone (MD –0·07; 95% CI –0·14 to 0·00) and a combination of exercise and behavioural therapy might reduce the BMI Z score (MD –0·08; 95% CI –0·16 to 0·00). Another review that examined the adolescent population only also noted moderately improved BMI with integrated interventions that included diet, education, and physical activity components.[64]

Evidence for obesity management suggests that exercise alone might reduce BMI by 0·88 kg/m² (95% CI –1·25 to –0·50) and behavioural therapy by 0·44 kg/m² (95% CI –0·78 to –0·10). Sensitivity analyses suggest that diet along with physical activity (MD –0·5; 95% CI –0·85 to –0·16) and a combination of diet, exercise, and

	Evidence of effect	Outcomes	Estimates from 2013	Current estimates	Implications for policy	Overall findings
Optimal maternal nutrition during pregnancy						
Iron-containing supplements						
MMN supplementation *vs* iron with or without folic acid	Strong evidence	Low birthweight; SGA births; preterm births; stillbirths	12% reduction (95% CI 9–15); 11% reduction (4–17); 3% reduction (1–6); not significant	MMN >4 micronutrients (most UNIMMAP): 21% reduction (95% CI 12–29); 10% reduction (4–15); 3% reduction (95% CI 3% excess to 9% reduction); 9% reduction (95% CI 2–15)	The evidence in support of MMN (UNIMAPP-like formulations) replacing iron–folic acid in pregnancy is strong, now supported by effects on low birthweight, SGA, and reduced stillbirths; in consonance with WHO guidance,[87] we support implementation research to encourage introduction of MMN supplements in pregnancy (for all women, including adolescents) and assessment of outcomes, benefits, and costs as feasible	Outcomes examined but no statistically significant pooled effects: maternal anaemia, maternal mortality, perinatal mortality, neonatal mortality, and infant mortality
Daily iron (with and without additional micronutrients) *vs* same supplement without iron		Maternal anaemia; low birthweight	Iron–folic acid: 66% reduction (95% CI 46–79) and iron alone: 70% reduction (95% CI 54–81); iron–folic acid: not significant and iron alone: 19% reduction (95% CI 3–32)	Iron–folic acid: 48% reduction (95% CI 34–59); iron–folic acid: 12% reduction (1–22)	Although the benefits of iron–folic acid on anaemia and low birthweight are noted, MMN was better in comparison; compliance and tolerance issues with iron–folic acid has been noted	Outcomes examined but no statistically significant pooled effects: preterm birth, SGA, perinatal mortality, neonatal mortality, and infant mortality
Calcium supplements in population with low calcium intake						
Calcium supplementation *vs* placebo	Moderate evidence	Pre-eclampsia and eclampsia; preterm births	52% reduction (95% CI 33–66); 24% reduction (3–40)	55% reduction (95% CI 6% excess to 81% reduction); 16% reduction (8% excess to 35% reduction)	We continue to recommend maternal calcium supplementation for which risk of low intake is present, although the exact formulation and ideal strategies remain to be defined to ensure effective programmatic responses that are currently missing	Outcomes examined but no statistically significant pooled effects: maternal mortality, stillbirth, and low birthweight
Maternal balanced energy protein supplements						
Balanced energy protein supplementation *vs* no intervention or low-energy supplement	Moderate evidence	Low birthweight; stillbirths; SGA	Not significant; 38% reduction (95% CI 2–60); 34% reduction (95% CI 11–52)	40% reduction (95% CI 14–59); 61% reduction (20–81); 29% reduction (6–46)	We continue to recommend maternal balanced energy protein supplementation for undernourished women, especially in food insecure populations	Outcomes examined but no statistically significant pooled effects: birthweight and birth length
Food distribution programmes for pregnant women (with or without dietary counselling)	Weak evidence	Perinatal mortality; neonatal mortality; low birthweight; stunting in children younger than 5 years; wasting in children younger than 5 years	None reported for all outcomes	33% reduction (95% CI 9% excess to 59% reduction); 54% reduction (95% CI 4% excess to 80% reduction); 8% reduction (95% CI 0–16); 18% reduction (6–29); 13% reduction (3–22)	Although food distribution programmes in food insecure areas also appear to have benefits, balanced energy protein supplements are most likely to have greater effects. We recommend that food supplements for women in food insecure households should be tailored to provide a reasonably balanced energy and daily protein balance	Outcomes examined but no statistically significant pooled effects: maternal mortality, preterm birth, SGA, and underweight in children younger than 5 years
Optimal nutrition for newborn babies						
Kangaroo mother care for term newborn babies *vs* standard of care (for breastfeeding only)	Weak evidence	Exclusive breastfeeding from 6 weeks to 6 months	At 1–4 months: 27% increase (95% CI 6–53)	41% increase (95% CI 18–69)	Summarised in the cell below	Outcomes examined but no statistically significant pooled effects: neonatal mortality
Kangaroo mother care for low birthweight newborn babies *vs* standard of care	Strong evidence	Mortality at latest follow-up; severe infection or sepsis at latest follow-up; exclusive breastfeeding at 6–12 months	40% reduction (95% CI 7–70); 58% reduction (27–76); not reported	26% reduction (95% CI 11–39); 15% reduction (8–21); 203% increase (131–297)	We recommend kangaroo mother care for all babies, but especially for those who are preterm and of low birthweight; the evidence in support of community kangaroo mother care is sufficiently robust for us to recommend community kangaroo mother care for all low birthweight infants as feasible	Outcomes examined but no statistically significant pooled effects: none

(Table 2 continues on next page)

	Evidence of effect	Outcomes	Estimates from 2013	Current estimates	Implications for policy	Overall findings
(Continued from previous page)						
Delayed cord clamping *vs* early cord clamping for preterm newborn babies	Strong evidence	Neonatal death; intraventricular haemorrhage	Not reported; 41% reduction (95% CI 15–59)	27% reduction (95% CI 2–46); 17% reduction (1–30)	We continue to recommend delayed cord clamping for preterm babies and further studies to assess outcomes in relation to anaemia and neurodevelopment in infancy	Outcomes examined but no statistically significant pooled effects: maternal blood loss, severe intraventricular haemorrhage, periventricular leukomalacia
Probiotics *vs* no probiotics for low birthweight or preterm newborn babies	Emerging evidence	All-cause mortality; necrotising enterocolitis; neonatal sepsis	None reported for all outcomes	20% reduction (95% CI 4–34); 54% reduction (41–65); 22% reduction (14–30)	Although promising and with notable benefits in several settings in LMICs, we recommend further well designed research to define the type of probiotics and synbiotics for use in LMIC settings, especially in community settings with appropriate morbidity and safety monitoring	Outcomes examined but no statistically significant pooled effects: none
Infant and young child feeding						
Breastfeeding promotion						
Breastfeeding counselling *vs* standard of care	Strong evidence	Early initiation of breastfeeding; exclusive breastfeeding at age 6 months	Not reported; 90% increase (95% CI 54–134)	20% increase (95% CI 12–28); 53% increase (47–58)	We recommend breastfeeding counselling for all mothers in all settings to promote early and exclusive breastfeeding; opportunities for exclusive breastfeeding should be maximised through legislation, supporting maternity leave, workplace facilities for breastfeeding, and strict enforcement of restrictions on market of infant formula substitutes	Outcomes examined but no statistically significant pooled effects: HAZ, WAZ, infant mortality
Complementary feeding education interventions						
Complementary feeding education (without provision of food) *vs* standard of care in food secure populations	Moderate evidence	HAZ; WAZ; stunting	SMD 0·22 increase (95% CI 0·01–0·43); not significant; not significant	MD 0·25 increase (95% CI 0·04–0·45); MD 0·41 increase (0·07–0·75); 52% reduction (95% CI 20–71)	Complementary feeding strategies to improve dietary intakes remain a major global gap; we recommend appropriate complementary feeding education and counselling in all food secure settings	Outcomes examined but no statistically significant pooled effects: WHZ, stunting, wasting, weight gain, height gain
Complementary food supplements with or without nutrition education						
Provision of complementary foods with education *vs* no intervention in food insecure populations	Strong evidence	HAZ; stunting; WAZ	SMD 0·39 increase (95% CI 0·05–0·73); 67% reduction (0–89); SMD 0·26 increase (0·04–0·48)	MD 0·14 increase (95% CI 0·04–0·24); 36% reduction (8–56); MD 0·34 increase (95% CI 0·35 reduction to 1·03 increase)	There are benefits to child growth outcomes when complementary feeding education is provided with foods among food insecure households; we recommend strategies that provide education along with appropriate food basket support or supplements in such settings	Outcomes examined but no statistically significant pooled effects: WHZ, wasting, weight gain, height gain
Micronutrient supplementation in children						
Vitamin A supplementation *vs* no vitamin A (1–59 months)	Strong evidence	All-cause mortality; diarrhoea incidence	24% reduction (95% CI 17–31); 15% reduction (13–18)	10% reduction (95% CI 2% excess to 20% reduction)*; 3% reduction (95% CI 14% excess to 17% reduction)	In countries with evidence of a public health problem with vitamin A deficiency, we recommend continuation of biannual vitamin A supplementation in children aged 6–59 months	Outcomes examined but no statistically significant pooled effects: lower respiratory tract infection
Preventive zinc supplementation *vs* no zinc (1–59 months)	Moderate evidence	Diarrhoea incidence; lower respiratory tract infection; mean height	13% reduction (95% CI 6–19); 19% reduction (10–27); MD 0·37 cm increase (SD 0·25)	11% reduction (95% CI 3–18); 22% reduction (95% CI 17% excess to 47% reduction); MD 0·04 cm increase (95% CI 0·12 reduction to 0·20 increase)†	The effect of preventive zinc supplementation on diarrhoea is robust, and although the effects on growth and lower respiratory infections are attenuated, we recommend exploration of preventive zinc supplementation in at-risk populations (possibly through improving MMN intake or fortification)	Outcomes examined but no statistically significant pooled effects: anaemia, stunting, wasting, underweight, all-cause mortality

(Table 2 continues on next page)

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	Evidence of effect	Outcomes	Estimates from 2013	Current estimates	Implications for policy	Overall findings
(Continued from previous page)						
Therapeutic zinc supplementation *vs* no zinc (6–23 months)	Strong evidence	Duration of diarrhoea; duration of persistent diarrhoea; vomiting	Reduced duration of acute diarrhoea by 0·5 days; reduced duration of acute diarrhoea by 0·68 days; not reported	MD 11·5 h reduction (95% CI 3·2–19·7); MD 15·8 h reduction (6·2–25·4); 57% increase (95% CI 32–86)	We continue to strongly recommend zinc supplements along with low osmolarity oral rehydration solution for diarrhoea management among children living in populations with high prevalence of zinc deficiency	Outcomes examined but no statistically significant pooled effects: death, hospitalisation
Micronutrient powders *vs* placebo or no intervention (1–59 months)	Moderate evidence	Anaemia; iron-deficiency anaemia; iron-deficiency; diarrhoea	Children aged 6 months to 11 years: 34% reduction (95% CI 23–43); children aged 6 months to 11 years: 57% reduction (95% CI 48–65); not reported; 4% excess (95% CI 1–6)	24% reduction (95% CI 16–31); 55% reduction (42–68); 50% reduction (37–60); 30% excess (11–53)	The role of micronutrient powders in reducing childhood anaemia is well established; however, few micronutrient powder programmes have reached scale and shown sustained benefits with graduation from home fortification; the notable increase in diarrhoea burden has led to considerations of reducing iron content of micronutrient powders	Outcomes examined but no statistically significant pooled effects: stunting, wasting, underweight
SQ-LNS *vs* no intervention	Strong evidence	Severe stunting; moderate stunting; moderate wasting; moderate underweight	None reported for all outcomes	17% reduction (95% CI 1–30); 8% reduction (0–16); 17% reduction (5–27); 12% reduction (4–20)	The evidence in support of SQ-LNS among at-risk children is strong and, in contrast to micronutrient powders alone, the benefits on growth and anaemia are advantageous.	Outcomes examined but no statistically significant pooled effects: severe wasting, severe underweight
Management of acute malnutrition						
Ready-to-use supplementary food *vs* corn-soy blend for moderate acute malnutrition	Strong evidence	Severe wasting	Not reported	26% reduction (95% CI 5–43)	A well established treatment regimen for children with severe acute malnutrition in all settings and should be continued; further studies are needed to assess sustained benefits and reduced relapse rates, which still remain a challenge	Outcomes examined but no statistically significant pooled effects: moderate stunting in children younger than 5 years, moderate wasting in children younger than 5 years, weight gain, recovery rate

Estimates from 2013 are from the 2013 *Lancet* Series on maternal and child nutrition. HAZ=height-for-age Z score. LMIC=low-income or middle-income country. MD=mean difference. MMN=multiple micronutrient. SGA=small-for-gestational-age. SMD=standardised mean difference. SQ-LNS=small-quantity lipid-based nutrient supplements. UNIMMAP=UN International Multiple Micronutrient Antenatal Preparation. WAZ=weight-for-age Z score. WHZ=weight-for-height Z score. *Results from sensitivity analysis that included older trials (risk ratio 0·80, 95% CI 0·70–0·92; 11 studies). †Results from sensitivity analysis that investigated height among undernourished children at baseline (MD 0·09, 95% CI 0·02–0·16; 15 studies).

***Table 2:* Comparison between 2013 estimates and current (2019) estimates of intervention effects on key maternal and child nutritional outcomes**

behavioural therapy (MD –0·51; –0·89 to –0·12) might also reduce BMI. Physical activity alone (MD –0·13; –0·20 to –0·06), diet along with behavioural therapy interventions (MD –0·16; –0·26 to –0·07), and a combination of all three (MD –0·08; –0·14 to –0·03) decreases the BMI Z score.

In comparison with an increase of literature on behavioural interventions for overweight and obesity prevention and management in high-income settings over the past 20 years,[70] there is a dearth of evidence on the efficacy of obesity prevention interventions for pregnant and non-pregnant women in LMICs. A meta-analysis of two studies revealed a reduction in mean birthweight by nearly 200 g with dietary interventions, counselling, and behaviour change strategies combined and provided during the antenatal period.

Indirect health-care sector nutritional interventions

Family planning and birth spacing

Findings from national-level data show the positive association between contraceptive use and nutrition outcomes, including anaemia among women of reproductive age, child stunting, and underweight, highlighting some of the consequences of unplanned and poorly spaced pregnancies.[71] Given data limitations, there are some questions around the link between interpregnancy intervals and maternal nutrition. However, birth spacing is associated with better maternal nutrition indicators and lower stunting prevalence (10–50% reduction) among children in several contexts.[72]

Disease prevention and management

WHO guidelines recommend treating all school-aged children at regular intervals with deworming drugs in areas where helminth infection is common.[73] Preventive chemotherapy is also recommended as a public health intervention in pregnancy (after the first trimester) if a country's baseline prevalence of hookworm or *Trichuris trichiura* infection is 20% or higher among pregnant women and anaemia is a severe public health problem among pregnant women. A Cochrane review evaluating the effects of mass deworming programmes that treat children with deworming drugs suggests no benefit to child height, haemo-

Panel 2: Delivery platforms

Various delivery platforms have been used to effectively deliver direct and indirect nutritional interventions to improve coverage, nutrition behaviours, and outcomes across diverse populations. In addition to schools, these delivery platforms include community-based platforms, financial incentives platforms, mHealth, and the use of mass media and social media.

Community health-care workers' outreach and women's groups

A Cochrane review assessing the effectiveness of health education strategies imparted through community health workers to mothers or their family members in community settings of low-income and middle-income countries suggests that these interventions can substantially improve the use of antenatal care and early initiation of breastfeeding, and can reduce newborn and perinatal mortality.[87] The review also suggests that educational interventions delivered through community health workers during the postnatal period were most effective at improving breastfeeding practices. Another review concluded that regular home visits to mothers by community health workers or peer volunteers to provide education and counselling are effective at improving early initiation of breastfeeding and exclusive breastfeeding practices.[16] A third review assessed the integration of health and nutrition programmes within primary care settings and found that integrating nutrition-specific interventions into health systems can encourage a more efficient service delivery and improve key nutrition outcomes.[88] Some benefits of community-based interventions on child linear growth are also notable through participatory women's groups.[89]

School nutrition and feeding programmes

Schools represent a unique platform to provide nutritional interventions to school-aged children. Interventions to improve nutrition in this age group could focus on changing school policies, educating students on good nutrition and dietary practices, or providing foods in the form of daily meals or snacks. Most school feeding programmes target vulnerable populations that are at risk of food insecurity, as a means for improving school enrolment and promoting positive, learned behaviours across the life course.[90,91] In 2017, the World Bank estimated that 368 million school-aged children and adolescents globally were reached by these programmes.[90] Although an update of a systematic review of the effectiveness of school feeding programmes is underway, Kristjansson and colleagues[92] found improvements in weight among children from low-income countries who participated in school feeding programmes (MD 0·39 kg, 95% CI 0·11–0·67; three studies).

Cash transfers

A review assessing the effect of conditional cash transfers on the delivery of direct nutritional interventions did not show an effect on stunting, underweight, and wasting among children younger than 5 years.[16] Another review assessing the effect of financial incentives on child health interventions suggested a potential positive effect on receiving colostrum, early initiation of breastfeeding, exclusive breastfeeding and mean duration of exclusive breastfeeding; however, the evidence quality was low.[93]

Mass media and mHealth

A review of mass media and mHealth as delivery platforms for nutritional interventions suggests very little availability of the data. However, included studies showed some evidence of the effect of mHealth (ie, SMS) interventions on breastfeeding practices and compliance with maternal and child micronutrient supplementation.[16] Another review assessing the design, implementation, and effectiveness of mass media, and nutrition education interventions for improving infant and young child feeding practices suggested that there is a potential benefit of mass media in improving feeding practices; however the studies were not consistent in reporting elements of the design of these interventions.[94] A third review assessed the effectiveness of social media-based interventions, such as chat rooms and discussion boards, to improve nutrition behaviours among adolescents.[95] Among effective interventions, a social support component was most frequently used as the behaviour change mechanism, and adolescents tended to increase intake of healthy foods more often than they decreased intake of unhealthy foods.

globin concentrations, cognition, school performance, or mortality.[74] An individual participant data network meta-analysis reinforces these findings of very little effect on nutritional status or cognition.[75] A systematic review of deworming with anthelmintic for soil-transmitted helminths during pregnancy suggests no effect on maternal anaemia, low birthweight, preterm birth, and perinatal mortality,[76] and an individual participant data meta-analysis suggests some benefit on anaemia, but no effect on other maternal or pregnancy outcomes.[77]

Insecticide-treated bednets compared with no bednets reduce child mortality from all causes by 17% (95% CI 11–23) and reduce the prevalence of *P falciparum* malaria by 17% (2–29).[78] Combined evidence from five trials showed that insecticide-treated bednets reduce placental malaria by 21% (2–37) and can reduce low birthweight by 23% (2–39).[79] Another review of 17 trials showed that malaria chemoprevention in pregnancy reduces the risk of moderate to severe anaemia by 40% (25–53), and leads to an increase in birthweight of 93 g and a reduction in low birthweight of 27% (13–39).[80] Intermittent preventive treatment for malaria in infants reduces the incidence of clinical malaria by 27% (18–35), but the effects of sulfadoxine–pyrimethamine appear to be attenuated over time, with trials done after 2009 showing little or no effect.[81]

A detailed discussion of non-health-care sector interventions is beyond the scope of this Review. However, we have reviewed the evidence on water, sanitation, and hygiene specifically, along with the nutritional benefits of non-health interventions from a country assessment of programmes in exemplar countries with exceptional reductions in stunting (appendix p 13–14).[12, 82–86]

Implications of the current evidence

This comprehensive evidence synthesis has reviewed the nutrition actions outlined in the 2013 *Lancet* Series on maternal and child nutrition along with several additional interventions that have been developed since (table 2). Although there has been a dearth of evidence for school-aged children and adolescents, and outside of pregnancy, we were able to assess various delivery strategies and platforms that could improve the reach of nutrition actions (panel 2). Taken together, several novel strategies should be prioritised and accelerated to reach marginalised populations.

Several things must be noted when comparing these results to previous reviews, particularly, the differing eligibility criteria used (appendix p 14). Limitations include the predominant exclusion of women and children with underlying conditions that are widely prevalent in LMICs, and the paucity of longer-term health and nutrition outcomes due to limitations with data collection. Methodological considerations are reported in appendix p 14.

Our evidence-based recommendations for malnutrition action are found in table 2, and we have summarised the strength of evidence for intervention implementation in figure 2. Other available promising interventions need to be studied at scale, in terms of feasibility of implementation and effectiveness. These interventions include delayed cord clamping for term newborn babies and the use of emollients (eg, coconut or sunflower oil) in appropriate settings. Probiotic supplementation for preterm and low birthweight newborn babies is a relatively new intervention that has elicited debate in terms of its routine recommendation and composition.[96–98] The fact that the evidence is highly variable and largely related to small studies is clear. Rigorous studies of adequate size are needed to assess the benefits and risks of probiotic use in community and facility settings.

The rising double burden trends are becoming a reality for nearly all LMICs, and strategies to tackle both underweight and overweight would require major and sustained societal shifts along with changes to the global food system. Scaling up nutrition-sensitive agricultural practices and implementing related policies around production, promotion, and consumption could help to foster diversity in dietary intake, particularly among countries experiencing a nutrition transition due to changing food environments.[98] In addition, educational initiatives and the use of health and social sector delivery platforms could together exert influence on dietary intake and choices.[99] The high prevalence of poverty and food insecurity globally further underscores the need for a multidimensional and multisectoral approach to tackle malnutrition.

Strong evidence for implementation	• Multiple micronutrient supplementation in pregnancy • Kangaroo mother care for preterm and low birthweight newborn babies • Delayed cord clamping for preterm newborn babies • Breastfeeding promotion and counselling • Complementary feeding education with food provision in food insecure populations • Vitamin A supplementation for children in vitamin A-deficient contexts • Therapeutic zinc supplementation for diarrhoea management • Small-quantity lipid-based nutrient supplements for growth among children • Ready-to-use supplementary food for management of acute malnutrition • Family planning and birth spacing* • Insecticide-treated bednets for the control of malaria* • Large-scale food fortification for the prevention of micronutrient deficiencies†
Moderate evidence for implementation	• Water, sanitation, and hygiene interventions‡ • Calcium supplementation in pregnancy in low intake populations • Balanced-energy protein supplementation in pregnancy for women who are undernourished • Complementary feeding education without food provision in food secure populations • Preventive zinc supplementation to reduce diarrhoea incidence • Micronutrient powders to reduce iron deficiency and anaemia among children
Weak evidence for implementation	• Food distribution programmes during pregnancy • Kangaroo mother care for term newborn babies
Emerging evidence	• Probiotics for preterm and low birthweight newborns • Emollient use (ie, coconut oil) for preterm and low birthweight newborns

Figure 2: **Recommended evidence-based interventions to address malnutrition, according to strength of evidence**

*Indirect health sector nutritional interventions. †Direct nutritional interventions outside of the health-care sector. ‡Indirect nutritional interventions outside of the health-care sector. All other points are direct health sector nutritional interventions.

Conclusion

Our overall interpretation of the effects remained consistent for most interventions and outcomes examined, and most of the ten *Lancet* priority interventions recommended in 2013 remain valid. These ten recommended interventions—previously nutrition-specific—are now considered direct health and nutrition-sector strategies, with the exception of salt iodisation, which is delivered outside the health-care system and requires coordinated action by the agricultural sector, private producers, consumers, and the local government. Regardless, countries will require a multisectoral action plan for nutrition to engage and align stakeholders on how to reach global nutrition targets with the inclusion of indirect non-health-care sector interventions, such as education, water, sanitation, and hygiene, and women's empowerment.

Finally, we did not discuss sustainable food systems and the role of the food environment in our Review. These are important issues and have been considered in detail by other groups.[100] However, we do concur that, in the final analysis, all nutritional interventions need to take into context the role of the environment, climate change, and sustainable agriculture, and we trust that this review of the evidence will reinforce actions to make maternal and child undernutrition history.

Contributors

ZAB, in consultation with REB, conceptualised the paper. JKD, ECK, RAS, ZSL, and AI did the set of new systematic reviews. ECK and JKD, with inputs from ZAB and REB, created the tables and drafted the various sections of the paper. All authors reviewed successive drafts and provided input.

Declaration of interests

ZAB reports grants from The Bill & Melinda Gates Foundation, during the conduct of the study, and is a member of the Independent Expert Group for Nutrition and the Larsson Rosenquist Foundation Advisory Board for the promotion of breastfeeding. ECK reports grants from the Gates Foundation, during the conduct of the study. All other authors declare no competing interests.

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