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The effects of antenatal interventions on gestational weight gain in low and middle-income countries: a systematic review

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ABSTRACT

Background Gestational weight gain (GWG) during pregnancy is a critical factor that affects maternal and child health outcomes. The considerable burden of inadequate GWG and the rising tide of excessive GWG are overlooked challenges in low and middle-income countries (LMICs).

Methods This systematic review assessed the impact of antenatal interventions on GWG in LMICs. Randomised controlled trials (RCTs) on antenatal interventions on GWG in LMICs were included. These interventions included educational, behavioural, nutritional supplementation and pharmacological therapies. A systematic literature search was conducted using PubMed, Embase, Web of Science, CINAHL and the Cochrane Library from the start of each database through September 2025.

Results Out of the 33 642 unique articles identified, 70 articles were included in our systematic review, with 59 individual RCTs and 11 cluster RCTs. Nutritional interventions (31 studies) included food and micronutrient supplementations. Micronutrient supplementation such as multiple micronutrient supplementations was found to reduce the risk of severely inadequate or inadequate GWG among pregnant women compared to iron only or iron and folic acid supplementation (Grading of Recommendations Assessment, Development and Evaluation [GRADE]: moderate certainty). Food supplementation showed mixed results, although most trials demonstrated higher mean GWG among undernourished pregnant women and a greater likelihood of achieving Institute of Medicine-recommended ranges (GRADE: moderate certainty). Behavioural (counselling/education) interventions (20 studies) were associated with significant reductions in excessive GWG among pregnant women with overweight or obesity and improved adequacy of GWG (GRADE: moderate certainty). Physical activity (seven studies) was found to reduce the risk of excessive GWG (GRADE: moderate certainty). Combined dietary and physical activity interventions (six studies) were found to reduce the risk of excessive GWG among pregnant women (GRADE: low certainty).

Conclusions Well-structured antenatal interventions, initiated before 20 weeks of gestation and continuing beyond this period, tailored to local cultural contexts and available resources, can effectively help pregnant women in LMICs in achieving optimal GWG.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Earlier interventions on gestational weight gain (GWG) were predominantly carried out in high-income countries, hence the existing evidence was mostly based on data from high-income countries.

WHAT THIS STUDY ADDS

⇒ Culturally tailored nutritional education and counselling, adapted from WHO and UNICEF recommendations, resulted in significantly higher GWG in the intervention group compared with the routine care group. Additionally, food-based interventions supplemented with micronutrients were effective in reducing the risk of inadequate GWG.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings of this study will guide policymakers in integrating evidence-based interventions into antenatal care programmes to improve maternal and child health outcomes. This includes nutritional, behavioural and educational strategies that are culturally and specifically tailored for low and middle-income countries.

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INTRODUCTION

Gestational weight gain (GWG), which refers to the weight gained during pregnancy, has profound impacts on maternal and child health outcomes.[1] GWG can be measured based on the total weight gained throughout the pregnancy or the rate of gain over a specific period, such as a week or a month.[2] It has been well-established that inadequate GWG is associated with adverse pregnancy outcomes, such as preterm birth, low birth weight, developmental issues, fetal and neonatal deaths,[1 3 4] while excessive weight gain is associated with preeclampsia, postpartum weight retention,

large-for-gestational age neonates, caesarean section deliveries and long-term obesity for both mother and child.[5 6]

A population-based study by Wang and colleagues identified that women in sub-Saharan Africa and the Middle East and North Africa had severely inadequate GWG, which met less than 60% of the minimum Institute of Medicine (IOM) GWG recommendation for normal-weight women.[4] Another study estimated that about 54% of women in low and middle-income countries (LMICs) have inadequate GWG, and approximately one-third (34%) experienced severely inadequate GWG.[7] In LMICs, despite the progress in healthcare access, women continue to face significant challenges and disparities related to healthcare access, food insecurity and low diet diversity, supply of micronutrient supplements and resources during pregnancy.[8] These disparities often result in suboptimal GWG, which can exacerbate the risk of adverse pregnancy outcomes and impact the long-term health outcomes of their children.[9 10] In contrast, women in high-income countries typically have greater access to nutrition counselling, healthcare access, micronutrient supplements and food insecurity, which is less prevalent.[11 12] Despite the growing interest in addressing excessive and inadequate GWG in LMICs, there is a noticeable gap in the literature regarding evidence-based interventions tailored to these contexts.[4]

Inadequate GWG and malnutrition before conception are frequently overlooked issues in many LMICs, particularly those in sub-Saharan Africa.[3] Recent research has indicated that inadequate GWG remains a significant public health concern in LMICs, with an emerging burden of excessive GWG also requiring attention. Various factors, including nutritional, behavioural and clinical elements, have been recognised as risk factors associated with inadequate GWG in these settings.[7] GWG is a modifiable risk factor that can be effectively monitored and managed through routine antenatal care interventions. It is, therefore, important to develop tailored interventions that consider the specific needs, resources and cultural practices of women in LMICs to effectively address GWG in these settings. While few studies in LMICs have implemented interventions specifically targeting GWG, several studies conducted in LMICs have found that the interventions increased GWG, typically as a secondary outcome.[13–17] The existing evidence is primarily based on data from high-income countries.[18] This underscores a significant research gap and a need for interventions specifically tailored for LMICs to improve maternal and fetal health outcomes related to GWG.

In this systematic review, we aimed to address this gap by analysing randomised controlled trials (RCTs) of interventions across multiple domains, including behavioural, educational, pharmacological therapies and nutritional interventions. We aimed to provide insights to inform the development of antenatal interventions aimed at reducing adverse pregnancy outcomes related to GWG in these settings.

METHODS

The methods for this systematic review were previously detailed in a protocol paper.[2] The eligibility criteria and the systematic search and synthesis strategies are briefly described below.

Registration and reporting

This work was registered with the International Prospective Register of Systematic Reviews (PROSPERO ID: CRD42022366354). The systematic review was reported following the Cochrane Handbook for Systematic Reviews of Interventions[19] and the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines.[20]

Information source

We conducted the literature search using PubMed, Embase, Web of Science, CINAHL and the Cochrane Library from the inception of each database through October 2025. We also reviewed references from previous systematic reviews on a similar topic to locate additional studies.

Search strategy

The search strategies for different databases were provided in online supplemental tables 9–13. The sensitivity of the search strategies was examined by confirming that several sentinel papers were identified. The initial search occurred on 7 October 2022. An updated systematic search was conducted on 13 September 2025, to capture additional studies published after the original search; 10 eligible studies were identified from this updated search and added to the synthesis.

Eligibility criteria

Inclusion criteria

The inclusion criteria for studies were as follows:

1. RCTs, which could be individually randomised, cluster randomised or involve a combination of both.
2. Participants were either pregnant at the time of enrolment or enrolled before pregnancy and followed throughout pregnancy.
3. Interventions provided to women either before or during pregnancy, including educational, behavioural, nutritional (food and micronutrient supplementations) or pharmacological therapies. This range is based on the IOM guidelines for the determinants of GWG.[2]
4. Interventions could be delivered alone or with a cointervention that was consistent across study arms.
5. At least one study arm did not receive the intervention being evaluated.
6. GWG was one of the study outcomes (primary or secondary outcomes) reported, measured by metrics such as total GWG, GWG Z-score, GWG adequacy ratio or weekly/monthly GWG rates. Only GWG outcomes based on body weights objectively measured by study teams were included.
7. Studies conducted in a low-income, lower middle-income or upper middle-income economy, as defined

by the World Bank's 2023 fiscal year country classification.[21] Multicountry studies involving both LMICs and high-income countries were included if they provided specific results for the LMICs.
8. No restrictions were placed on the year or sample size of the study.

Exclusion criteria

The exclusion criteria of the studies included:
1. Studies that did not include GWG as a study outcome or that relied on self-reported body weights or medical-record abstraction due to potential measurement error.
2. Non-randomised interventional studies, observational studies and other publications such as editorials, commentaries, opinion pieces and review papers.
3. Studies conducted exclusively among women with pre-existing health conditions (eg, anaemia, HIV infection, diabetes). However, studies restricted to women with underweight, overweight or obesity were included.
4. Studies published in languages other than English.

Data management

EndNote (V.20; Clarivate Analytics) was used to store the records retrieved from the databases. The records were then imported into Covidence (Veritas Health Innovation, Melbourne, Australia), which was used for study screening and data extraction.

Selection of studies

Titles and abstracts were independently screened by two reviewers (PAA, AV, LC, AA-K, MP, CHN and DW), with conflicts resolved through team discussions involving additional reviewers who were not part of the assigned team (PAA, AA-K, CHN and DW). Full texts of the remaining articles were retrieved and independently reviewed for inclusion by two reviewers, with conflicts resolved through discussions involving additional team reviewers (PAA, AA-K, CHN and DW).

Data extraction

Data extraction was conducted independently by two of the reviewers (PAA, AA-K and CHN). The data extracted included information on study reference, setting and country of the study population, calendar year of intervention, randomisation approach, sample size, sample characteristics, timing and duration of intervention, description of the intervention, control, primary and secondary study outcomes, approach to defining and measuring GWG and main findings (with point estimates and measures of variance). We extracted effect estimates for continuous outcomes as mean differences (with 95% CIs), and effect estimates for categorical outcomes as risk ratios, rate ratios, HRs or ORs (with 95% CIs), comparing the intervention group with the control group. We extracted results adjusted for potential confounders whenever available. Disagreements in the extracted information between reviewers were resolved by discussion or by a third reviewer (PAA, AA-K, CHN and DW).

Assessment of risk of bias

We assessed the risk of bias using version 2 of the Cochrane risk-of-bias tool (ROB-V.2).[22] For cluster-randomised trials, we used the ROB-2 tool for cluster-randomised studies.[23] These assessments were done using the tool across five domains: (1) bias arising from the randomisation process; (2) deviations from intended interventions; (3) missing outcome data; (4) measurement of the outcome and (5) selection of the reported result. Two reviewers independently assessed each study with disagreement resolved by a third reviewer. We summarised domain-level and overall risk as low risk, some concerns or high risk.

Data synthesis

We conducted a narrative synthesis of all included studies due to significant heterogeneity among the interventions and in how GWG was measured or defined in the identified studies. We conducted a narrative synthesis because the included studies varied substantially in design, populations and intervention types. Key study characteristics, description of interventions, study outcomes and main findings for studies and GWG effect estimates are summarised in online supplemental tables 1–8. We summarised the overall Risk of Bias (online supplemental figures 1 and 2) and GRADE assessments once per intervention type (online supplemental table 14).

Certainty of evidence

The certainty of evidence was assessed by using the GRADE approach via GRADEPro GDT.[24] The overall certainty of evidence was categorised as high certainty (further research is very unlikely to change our confidence in the estimated effect), moderate certainty (further research may change our confidence in the estimate or alter the estimate itself), low certainty (further research is likely to change the estimate and may have an important impact on confidence in the effect) and very low certainty (the true effect is likely to be substantially different from the estimate of effect). The GRADE summary of findings for each intervention is presented in online supplemental table 14.

Patient and public involvement

Patients and the public were not involved in this systematic review.

RESULTS

Study characteristics

We identified 33 642 unique articles from our search of five electronic databases, after removing duplicates. From this set of articles, 33 519 were found to be irrelevant and eliminated after reviewing their titles and abstracts. In the subsequent full-text assessment of the remaining 136

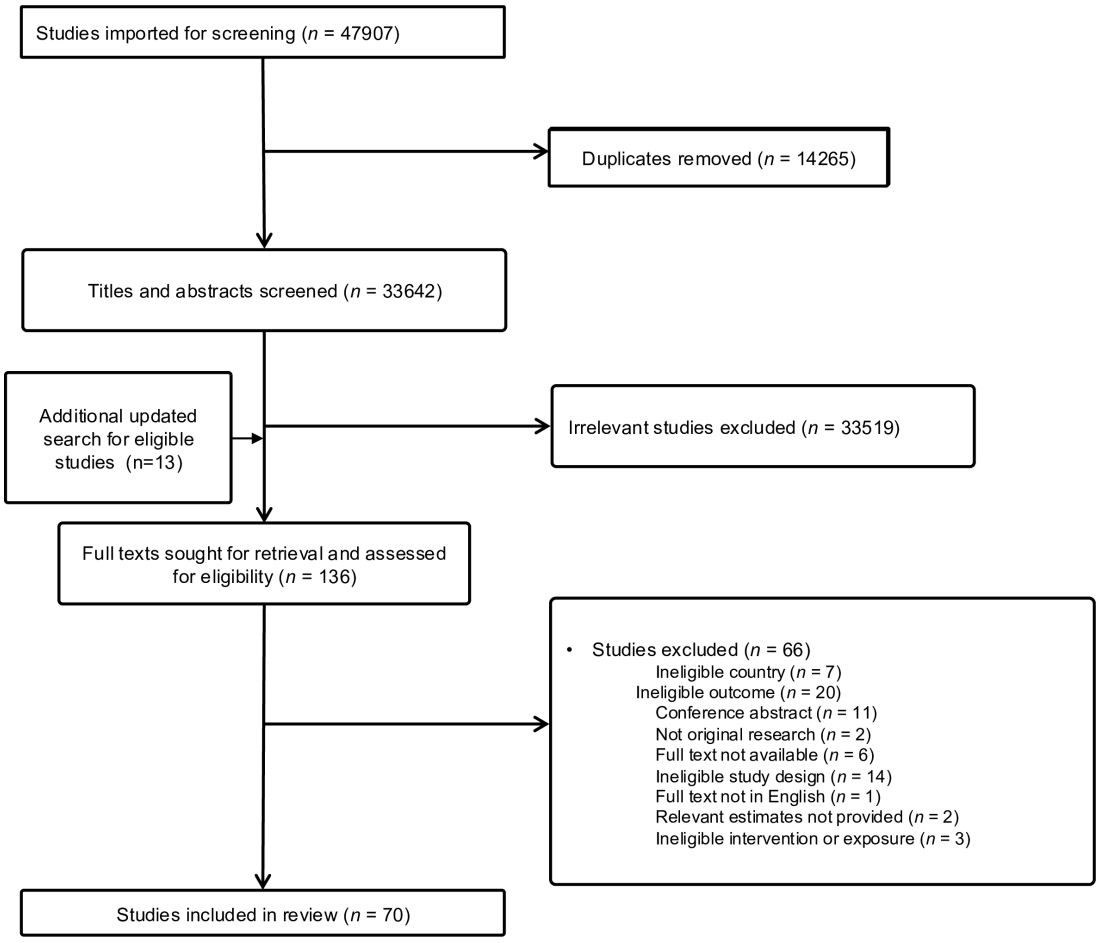


Figure 1 PRISMA flow diagram for the systematic review of the effects of antenatal interventions on GWG in LMICs. GWG, gestational weight gain; LMICs, low and middle-income countries; PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

articles, 66 did not meet the eligibility criteria, leaving 70 articles for data extraction (figure 1).

Of the 70 articles retained, 59 were studies based on RCTs with individual randomisation, and 11 were studies based on RCTs with cluster randomisation. Among the 59 studies based on RCTs with individual randomisation, 8 studies were conducted in Sub-Saharan Africa,[17 25–31] 6 studies in South Asia,[15 32–36] 23 studies in East Asia and Pacific,[16 37–58] 9 studies in Latin America and the Caribbean,[59–67] 10 studies in Middle East and North Africa,[14 68–76] 1 study in Europe and Central Asia[77] and 2 studies were multicountry studies spanning multiple world regions.[13 78] Among the 11 studies based on RCTs with cluster randomisation, 5 studies were conducted in Sub-Saharan Africa,[79–83] 4 studies in South Asia,[84–87] 1 study in East Asia and Pacific[88] and 1 study in Latin America and the Caribbean.[89] The basic characteristics of these studies are shown in online supplemental table 1.

Online supplemental tables 1–7 show the frequently studied interventions and the key findings of each study. These interventions include 16 studies on micronutrient supplementation, 17 on food supplementation, 20 on counselling/education, 7 studies on physical activity, 6 studies on a combination of exercise and diet and 4 on medication.

Outcome definitions

Online supplemental tables 2–7 summarise the definition of GWG for each identified study. In most studies, GWG was defined according to the IOM guidelines, which classify GWG recommendations based on prepregnancy BMI categories, which are underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²) and obesity (≥30.0 kg/m²).[90] However, some studies adopted alternative approaches to defining GWG. For example, several studies reported total GWG in kilograms without reference to specific guidelines. Online supplemental table 8 provides a summary of some of the key findings that were found in this review.

Food supplementation

Twenty-four studies examined the effects of food supplementation on GWG (online supplemental table 5). Food supplementation interventions in this review refer to interventions that provide energy and macronutrients regardless of whether they added micronutrients to the interventions. Studies on food supplementation during

pregnancy show mixed results. Several studies found no significant differences in GWG between groups. In a study in Indonesia, providing a high-energy supplement (465 kcal/day) in the last trimester had no meaningful effect on GWG compared with the low-energy supplement (52 kcal/day) with GWG remaining similar across groups (3.3 kg vs 3.1 kg). Another study reported no meaningful difference between pumpkin seed and placebo biscuits, with weight gain averaging 4.50 kg in the pumpkin seed group and 4.43 kg in the placebo group.[47] In Pakistan, among pregnant women at risk of malnutrition, wheat–soya blend plus supplementation showed no significant effect on the average weekly maternal weight gain at the end of the pregnancy (326.7 g/week, 95% CI 315.2 to 338.1, vs 306.9 g/week, 95% CI 279.9 to 333.9) between the intervention and control groups, respectively.[85] In India, sesame cake, jaggery and oil supplementation had no significant impact on maternal weight gain in the last trimester.[33] Similarly, in Vietnam, nutrient-rich food supplements starting either preconception or at mid-gestation had no effect on GWG. Adjusted mean differences were −0.1 kg for mid-gestation supplementation and −0.1 kg for preconception supplementation.[45]

In contrast, other studies showed a significant increase in GWG in the supplemented group. In Malawi,[26] moderately malnourished pregnant women in their second trimester received one of these three supplementation regimens until delivery; ready-to-use supplemental food (RUSF), corn soya blend plus (CSB+) with the United Nations International Multiple Micronutrient Antenatal Preparation (UNIMMAP), or CSB+ with iron-folic acid (the control group). RUSF provided the highest increased GWG during supplementation (3.4±2.6 kg), followed by CSB+ + iron and folic acid (IFA) (3.2±2.4 kg) and CSB+ + UNIMMAP (3.0±2.2 kg; p=0.03). Increased weight gain during pregnancy with biscuit supplementation in Gambia was reported to be significant among undernourished women.[83] One study in Guatemala, in an area of high prevalence of overweight and obesity,[89] observed that a food-assisted maternal and child health and nutrition programme had a significant impact on women's body weight, and the programme impacts of 0.50–0.65 kg were found to be significant (p<0.05). An RCT in Iran noted significantly higher average weight gain in the supplemented group that received 1500 kcal/day worth of food compared with the control group, with lower rates of poor maternal weight gain in the supplemented group at various stages of pregnancy.[75] Similarly, it was found that in Thailand, supplemented groups had significantly higher rates of weight gain compared with the control group during the third trimester.[48]

A study in the rural areas of Asia, North America and Sub-Saharan Africa[13] noted that women who received lipid-based nutrient supplements (LNS) from 3 months before conception until delivery gained significantly more weight than those who started supplementation in the second or third trimesters or those who did not receive any supplementation.

Two studies[30 40] investigated the impact of a combination of micronutrients and food supplementation on GWG. In South Africa, Zulu women received either a placebo, zinc gluconate or daily food supplements designed to raise their energy, protein and vitamin intakes to levels either in high or low bulk. However, after the intervention, GWG was similar across all groups. Zinc, high bulk, low bulk and placebo supplementation had average GWG of 7.2±2.6 kg, 8.3±4.0 kg, 8.1±3.7 kg and 8.8±3.8 kg, respectively.[30] In rural Vietnam, moderately underweight pregnant women receiving either fortified milk (enriched with iron) or non-fortified milk had similar GWG (5.0±2.0 vs. 5.8±2.1 kg). However, both milk groups gained significantly more weight than women who received 60 mg iron tablets (4.6±3.1 kg; p<0.05) or placebo (3.8±2.5 kg; p<0.001).[40] Overall, the food supplementation trials demonstrated some concerns for risk of bias, with the primary limitation arising from lack of blinding and the certainty of evidence for a combined food supplementation was rated as moderate (online supplemental table 14).

Micronutrient supplementation

Nine studies[14 17 27 66 69 70 78 79 84] examined the effects of micronutrient supplementation on GWG (online supplemental table 6). Several studies conducted in Pakistan and Tanzania reported increased GWG during pregnancy among undernourished women who had multiple micronutrient supplementation (MMS)[17 27 84] compared with undernourished women who received IFA supplementation.[84] In Iran, overweight women who had MMS had less GWG compared with overweight pregnant women who received multivitamin supplements (weight at baseline: 66.7±10.6 vs 64.3±10.8 kg, p=0.26); weight at week 28 of gestation: 67.5±11.4 vs 71.6±10.3 kg, p=0.06).[69] Another study in Iran found that women who received daily intake of 2000 mg myo-inositol plus 400 µg folic acid from 14 to 24 gestational weeks had less inappropriate GWG compared with women who took 400 µg folic acid (40.8% vs 75.9%, (p=0.038)).[70] In studies conducted in Gambia,[79] South Africa, Zimbabwe and Argentina,[78] the GWG of pregnant women who received calcium supplementation was no different from that of those who received routine care.

In an RCT in Iran, women assigned to receive a weekly dose of 50 000 IU of vitamin D3 gained more weight during pregnancy compared with those assigned in the control group who received a daily multivitamin containing 400 IU of vitamin D3 and 200 mg of elemental calcium (13.3±2.4 kg vs 11.7±2.7 kg; p=0.006), and this was inversely correlated with maternal BMI at enrolment.[14] The overall certainty of evidence for micronutrient supplementation was rated as moderate, and the overall risk of bias was low (online supplemental table 14).

Counselling/education

Twenty studies examined the impact of counselling and education on GWG (online supplemental table 2),

including nutritional education, personalised materials, one-on-one and group counselling and lifestyle interventions. Nutritional education and counselling were the most used intervention across studies. Comprehensive nutrition education delivered by experienced health education and nutrition experts that included information on the nutritional value of food and cooking practices[15 32 57 73 80 81] was shown to significantly increase GWG among undernourished pregnant women.

In two studies in Bangladesh, one[15] reported that culturally tailored nutrition education based on the UNICEF nutrition-triangle principles significantly increased GWG during the third trimester. Women in the intervention group gained 8.60 kg compared with 5.38 kg in the routine-care group (p=0.011), representing a 60% higher weight gain. Another study among urban poor pregnant women[32] found that women who were assigned to nutritional counselling during the third trimester had increased GWG (5.61 vs 3.88 kg, p<0.001) compared with women who received routine advice. Similarly, in Ethiopia, undernourished pregnant women who received intensive WHO-based education and counselling at the end of the intervention, the adjusted mean difference in maternal GWG between the intervention and control groups was 10.08 kg (95% CI 9.55 to 10.60).[80] In China, women with overweight or obesity were instructed to begin a low-glycaemic index diet at or before 16 weeks' gestation, as the intervention was designed to reduce early pregnancy insulin resistance. This dietary approach resulted in less GWG compared with standard care (9.6 (7.4) kg vs 11.2 (6.3) kg, p=0.02).[52]

Some interventions were shown to reduce excessive GWG among pregnant women with overweight and obesity.[67 76] In Brazil, counselling to increase minimally processed food intake and physical activity lowered the odds of excessive GWG by 44% compared with controls (OR 0.56; 95% CI 0.32 to 0.98).[67]

Many interventions emphasised modifying maternal lifestyle behaviours, aiming to promote self-management skills, support healthier eating patterns and increase physical activity during pregnancy.[16 51 53 55 56 72 74 77 82 87] In China, an online–offline continuous group care intervention delivered through structured antenatal group sessions and ongoing WeChat-based support helped women maintain GWG within IOM recommendations, with significantly lower mean weight gain (13.40±3.30 kg) and a reduced rate of excessive GWG (16.7%) compared with women receiving routine care (15.10±4.50 kg; 38.9%; p=0.01 and p=0.003, respectively).[55] In Nepal, strengthening Female Community Health Volunteers through training, supervision and monitoring, combined with regular mobile text messages to undernourished pregnant women about antenatal care and nutrition, increased their total GWG by 6.9 kg (95% CI 6.2 to 7.7) compared with controls 5.8 kg (95% CI 5.2 to 5.9).[87]

Routine care plus group counselling showed no significant GWG differences between the intervention and control groups.[74] In Iran, an early-pregnancy educational intervention with and without spouse participation significantly reduced GWG compared with routine care, with mean GWG of 13.50±3.85 kg and 13.55±3.20 kg in the two intervention groups versus 15.53±4.20 kg in controls (p=0.024). The proportion achieving IOM-recommended GWG was also higher in the intervention groups (69% and 61.9%) than in the control group (37.5%).[73] Overall, the counselling educational interventions were rated low for risk of bias, and the overall certainty of evidence was rated as moderate (online supplemental table 14).

Physical activity

Seven studies (online supplemental table 7) examined physical activity's impact on GWG, including water aerobics, vigorous exercise, exercise training programmes and supervised cycling. Most showed no significant effect on GWG. However, in Argentina, a supervised aquatic exercise programme performed three times per week, 55–60 min per session, at light-to-moderate intensity (Borg rating, 10–14) from 10 to 12 to 38–39 weeks' gestation significantly reduced excessive GWG compared with standard care (24.5% vs 45.2%; OR 0.39, 95% CI 0.17 to 0.89; p=0.02),[59] highlighting its potential to reduce the risk of excessive GWG among pregnant women.

In Brazil, a supervised antenatal exercise programme consisting of weekly 40 min light-to-moderate physical activity sessions (≤140 bpm; 10 min stretching, 22 min strengthening and 10 min relaxation), combined with home exercises five times per week, resulted in significantly lower total GWG among women with overweight compared with controls (10.0±1.7 kg vs 16.4±3.9 kg; p=0.001).[64] In India, a home-based antenatal exercise programme consisting of an initial 1 hour supervised session followed by unsupervised aerobic, stretching, muscle-strengthening and flexibility exercises performed at light-to-moderate intensity (Borg 12–14) at least four times per week, together with 30 min of walking on most days, resulted in slightly lower GWG compared with routine care among women with (11.95±5.68 kg vs 12.8±4.69 kg; p=0.609).[35] In Colombia, pregnant women assigned to vigorous exercise 60 min supervised sessions three times per week from 16 to 20 to 32–36 weeks' gestation, performed at 55%–75% of maximum heart rate and including walking, 30 min of aerobic training, stretching and relaxation did not differ from controls in GWG (mean gain 10.3±5.0 kg vs 11.5±7.4 kg, p=0.543).[65]

Distinct from these findings, in China, participants engaged in a supervised cycling programme three times per week, each session lasting at least 30 min, beginning within 3 days of randomisation and continuing until 27 weeks' gestation. By 25 weeks, women in the intervention group had significantly lower GWG than controls (11.0±3.0 kg vs 12.3±3.6 kg; p<0.05), but this effect was not sustained later in pregnancy, with no significant differences observed between 25 and 36 weeks (14.7±3.7 kg vs 15.3±4.1 kg; p=0.41).[50]

Two studies conducted in Brazil found no significant impact of exercise interventions on GWG. One study

concluded that a structured exercise intervention three times per week for 16 weeks did not significantly impact GWG among pregnant women, as there were no meaningful differences in mean GWG between groups.[61] Overall, the physical activity demonstrated some concerns for risk of bias, with the primary limitation arising from lack of blinding, and the overall certainty of the evidence was rated as low (online supplemental table 14).

Combination of exercise and diet

Six studies[16 34 36–38 43] examined the effects of exercise and diet on GWG (online supplemental table 3). In China, a WeChat-based dietary (energy-controlled diet based on BMI and macronutrient targets like 50%–60% carbohydrate and less than 30% fat) and exercise programme (walk at least 6000 steps per day), which included three face-to-face counselling sessions plus ongoing monitoring and guidance via the app. Compared with routine advice alone, women in the intervention group gained significantly less total GWG (11.2±4.9 kg vs 13.4±5.0 kg; p=0.002) and had lower GWG by 25 weeks (4.9±3.1 kg vs 6.9±3.2 kg; p<0.001). Excessive GWG was also reduced in the intervention group (47.1% vs 64.0%; p=0.013).[38] In China, a combined diet (such as dietary management guidance)-and-exercise intervention (such as guidance on healthy exercise habits), delivered through three structured counselling sessions, three follow-up phone calls and a moderate-intensity antenatal exercise plan performed for at least 30 min three times per week starting at 20 weeks of gestation, significantly reduced total GWG (17.57±3.28 kg vs 19.09±3.43 kg; p=0.045) and weekly weight gain (0.50 kg vs 0.67 kg; p=0.008) compared with routine care.[43] Several studies in Asia found that exercise groups gained less weight[16 34 36] and had fewer women gaining above the recommended GWG, suggesting the effectiveness of supervised exercise in preventing excessive GWG. Although these findings indicate a consistent positive effect of diet and exercise interventions on GWG, the overall certainty of evidence for combined exercise and diet interventions was rated as low, and the overall risk of bias is moderate (online supplemental table 14).

Pharmacological therapies

Four studies explored the effects of different medications and treatments on GWG during pregnancy (online supplemental table 4). In Iran, pregnant women with overweight initiated metformin (1000 mg/day from 12 to 16 weeks' gestation) to reduce insulin resistance. The intervention significantly lowered total GWG compared with placebo (7.6±2.3 kg vs 10.2±3.3 kg; p<0.001) and reduced the risk of excessive weight gain (OR 0.15; 95% CI 0.07 to 0.31).[71] However, in Brazil, women with obesity initiated metformin (1000 mg/day) combined with walking (150 min/week) at 20 weeks' gestation to improve insulin sensitivity. Although the metformin group gained less weight than controls from 20 to 35 weeks (2.7 kg vs 4.8 kg, p=0.60).[62] Additionally, in Papua New Guinea, intermittent preventive treatment (IPT) with sulphadoxine-pyrimethamine (SP-1500/75 mg) plus azithromycin (AZ-4 g per course), started in the second trimester to prevent malaria and other maternal infections, increased GWG by 58 g/week (95% CI 26 to 90) and reduced risk of underweight compared with standard care.[49] Similar study in Malawi, IPT beginning in the second trimester to prevent malaria and reproductive tract infections involved monthly SP (1,500/75 mg) alone or combined with AZ (1 g). Women receiving SP plus AZ had higher GWG (453 g/week) than those receiving monthly SP alone (432 g/week) or standard care (428 g/week), corresponding to an adjusted increase of 25 g/week (95% CI 8 to 41), while SP alone produced a non-significant increase of 4 g/week (95% CI −13 to 20).[31] The overall certainty of the evidence for pharmacological therapies was rated as moderate (online supplemental table 14), and the overall risk of bias was low.

Risk of bias

Among the 59 RCTs with individual randomisation, 39 had a low risk of bias, 11 had some concerns and 10 had a high risk of bias (online supplemental figure 1). The primary domain of bias for this group of studies was bias due to deviations from the intended intervention, with eight studies having some concerns in this domain. Among the 11 RCTs with cluster randomisation, 8 had a low risk of bias, 2 had some concerns and 1 had a high risk of bias (online supplemental figure 2). The primary domain of bias for this group of studies was bias in the measurement of the outcome, with two studies having some concerns and one having a high risk in this domain. For instance, some assessors were not blinded to group allocation and in measuring of GWG.

DISCUSSION

In this systematic review, we investigated the potential impact of antenatal interventions on GWG. Nutritional interventions, particularly those involving multiple micronutrients and some food supplementations, reduce the risk of inadequate GWG. Behavioural interventions, including education or counselling, reduce the risk of inadequate and excessive GWG. Combining physical activity and dietary interventions appears to prevent excessive GWG, offering an integrative approach to supporting maternal health. Physical activity interventions, such as cycling, aerobic and resistance aquatic exercises, when initiated earlier during pregnancy may also reduce the risk of excessive GWG.

Our findings on micronutrient supplementation revealed that women who received MMS experienced increased GWG and were less likely to have severely inadequate or inadequate GWG compared with those who received IFA supplements.[17 84] Across specific interventions, calcium-containing multivitamins and vitamin D enhanced supplementations had a lower risk of inadequate GWG compared with those who received standard care.[14] These findings were consistent with a recent

individual participant data meta-analysis of the effect of antenatal nutritional supplements on GWG, which reported that MMS reduced the risk of severely inadequate GWG and increased GWG per cent adequacy compared with IFA.[91] Administration of milk fortified (enriched with vitamin C and folic acid) was effective in reducing the risk of inadequate GWG among pregnant women who were underweight than those who had IFA.[40] Similarly, evidence[92 93] suggests that MMS reduces the risk of inadequate GWG compared with iron and folic supplements alone. This finding can inform policy decisions and support public health initiatives that advocate for more comprehensive supplementation programmes, particularly in areas where inadequate GWG is common. The overall certainty of the evidence for MMS interventions was moderate.

We found mixed evidence regarding the effects of food supplementation during pregnancy on GWG. More than half of these studies found that their interventions reduced the risk of inadequate GWG.[26 39 46–48 63 75 83 89] Food supplementations provided to the pregnant women for most of these interventions were made from locally available ingredients such as rice, oil, sugar, flour, shrimp and legumes (mainly soybeans, peanuts, beans and lentils). Some were made in the form of biscuits, while others included additional micronutrients.[26 46 63 89] The number of calories consumed per day from these supplementations ranged from 155 kcal to 4250 kcal. Our results indicate that using locally available ingredients for food supplementation interventions can make nutritional support more sustainable, affordable and acceptable to pregnant women in low-resource settings. The overall certainty of the evidence for food supplementation interventions was moderate.

Physical activity initiated before 20 weeks of gestation and lasting beyond 20 weeks may be more effective in preventing the risk of excessive GWG, and these findings were similar to a recent review that included mostly high-income countries.[94] Notably, less common activities, such as cycling from 10 weeks' gestation for at least 30 min, three times weekly over 27 weeks, significantly reduced the risk of excessive GWG in women with overweight or obesity.[50] Several reviews have similar findings that physical activity reduces the risk of excessive GWG in pregnant women.[95–97] These findings highlight the need for early and sustained exercise during pregnancy. Policy decisions and campaigns should focus on educating pregnant women about the benefits of incorporating regular exercise from the first trimester to maximise the prevention of excessive GWG, particularly for women with overweight or obesity. The overall certainty of the evidence for physical activity interventions was moderate.

Antenatal education and counselling help maintain optimal GWG. Studies from Asia, South America and Sub-Saharan Africa show that nutrition education reduces the risk of both inadequate[15 32 77 80 87] and excessive GWG,[67 73] consistent with a systematic review of meta-analyses.[98] Overall, mothers who were provided with these interventions had a lower risk of inappropriate GWG compared with the control groups. Policymakers should develop culturally tailored antenatal education and nutrition-focused counselling interventions that align with WHO guidelines and are delivered by trained professionals to improve maternal and infant health outcomes. The overall certainty of the evidence for education/counselling interventions was moderate.

Combining diet and physical activity effectively prevents excessive GWG. Studies from China and India show that interventions such as personalised dietary care, dietary guidelines, supervised antenatal exercises and text message reminders on healthy eating can reduce the risk of excessive GWG.[16 34 36 38 43] Similar findings from systematic reviews[18 99 100] confirm the effectiveness of such combined strategies. Interventions including hospital-based weekly antenatal exercise programmes, use of messaging apps to regular text reminders promoting healthy eating choices during pregnancy and tailored nutritional guidance have been found to be effective in helping pregnant women attain optimal GWG. Policymakers can integrate these evidence-based approaches into antenatal care to improve maternal and child health outcomes. The overall certainty of the evidence for combined exercise and diet interventions was low.

The strengths of this systematic review included the comprehensive coverage of all intervention types and the inclusion of diverse geographical regions and contexts. This diverse range of studies from different regions and cultural contexts enhances the generalisability of the findings. It examined various interventions, including physical activity, behavioural interventions, educational interventions, pharmacological therapies and nutritional supplementation. This comprehensive approach provides a holistic understanding of how various interventions during antenatal impact GWG. This systematic review had some limitations. Most RCTs did not report on the cost-effectiveness of the interventions, hence this review lacked synthesis of cost-effectiveness. Understanding the economic feasibility of implementing these interventions in resource-constrained settings is important for policymaking and practical application. Additionally, restricting the review to English-language studies may have led to an incomplete representation of the available evidence.

In conclusion, our findings highlighted the multifaceted nature of GWG management. While physical activity interventions like cycling, aquatic exercises and aerobic activities showed effectiveness in reducing excessive GWG, their impact was further improved when combined with dietary modifications. Nutritional interventions, such as micronutrient supplementation and dietary counselling, also emerged as important components of GWG management. Future research should examine the cost-effectiveness of these interventions in LMIC settings and investigate the long-term impact of GWG management on maternal and child health outcomes. Tailored interventions combining physical activity, dietary modifications

and health behavioural changes are likely to be most effective in achieving optimal pregnancy outcomes.

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