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Key Components of Antenatal Lifestyle Interventions to Optimize Gestational Weight Gain
Secondary Analysis of a Systematic Review

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Abstract

IMPORTANCE Randomized clinical trials have found that antenatal lifestyle interventions optimize gestational weight gain (GWG) and pregnancy outcomes. However, key components of successful interventions for implementation have not been systematically identified.

OBJECTIVE To evaluate intervention components using the Template for Intervention Description and Replication (TIDieR) framework to inform implementation of antenatal lifestyle interventions in routine antenatal care.

DATA SOURCES Included studies were drawn from a recently published systematic review on the efficacy of antenatal lifestyle interventions for optimizing GWG. The Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Health Technology Assessment Database, MEDLINE, and Embase were searched from January 1990 to May 2020.

STUDY SELECTION Randomized clinical trials examining efficacy of antenatal lifestyle interventions in optimizing GWG were included.

DATA EXTRACTION AND SYNTHESIS Random effects meta-analyses were used to evaluate the association of intervention characteristics with efficacy of antenatal lifestyle interventions in optimizing GWG. The results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses reporting guideline. Data extraction was performed by 2 independent reviewers.

MAIN OUTCOMES AND MEASURES The main outcome was mean GWG. Measures included characteristics of antenatal lifestyle interventions comprising domains related to theoretical framework, material, procedure, facilitator (allied health staff, medical staff, or researcher), delivery format (individual or group), mode, location, gestational age at commencement (<20 wk or ≥20 wk), number of sessions (low [1-5 sessions], moderate [6-20 sessions], and high [≥21 sessions]), duration (low [1-12 wk], moderate [13-20 wk], and high [≥21 wk]), tailoring, attrition, and adherence. For all mean differences (MDs), the reference group was the control group (ie, usual care).

RESULTS Overall, 99 studies with 34 546 pregnant individuals were included with differential effective intervention components found according to intervention type. Broadly, interventions delivered by an allied health professional were associated with a greater decrease in GWG compared with those delivered by other facilitators (MD, −1.36 kg; 95% CI, −1.71 to −1.02 kg; *P* < .001). Compared with corresponding subgroups, dietary interventions with an individual delivery format

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Key Points

Question What are the efficacious components of antenatal lifestyle interventions to inform implementation in antenatal care settings?

Findings In this meta-analysis of 99 randomized clinical trials of antenatal lifestyle interventions among 34 546 pregnant individuals, intervention delivery by an allied health professional was associated with optimized gestational weight gain (GWG). Among dietary interventions, previously found to be associated with a greater decrease in GWG, those with individual delivery format and moderate intensity were associated with the greatest decrease in GWG, while physical activity and mixed behavioral interventions may benefit with earlier commencement and a longer duration for effective associations with decreased GWG.

Meaning These findings provide insight to characteristics of efficacious interventions, as well as those that may be considered adaptable according to contextual needs and available resources.

+ Supplemental content

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Abstract (continued)

(MD, −3.91 kg; 95% CI −5.82 to −2.01 kg; P = .002) and moderate number of sessions (MD, −4.35 kg; 95% CI −5.80 to −2.89 kg; P < .001) were associated with the greatest decrease in GWG. Physical activity and mixed behavioral interventions had attenuated associations with GWG. These interventions may benefit from an earlier commencement and a longer duration for more effective optimization of GWG.

CONCLUSIONS AND RELEVANCE These findings suggest that pragmatic research may be needed to test and evaluate effective intervention components to inform implementation of interventions in routine antenatal care for broad public health benefit.

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Introduction

Accelerated weight gain before, during, and after pregnancy is prevalent, with approximately 70% of female adults in the US[1] experiencing overweight or obesity. Pregnancy presents a critical risk, with half of all pregnant individuals exceeding recommendations for gestational weight gain (GWG),[2] with associated increased adverse risk of maternal and neonatal sequale,[3] including obesity development.[4] Therefore, optimizing GWG during pregnancy with lifestyle intervention has been advocated as a public health strategy to reduce maternal weight accretion, as emphasized by the US Preventive Services Task Force.[5] In our review[6] of 117 randomized clinical trials (RCTs), antenatal lifestyle intervention was associated with decreased GWG and reduced risk of gestational diabetes and total adverse maternal outcomes compared with routine care. Differential effects were noted by intervention type, with dietary intervention associated with the greatest benefits for optimizing GWG compared with physical activity, diet with physical activity, or mixed interventions overall. With demonstrated cost-effectiveness,[7,8] pragmatic implementation of effective interventions in routine care remains a vital next step to leverage investment in the evidence generated to date.[9] However, in the context of highly heterogeneous intervention design, limited guidance exists on what interventions should be implemented and how, curtailing effective translation into antenatal care settings.[10]

Frameworks to guide implementation of programs and interventions into practice, such as the Consolidated Framework Implementation Research (CFIR), emphasize the identification of core intervention characteristics as part of this process. Alongside the intervention to be implemented, the CFIR comprises 5 domains, including the outer setting (ie, policy, guidelines, and population needs), inner setting (ie, organizational structure, culture, and readiness to change), individuals who influence implementation, and iterative processes, including executing and evaluating implementation activities.[11] The framework proposes that an intervention retains core, or essential, characteristics that are fundamental to intervention efficacy and peripheral, or adaptable, characteristics informed by inner and outer settings and individuals within the intervention setting.[11] This presents a pragmatic approach in defining what intervention components are essential for efficacy compared with those that can be adapted to best meet the context, health system, resource setting, and population needs during implementation design.[11]

To date, published systematic reviews in the field are limited in providing understanding of effective components beyond classification of intervention type (eg, diet, physical activity, mixed, or behavioral). Consequently, implementation research remains stalled without detailed knowledge of optimal components that comprise an intervention, including but not limited to delivery mode, format, intensity, facilitator type, and training.[12,13] In a secondary analysis of our 2022 systematic review reporting on the associations of lifestyle interventions with efficacy in optimizing GWG,[6] this meta-analysis aims to elucidate and describe components of antenatal lifestyle interventions that are associated with optimized GWG within published RCTs, providing critical and pragmatic information for implementation of trials in antenatal care settings.

Methods

Search Strategy and Study Selection

This meta-analysis and the original systematic review and meta-analysis[6] were reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting guideline. This is a secondary analysis of a recent systematic review and meta-analysis[6] to expand on the association of intervention components with optimization of GWG according to the Template for Intervention Description and Replication (TIDieR) framework.[14] The TIDieR framework is an extension of the Consolidated Standards of Reporting Trials (CONSORT) and SPIRIT reporting templates and is designed to enhance replicability of interventions by including domains of what (eg, resources, materials, and procedure), who (eg, the facilitator), how (eg, the delivery format), where (eg, the setting), when (eg, intervention commencement), and how much (eg, frequency and intensity), along with tailoring and factors associated with fidelity.[14]

Systematic review methods have been reported in detail elsewhere.[6,15-17] In brief, we searched the Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Health Technology Assessment Database, MEDLINE, and Embase up to May 6, 2020, with no language restrictions. Eligible studies were identified as RCTs of antenatal diet, physical activity, or mixed interventions in pregnant individuals that reported mean GWG per group. Studies were ineligible if they recruited individuals with multiple pregnancies or preexisting conditions (eg, gestational diabetes); involved non–lifestyle interventions (ie, GWG monitoring only), or were published prior to 1990. Eligibility of the studies was assessed by 2 reviewers (including M.B.K.) independently, and discrepancies were resolved by a third reviewer (H.J.T.).

Data Extraction

Data extraction on general study characteristics (eg, author, year of publication, country, sample size, mean body mass index [BMI; calculated as weight in kilograms divided by height in meters squared] for total included population, and mean [SD] of GWG per group) was performed by 2 reviewers (including M.B.K.). Countries where interventions were conducted were classified according to United Nations definitions.[18] Details of intervention classification were reported previously.[6] In brief, diet interventions were classified as those using specified dietary targets (self-directed or facilitator led [researcher, instructor, trainer, or dietitian]) with or without monitoring (logs, recalls, or diaries) and with or without supply of food. Physical activity interventions were classified as those conducted in controlled conditions (research facility, gym, or classes) or a minority that were structured but self-led (activity targets and equipment provided). Diet with physical activity required at least 1 structured component, and mixed interventions were classified as those not meeting the listed criteria for structured interventions and that instead included a combination of lifestyle advice, with or without weight monitoring, those that included behavioral strategies alone, or those in which structured diet and physical activity components were not adequately described.[6]

Descriptions of intervention characteristics according to the TIDieR framework[14] are presented in **Table 1**. Characteristics included the theoretical framework underpinning the intervention, resources provided to the intervention group (eg, pamphlets, manual, handouts, and GWG charts), intervention facilitators (eg, allied health professional, medical staff, or researcher), intervention training provided to the facilitator delivering the intervention, mode (eg, face to face or remote) and format (eg, group or individual) of intervention delivery, setting of intervention delivery (eg, clinical setting or exercise facility), number (low [1-5 sessions], moderate [6-20 sessions], or high [≥21 sessions]) and duration of delivered sessions, gestational age at commencement (<20 wk or ≥20 wk) and completion of interventions, intervention duration in weeks (low [1-12 wk], moderate [13-20 wk], and high [≥21 wk]), tailoring applied to the intervention (eg, personalized to participant), and intervention adherence and attrition.

Table 1. Description of Intervention Characteristics According to the TIDieR Framework

TIDieR checklist item	Description	Variable adapted from TIDieR checklist
Why (rationale/theory)	Rationale, theory, or goal of elements essential to the intervention	Behavioral theory: must state a behavioral change theory or approach used to support design or delivery of the intervention. Examples could include social cognitive theory and motivational interviewing • Yes • No or not reported
What (materials)	Physical or informational materials used in the intervention	Resources provided to participants: • Self-monitoring tool: GWG charts and self-monitoring tools (pedometers and exercise diary) • Other resource, including written or electronic brochure, handbook, manual, article link, or website • Combination: self-monitoring tool with other resource • None
What (procedure)	Procedures, activities, or processes used in the intervention	Type of intervention: • Diet • Physical activity • Diet and physical activity • Mixed
Who provided	Intervention facilitator and their expertise, background, and any specific training given	Intervention facilitator: • Allied health staff: defined as nonmedical health trained staff, including physiotherapist; exercise physiologist, scientist, or trainer; gym, aerobics, or fitness instructor; kinesiologist; dietitian; food technologist; nutritionist; and community health worker • Medical staff: medical or nursing trained facilitator, including obstetrician, gynecologist, clinician, doctor, midwife, and nurse • Other: category not fitting allied health staff or medical staff, including researcher, health coach, peer facilitator, and not reported • eHealth: coded as not applicable given that facilitator not provided Prior training: Was intervention-specific training received prior to delivering the intervention? (This does not refer to the educational or professional background of this person.) • Yes • No or not reported
How	Modes of delivery (face to face or remote) of the intervention and whether provided individually or in a group	Mode of intervention delivery: • Face to face • Remote • Face to face and remote Intervention format: Where there was a combination of individual and group delivery, the format that most sessions were delivered by was considered • Individual session • Group session
Where	Physical location where the intervention was carried out. Note: this is independent of where recruitment took place, with most trials recruiting from antenatal care clinics	Location: • Exercise center • Hospital or antenatal clinic • Other: not exercise center, hospital, or antenatal clinic, including home-based session and research center
When and how much	• No. of planned intervention sessions delivered to the participant, not inclusive of ongoing or optional support or provision of resources • The week when the first session was delivered • Length of sessions in minutes • No. of weeks between first and last weeks of intervention delivery	No. sessions: • Low: 1-5 • Moderate: 6-20 • High: ≥21 Gestational age at commencement, w • Early pregnancy: <20 • Late pregnancy: ≥20 Length of sessions, min: Where a range was reported, the lower limit was considered (as the length of session provided to all participants for sure). Where different lengths were reported for each format or method type, the mean was considered • Low: 1-30 • Moderate: 31-60 • High: ≥61 • Not reported Intervention duration, wk • Low: 1-12 • Moderate: 13-20 • High: ≥21 • Not able to calculate: first or last week of intervention delivery was not reported
Tailoring	If the intervention was planned to be personalized, titrated, or adapted, then describe what, why, when, and how	Tailoring: Was the intervention planned to be personalized or adapted for the participant? • Yes • No or not reported
How well actual	Participant attrition and adherence. Attrition: dropout rate of the intervention reported at conclusion of the study excluding medical indications. Adherence: adherence to the delivery of the intervention in relation to attendance of sessions. This will be entered as a numerical character sourced from the referenced research study and expressed as a % value	Attrition, % • Low: <15 • High: ≥15 • Not reported Compliance, % • Low: <75 • High: ≥75 • Not reported

(continued)

Table 1. Description of Intervention Characteristics According to the TIDieR Framework (continued)

TIDieR checklist item	Description	Variable adapted from TIDieR checklist
GWG	GWG as reported in the study	Intervention group: • GWG mean_i (kg): mean GWG in intervention group • GWG sd_i: GWG in intervention group: SD • total_i (n): No. participants in intervention group Control group: • GWG mean_c (kg): mean GWG in control group • GWG sd_c: GWG in control group - SD • total_c (n): No. participants in control group
Intervention vs control	Intervention vs control: was the GWG statistically significant as reported in the study?	Significant: GWG in intervention vs control comparison statistically significant as reported in study Not significant: GWG intervention vs control comparison not statistically significant as reported in study
Ongoing support	Direct support or contact provided independent to intervention sessions as part of the intervention	Direct ongoing support or contact provided independent to intervention sessions as part of the intervention. Examples include text message, email, telephone, and mail • Yes • No

Abbreviations: GWG, gestational weight gain; TIDieR, Template for Intervention Description and Replication.

Statistical Analysis

The primary outcome was mean difference (MD) with 95% CI of GWG using the intention-to-treat principle. We assessed the association of TIDieR components with efficacy of lifestyle interventions overall and by intervention type using subgroup random effects meta-analysis of effect statistics to calculate summary effect estimates and 95% CIs (applying DerSimonian and Laird random effects models using the metan Stata command[19]). For all MDs, the reference group was the control group (ie, usual care). Heterogeneity was assessed using the I^2 statistic, with I^2 > 50% indicating substantial heterogeneity.[20] To account for 15 multiple comparisons, which increase the risk of type I errors, we applied a Bonferroni correction and the statistical significance was set at a 2-sided $P < .003$. Given this more stringent significance level when making comparisons between the 15 Tidier factors examined, *P* values are reported as well as 95% CIs. Statistical analyses were conducted using Stata statistical software version 16 (StataCorp).

Results

Of 117 studies included in our systematic review,[6] 99 studies[21-119] reported GWG data and were included in this TIDieR meta-analysis (eFigure in Supplement 1),[6,120] with general characteristics of studies previously reported.[6] Of 34 546 pregnant individuals recruited, the mean (SD) baseline BMI ranged from 20.6 (2.5)[21] to 38.6 (6.1).[22] Most studies in this analysis were conducted in high-income countries (81 studies [81.8%]).[22-26, 32, 33, 35, 36, 38-58, 60, 62-64, 66, 67, 70-81, 83-86, 88-94, 96-111, 113, 115-119] As previously reported, lifestyle interventions were associated with an MD in GWG by 1.15 kg (95% CI, −1.40 to −0.91 kg) compared with control groups, with all intervention types found to be efficacious.[6]

Overall Intervention Characteristics and Association With GWG

Table 2 summarizes intervention characteristics according to the TIDieR framework,[21-119] and **Table 3** summarizes the association of intervention characteristics with efficacy in decreased GWG (see eTables 1-4 in Supplement 1 for subgroup analyses by intervention type). Overall, most interventions were delivered in a group format (51 studies [51.5%])[23-73] using a face-to-face delivery mode (84 studies [84.8%]),[21-47,49-53,55-63,65-107] with no distinguishable differences across formats or modes in GWG outcome. Most studies (67 studies [67.7%]) did not train intervention facilitators or did not report training.[22, 24-26, 28-32, 34-36, 38-40, 42-44, 46-51, 53, 55, 56, 58-60, 62, 65-67, 71-75, 78-81, 83-85, 88, 89, 91-94, 96-99, 101, 107-116] Efficacy in GWG outcomes differed significantly by intervention facilitator type ($P < .001$), with allied health staff being the most efficacious (MD, −1.36 kg; 95%CI, −1.71 to −1.02 kg)[22, 25-27, 30-33, 35-41, 43, 44, 46-49, 51, 53, 55, 56, 58, 60, 61, 63-67, 69, 70, 72-77, 80, 81, 83-85, 87-93, 97-99, 101-104, 108, 114, 116, 117] and no facilitator (ie, remote delivery) being nonefficacious (MD, −0.25 kg; 95% CI, −0.98 to

Table 2. Intervention Characteristics of Lifestyle Interventions in Pregnancy

Study	Country (No.) [mean BMI]	Intervention type; theory; resource	Intervention format; delivery mode	Intervention facilitator; location	Intervention duration, wk	No. sessions (min/session)	Tailoring; adherence
Kihlstrand et al,[23] 1999	Sweden (241) [NR]	Physical activity; NA theory; none	Group; face to face	Medical staff (trained); clinical setting	20	20 (60)	Not tailored; 0.552
Clapp et al,[24] 2000	US (46) [NA]	Physical activity; NA theory; none	Group; face to face	Others; clinical setting	32	96 (20)	Not tailored; 0.45
Marquez-Sterling et al,[25] 2000	US (15) [23.7]	Physical activity; NA theory; none	Group; face to face	Allied health staff; exercise center	15	45 (60)	Not tailored; NA
Blackwell et al,[26] 2002	US (46) [NA]	Diet; NA theory; none	Group; face to face	Allied health staff; clinical setting	24	3 (20)	Not tailored; NA
Briley et al,[74] 2002	US (20) [24]	Mixed; NA theory; other resources	Individual; face to face	Allied health staff; home-based session	9	6 (NA)	Tailored; NA
Polley et al,[108] 2002	US (110) [27.7]	Mixed; NA theory; combination	Individual; face to face and remote	Allied health staff; clinical setting	19	NA (NA)	Tailored; NA
Prevedel et al,[27] 2003	Brazil (39) [24.7]	Physical activity; NA theory; none	Group; face to face	Allied health staff (trained); exercise center	19	57 (60)	Not tailored; NA
Garshasbi et al,[28] 2005	Iran (266) [25.8]	Physical activity; NA theory; none	Group; face to face	Medical staff; clinical setting	12	36 (60)	Not tailored; 0.916
Khoury et al,[75] 2005	Norway (289) [24.3]	Diet; NA theory; other resources	Individual; face to face	Allied health staff; clinical setting	18	4 (NA)	Tailored; NA
Santos et al,[29] 2005	Brazil (90) [27.8]	Physical activity; NA theory; none	Group; face to face	Others; clinical setting	12	36 (60)	Not tailored; 0.4
Sedaghati et al,[30] 2007	Iran (90) [24.2]	Physical activity; NA theory; none	Group; face to face	Allied health staff; research center	8	24 (45)	Not tailored; NA
Baciuk et al,[31] 2008	Brazil (70) [NA]	Physical activity; NA theory; other resources	Group; face to face	Allied health staff; exercise center	21	60 (50)	Not tailored; NA
Barakat et al,[32] 2008	Spain (140) [23.8]	Physical activity; NA theory; none	Group; face to face	Allied health staff; antenatal clinic	26	78 (35)	Tailored; 0.90
Wolff et al,[76] 2008	Denmark (59) [34.9]	Diet; NA theory; none	Individual; face to face	Allied health staff; clinical setting	19	10 (60)	Tailored; 0.913
Asbee et al,[77] 2009	US (100) [26.1]	Diet with physical activity; NA theory; none	Individual; face to face	Allied health staff (trained); clinical setting	1	1 (NA)	Tailored; 0.614
Jeffries et al,[78] 2009	Australia (282) [25.7]	Mixed; NA theory; self-monitoring tool	Individual; face to face	Medical staff; clinical setting	22	2 (NA)	Not tailored; NA
Ong et al,[79] 2009	Australia (12) [36.0]	Physical activity; NA theory; other resources	Individual; face to face	Others; home-based session	10	30 (45)	Not tailored; 0.94
Thornton et al,[80] 2009	US (232) [37.8]	Diet; NA theory; self-monitoring tool	Individual; face to face	Allied health staff; clinical setting	12	NA (NA)	Not tailored; NA
Guelinckx et al,[33] 2010	Belgium (195) [33.6]	Mixed; theory based; other resources	Group; face to face	Allied health staff; clinical setting	17	3 (60)	Tailored; NA
Hopkins et al,[81] 2010	New Zealand (84) [25.5]	Physical activity; NA theory; combination	Individual; face to face	Allied health staff; home-based session	16	8 (40)	Tailored; 0.75
Khaledan et al,[34] 2010	Iran (39) [28.3]	Physical activity; NA theory; none	Group; face to face	Others; clinical setting	8	24 (30-45)	Not tailored; NA
Barakat et al,[35] 2011	Spain (67) [NA]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	29	85 (35-45)	Tailored; 0.90
Haakstad et al,[36] 2011	Norway (101) [25.3]	Physical activity; NA theory; self-monitoring tool	Group; face to face	Allied health staff; exercise center	12	24 (60)	Tailored; 0.71
Huang et al,[82] 2011	Taiwan (189) [21.0]	Mixed; NA theory; combination	Individual; face to face	Medical staff (trained); clinical setting	20	3 (30-40)	Tailored; NA
Jackson et al,[109] 2011	US (287) [27]	Mixed; theory based; other resources	Individual; remote	eHealth; clinical setting	4	NA (NA)	Tailored; NA
Nascimento et al,[37] 2011	Brazil (80) [36.9]	Physical activity; NA theory; self-monitoring tool	Group; face to face	Allied health staff; clinical setting	12	12 (40)	Tailored; NA
Phelan et al,[83] 2011	US (393) [27.4]	Mixed; theory based; combination	Individual; face to face	Allied health staff; research center	14	1 (NA)	Tailored; NA
Quinlivan et al,[84] 2011	Australia (124) [NA]	Diet; NA theory; none	Individual; face to face	Allied health staff; clinical setting	NA	NA (5)	Tailored; NA
Barakat et al,[39] 2012	Spain (290) [22.9]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	29	87 (40-45)	Tailored; 0.87
Barakat et al,[38] 2012a	Spain (83) [24.4]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	29	87 (35-45)	Tailored; 0.85
Hui et al,[40] 2012	Canada (183) [NA]	Diet with physical activity; NA theory; combination	Individual (2 diet) and group (10 exercise; face to face)	Allied health staff; exercise center	10	12 (45)	Tailored; 0.87
Korpi-Hyövälti et al,[85] 2012	Finland (54) [26.4]	Diet; NA theory; other resources	Individual; face to face	Allied health staff; clinical setting	24	6 (NA)	Tailored; NA

(continued)

Table 2. Intervention Characteristics of Lifestyle Interventions in Pregnancy (continued)

Study	Country (No.) [mean BMI]	Intervention type; theory; resource	Intervention format; delivery mode	Intervention facilitator; location	Intervention duration, wk	No. sessions (min/session)	Tailoring; adherence
Oostdam et al,[41] 2012	Netherlands (105) [35.6]	Physical activity; NA theory; none	Group; face to face	Allied health staff (trained); clinical setting	25	50 (60)	Tailored; 0.111
Price et al,[42] 2012	US (62) [27.7]	Physical activity; NA theory; none	Group; face to face	Medical staff; clinical setting	22	66 (45-60)	Tailored; 0.930
Walsh et al,[43] 2012	Ireland (759) [27.1]	Diet; NA theory; other resources	Group; face to face	Allied health staff; clinical setting	16	3 (120)	Not tailored; NA
Althuizen et al,[86] 2013	Netherlands (269) [27.6]	Mixed; theory based; other resources	Individual; face to face	Others; clinical setting	17	4 (30)	Tailored; 0.67
Barakat et al,[44] 2013	Spain (279) [23.9]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	26	78 (50-55)	Tailored; 0.95
Bogaerts et al,[45] 2013	Belgium (197) [34.7]	Mixed; theory based; other resources	Group; face to face	Medical staff (trained); clinical setting	20	4 (90-120)	Tailored; 0.79
Deveer et al,[87] 2013	Turkey (100) [28.6]	Diet; NA theory; none	Individual; face to face	Allied health staff; clinical setting	12	8 (NA)	Tailored; NA
Harrison et al,[88] 2013	Australia (238) [31.4]	Mixed; theory based; combination	Individual; face to face	Allied health staff; clinical setting	12	4 (60)	Tailored; NA
Ruiz et al,[46] 2013	Spain (927) [NA]	Physical activity; NA theory; none	Group; face to face	Allied health staff; exercise center	29	87 (50-55)	Tailored; 0.97
Barakat et al,[47] 2014	Spain (200) [23.9]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	26	78 (55-60)	Tailored; 0.95
Di Carlo et al,[89] 2014	Italy (120) [25.8]	Diet; NA; other resources	Individual; face to face	Allied health staff; clinical setting	24	6 (NA)	Tailored; NA
Dodd et al,[90] 2014	Australia (2199) [32.49]	Mixed; theory based; combination	Individual; face to face and remote	Allied health staff (trained); clinical setting	16	3 (NA)	Tailored; 0.77
Hui et al,[48] 2014	Canada (113) [NA]	Diet with physical activity; NA theory; combination	Individual and group; face to face and remote	Allied health staff; exercise center	10	30-80 (45)	Tailored; 1
Ko et al,[49] 2014	US (1196) [25.7]	Physical activity; theory based; other resources	Group; face to face	Allied health staff; exercise center	16	52 (30)	Tailored; NA
Kong et al,[50] 2014	US (37) [30.7]	Physical activity; NA; combination	Group; face to face	Others; home-based session	20	1 (NA)	Not tailored; 1.0
Petrella et al,[91] 2014	Italy (61) [33.8]	Diet with physical activity; NA theory; self-monitoring tool	Individual; face to face	Allied health staff; clinical setting	24	5 (60)	Tailored; NA
Vesco et al,[51] 2014	US (114) [36.7]	Diet with physical activity; theory based; self-monitoring tool	Individual and group; face to face	Allied health staff; clinical setting	13	18 (45- 90)	Tailored; 0.816
Bisson et al,[92] 2015	Canada (45) [34.75]	Physical activity; NA theory; none	Individual; face to face	Allied health staff; exercise center	12	36 (60)	Tailored; 0.5135
Dekker et al,[93] 2015	Australia (35) [36.8]	Physical activity; NA theory; other resources	Individual; face to face	Allied health staff; clinical setting	24	4 (NA)	Tailored; 1.0
Gesell et al,[52] 2015	US (87) [NA]	Diet with physical activity; theory based; none	Group; face to face	Others (trained); exercise center	12	12 (90)	Tailored; 0.333
Hawkins et al,[118] 2015	US (68) [NA]	Mixed; theory based; combination	Individual; face to face	Others (trained); clinical setting	22	6 (NA)	Tailored; 0.66
Jing et al,[21] 2015	China (221) [20.6]	Mixed; theory based; other resources	Individual; face to face	Others (trained); clinical setting	12	3 (20)	Tailored; NA
Perales et al,[53] 2015	Spain (167) [NA]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	27	81 (60)	Tailored; NA
Poston et al,[54] 2015	UK (1554) [36.3]	Mixed; theory based; combination	Individual and group; face to face and remote	Others (trained); clinical setting	8	8 (60)	Tailored; 0.875
Ronnberg et al,[94] 2015	Sweden (374) [25.3]	Physical activity; NA theory; self-monitoring tool	Individual; face to face	Medical staff; clinical setting	24	NA (NA)	Tailored; NA
Aşcı et al,[95] 2016	Turkey (90) [23.3]	Mixed; theory based; self-monitoring tool	Individual; face to face	Medical staff; clinical setting	5	3 (60)	Tailored; NA
Barakat et al,[55] 2016	Spain (765) [23.5]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	27	81 (55)	Tailored; 0.80
Garnæs et al,[56] 2016	Norway (74) [34.5]	Physical activity; theory based; self-monitoring tool	Individual and group; face to face	Allied health staff; clinical setting	18	37 (60)	Tailored; 0.5
Herring et al,[110] 2016	US (56) [32.9]	Mixed; theory based; combination	Individual; remote	Others; home-based session	20	8 (15-20)	Tailored; 0.7
Koivusalo et al,[57] 2016	Finland (269) [32.3]	Diet with physical activity; NA theory; self-monitoring tool	Individual and group; face to face	Allied health staff (trained); clinical setting	17	3 (120)	Tailored; NA
McCarthy et al,[96] 2016	Australia (371) [30.3]	Mixed; NA theory; combination	Individual; face to face	Medical staff; clinical setting	16	1 (30)	Not tailored; 1.0

(continued)

Table 2. Intervention Characteristics of Lifestyle Interventions in Pregnancy (continued)

Study	Country (No.) [mean BMI]	Intervention type; theory; resource	Intervention format; delivery mode	Intervention facilitator; location	Intervention duration, wk	No. sessions (min/session)	Tailoring; adherence
Perales et al,[58] 2016	Spain (166) [NA]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	28	84 (55-60)	Tailored; NA
Seneviratne et al,[97] 2016	New Zealand (75) [33.1]	Physical activity; NA theory; combination	Individual; face to face	Allied health staff; home-based session	15	1 (30)	Tailored; 0.33
Smith et al,[111] 2016	US (45) [26.4]	Mixed; theory based; combination	Individual; remote	eHealth; home-based session	20	NA (NA)	Tailored; NA
Sun et al,[112] 2016	China (66) [26.7]	Diet with physical activity; NA theory; none	Individual; face to face	Medical staff; clinical setting	16	5 (NA)	Tailored; NA
Wang et al,[59] 2016	China (226) [26.8]	Physical activity; NA theory; none	Group; face to face	Others; hospital and antenatal clinic	24	72 (30)	Tailored; 0.73
Assaf-Balut et al,[60] 2017	Spain (874) [23.9]	Diet; NA theory; none	Group; face to face	Allied health staff; clinical setting	1	1 (60)	Tailored; 1.0
Bruno et al,[98] 2017	Italy (131) [34.2]	Diet with physical activity; NA theory; self-monitoring tool	Individual; face to face	Allied health staff; clinical setting	24	5 (60)	Tailored; 0.579
Chao et al,[117] 2017	US (38) [31.2]	Diet with physical activity; theory based; self-monitoring tool	Individual; remote	Allied health staff (trained); others	20	20 (20)	Tailored; 0.625
da Silva et al,[61] 2017	Brazil (594) [25.2]	Physical activity; NA theory; none	Group; face to face	Allied health staff (trained); exercise center	16	48 (60)	Tailored; 0.404
Daly et al,[62] 2017	Ireland (76) [34.7]	Physical activity; NA theory; other resources	Group; face to face	Medical staff; clinical setting	19	57 (60)	Tailored; 0.789
Peaceman et al,[63] 2017	US (280) [31]	Diet with physical activity; theory based; combination	Group; face to face	Allied health staff; clinical setting	21	6 (30)	Tailored; NA
Sagedal et al,[64] 2017	Norway (600) [25.6]	Diet with physical activity; NA theory; other resources	Individual and group; face to face and remote	Allied health staff (trained); exercise center	16;	34 (20-60)	Tailored; 0.926
Sewell et al,[99] 2017	UK (28) [NA]	Diet; theory based; other resources	Individual; face to face	Allied health staff; clinical setting	24	1 (15)	Tailored; NA
Simmons et al,[119] 2017	UK (436) [36]	Mixed; theory based; combination	Individual; face to face and remote	Others (trained); clinical setting	15	5 (30-45)	Not tailored; NA
Willcox et al,[113] 2017	Australia (91) [31]	Mixed; theory based; combination	Individual; remote	eHealth; others	19	NA (NA)	Tailored; 0.952
Bacchi et al,[65] 2018	Argentina (111) [23.55]	Physical activity; NA theory; none	Group; face to face	Allied health staff; exercise center	27	85 (60)	Not tailored; 0.85
Barakat et al,[66] 2018	Spain (325) [NA]	Physical activity; NA theory; none	Group; face to face	Allied health staff; clinical setting	27	81 (55-60)	Tailored; 0.80
Cahill et al,[100] 2018	US (240) [32.4]	Mixed; theory based; none	Individual; face to face	Others (trained); others	20	10 (60)	Not tailored; NA
Chan et al,[114] 2018	China (229) [23.6]	Diet with physical activity; NA theory; other resources	Individual; face to face and remote	Allied health staff; clinical setting	12	7 (20-30)	Tailored; 0.925
Kennelly et al,[67] 2018	Ireland (535) [29.3]	Mixed; theory based; other resources	Individual and group; face to face	Allied health staff; clinical setting	22	3 (75)	Tailored; NA
Kiani Asiabar et al,[68] 2018	Iran (150) [23.8]	Mixed; NA theory; other resources	Group; face to face	Medical staff (trained); clinical setting	1	2 (90)	Not tailored; NA
Olson et al,[115] 2018	US (1689) [NA]	Mixed; theory based; combination	Individual; remote	eHealth; others	17	NA (NA)	Tailored; 0.461
Phelan et al,[101] 2018	US (256) [32.5]	Diet with physical activity; theory based; combination	Individual; face to face	Allied health staff; research center	20	6 (20)	Tailored; 0.9
Al Wattar et al,[102] 2019	UK (1252) [NA]	Diet; theory based; none	Individual and group; face to face	Allied health staff (trained); clinical setting	14	3 (NA)	Tailored; 0.74
Anleu et al,[69] 2019	Chile (1002) [NA]	Diet; theory based; other resources	Group; face to face	Allied health staff (trained); clinical setting	13	3 (NA)	Tailored; NA
Barakat et al,[70] 2019	Spain (520) [23.6]	Physical activity; NA theory; none	Group; face to face	Allied health staff (trained); clinical setting	28	84 (55-60)	Tailored; 0.8
Brik et al,[71] 2019	Spain (120) [23.9]	Physical activity; NA theory; none	Group; face to face	Medical staff; clinical setting	22	66 (60)	Tailored; 0.70
Buckingham et al,[103] 2019	US (56) [25]	Diet with physical activity; theory based; combination	Individual; face to face	Allied health staff (trained); clinical setting	22	6 (15-30)	Tailored; NA
Clark et al,[104] 2019	US (42) [26.3]	Physical activity; NA theory; none	Individual; face to face	Allied health staff (trained); exercise center	20	60 (58-60)	Tailored; 0.79
Daley et al,[105] 2019	UK (616) [26]	Mixed; theory based; self-monitoring tool	Individual; face to face	Medical staff (trained); clinical setting	24	8 (1-2)	Tailored; 0.51

(continued)

Table 2. Intervention Characteristics of Lifestyle Interventions in Pregnancy (continued)

Study	Country (No.) [mean BMI]	Intervention type; theory; resource	Intervention format; delivery mode	Intervention facilitator; location	Intervention duration, wk	No. sessions (min/session)	Tailoring; adherence
Kunath et al,[106] 2019	Germany (2261) [24.4]	Mixed; NA theory; combination	Individual; face to face	Medical staff (trained); clinical setting	14	3 (30-45)	Tailored; 0.85
Okesene-Gafa et al,[22] 2019	New Zealand (230) [38.6]	Mixed; theory based; other resources	Individual; face to face	Allied health staff (NA); home-based setting	12	4 (30-60)	Tailored; 0.81
Pelaez et al,[72] 2019	Spain (345) [23.7]	Physical activity; NA theory; none	Group; face to face	Allied health staff (NA); clinical setting	24	70 (60)	Not tailored; 0.80
Arthur et al,[107] 2020	Australia (396) [27.5]	Mixed; NA theory; self-monitoring tool	Individual; face to face	Others; home-based setting	20	1 (NA)	Not tailored; NA
Ferrara et al,[116] 2020	US (398) [29.4]	Diet with physical activity; theory based; combination	Individual; face to face and remote	Allied health staff; clinical setting	13	2 (55)	Not tailored; 0.81
Rodriquez-Blanque et al,[73] 2020	Spain (162) [24.4]	Physical activity; NA theory; none	Group; face to face	Allied health staff; exercise center	17	51 (60)	Not tailored; 0.8

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not available.

0.48 kg).[107,109,111,113,115] Most interventions were delivered in early pregnancy (67 studies [67.7%])[21, 22, 24, 26, 31-33, 35, 38, 39, 42-47, 50, 53-60, 62, 63, 65-72, 75-79, 82, 83, 85, 86, 88, 89, 91-95, 98-106, 111-114, 116-118] and in a clinical setting (68 studies [68.7%]).[21, 23, 24, 26, 28, 29, 32-35, 37-39, 41-45, 47, 51, 53-60, 62, 63, 66-72, 75-78, 80, 82, 84-91, 93-96, 98, 99, 102, 103, 105, 106, 108, 109, 112, 114, 116, 118, 119] Most studies involved interventions with a high (40 studies [40.4%])[24, 25, 27-32, 34-36, 38, 39, 41, 42, 44, 46-49, 51, 53, 55, 59, 61, 62, 64-66, 70-73, 79, 92, 95, 104, 113] or low (33 studies [33.3%])[21, 22, 26, 33, 43, 45, 50, 57, 60, 67-69, 75, 77, 78, 82, 83, 86, 88, 90, 91, 93, 96-99, 102, 106, 107, 109, 112, 116, 119] number of sessions, low (24 studies [24.2%])[21, 24, 26, 34, 48, 49, 59, 63, 64, 82, 84, 86, 96, 97, 99, 101, 103, 105, 106, 109, 110, 114, 117, 119] to moderate (47 studies [47.5%]),[22, 23, 25, 27-33, 35-42, 44, 46, 47, 51, 53-56, 58, 60-62, 65, 66, 70-73, 76, 79, 81, 88, 91, 92, 95, 98, 100, 104, 116] length, and moderate (36 studies [36.4%])[27, 33, 43, 45, 49-51, 56, 57, 61, 62, 64, 69, 73, 75, 81-83, 86, 90, 96, 97, 100-102, 104, 106, 107, 110-113, 115-117, 119] to high (32 studies [32.3%])[26, 31, 32, 35, 38, 39, 42, 44, 46, 47, 53, 55, 58, 59, 63, 65, 66, 71, 72, 78, 85, 89, 91, 93, 94, 98, 99, 103, 105, 118] duration. There were 23 studies (23.2%) reporting provision of ongoing support.[21-23, 49, 52, 54, 63, 64, 67, 74, 83, 93, 95-97, 99, 102, 103, 112, 115, 116, 118, 119] Attrition was low in most studies (56 studies [56.6%]).[21, 22, 32, 33, 35-40, 43, 44, 46, 48, 50, 53-55, 57, 61, 62, 64-68, 70, 72, 73, 75, 78, 81, 84, 86, 88-90, 92-95, 99-104, 106-109, 111-115, 117] However, adherence was not commonly reported (50 studies [50.5%]).[21, 25-27, 30, 31, 33, 34, 37, 40, 41, 43, 49, 53, 57, 58, 63, 67-69, 74, 75, 78, 80, 82-91, 94, 95, 98-100, 102, 103, 105, 107-112, 114, 119] The association of intervention session number, length of sessions, duration of intervention, provision of ongoing support or resources, tailoring, adherence, and attrition with reduction in GWG could not be delineated.

Association of Diet Intervention Characteristics With GWG

Of 13 dietary interventions (eTable 1 in Supplement 1),[26,43,60,69,75,76,80,84,85,87,89,99,102] most were delivered in an individual format (9 studies [69.2%]),[75,76,80,84,85,87,89,99,102] and all adopted a face-to-face delivery mode by allied health staff in a clinical setting.[26,43,60,69,75,76,80,84,85,87,89,99,102] Individual delivery format (MD, −3.91 kg; 95% CI, −5.82 to −2.01 kg) was associated with a greater decrease in GWG compared with group format (MD, −0.23 kg; 95% CI, −1.28 to 0.82 kg; P = .002). Most studies comprised a low number of sessions (7 studies [53.8%]),[26,43,60,69,75,99,102] with moderate (4 studies [30.8%])[43,69,75,102] to high (4 studies [30.8%])[26,85,89,99] intervention duration. Compared with corresponding subgroups, a moderate number of sessions (MD, −4.35 kg; 95% CI, −5.80 to −2.89 kg; P < .001) was associated with a greater decrease in GWG. Intervention tailoring, provision of resources, ongoing support, and attrition were not associated with GWG. Attrition was low (6 studies [46.2%])[43,75,84,89,99,102] or not reported (6 studies [46.2%])[26,60,76,80,85,87] in most studies. Most studies did not report adherence (11 studies [84.6%]).[26,43,69,75,80,84,85,87,89,99,102]

Table 3. Association of Lifestyle Intervention TIDieR Component Subgroups With GWGs

TIDieR intervention component	Studies (No.)	GWG, MD (95% CI), kg[a]	I^2 (%)	*P* value for subgroup differences
Theory based				
Yes	33	−0.74 (−1.07 to −0.42)	73.7	.02
No or NA	66	−1.37 (−1.70 to −1.03)	79.5	
Resource				
Self-monitoring tool	14	−1.33 (−2.48 to −0.19)	87.5	.41
Other resource	22	−1.01 (−1.54 to −0.48)	74.4	
Combination	23	−0.81 (−1.17 to −0.45)	70.6	
None	40	−1.32 (−1.70 to −0.95)	75.2	
Format				
Individual	48	−1.34 (−1.74 to −0.93)	86.7	.22
Group	51	−1.03 (−1.31 to −0.75)	67.4	
Mode				
Face to face	84	−1.21 (−1.50 to −0.93)	78.5	.49
Remote	6	−0.31 (−1.46 to 0.84)	59.8	
Face to face and remote	9	−1.10 (−1.69 to −0.51)	57.4	
Facilitator				
Allied health staff	64	−1.36 (−1.71 to −1.02)	80.6	<.001
Medical staff	16	−0.85 (−1.41 to −0.28)	70.8	
Other	14	−0.91 (−1.39 to −0.43)	43.8	
NA	5	−0.25 (−0.98 to 0.48)	50.0	
Prior training				
Yes	32	−0.87 (−1.21 to −0.53)	66.1	.14
No or NA	67	−1.28 (−1.63 to −0.94)	88.0	
Location				
Hospital or antenatal clinic	68	−1.24 (−1.55 to −0.92)	80.5	.54
Exercise center	15	−0.99 (−1.59 to −0.40)	69.9	
Other	16	−0.93 (−1.58 to −0.29)	71.0	
Intervention commencement				
Early pregnancy	67	−1.09 (−1.35 to −0.83)	68.0	<.001
Late pregnancy	31	−1.13 (−1.62 to −0.64)	87.1	
NA	1	−6.80 (−8.63 to −4.97)		
Duration				
High	32	−1.26 (−1.57 to −0.95)	53.2	.47
Moderate	36	−0.91 (−1.25 to −0.56)	82.1	
Low	26	−1.28 (−1.91 to −0.65)	82.5	
Insufficient data to calculate	5	−2.60 (−6.19 to 0.98)	88.9	
No. of sessions				
High	40	−1.13 (−1.43 to −0.82)	60.9	.37
Moderate	20	−1.50 (−2.21 to −0.79)	71.9	
Low	33	−0.87 (−1.21 to −0.53)	68.3	
NA	6	−2.40 (−5.12 to 0.32)	96.8	
Ongoing support				
Yes	23	−0.91 (−1.33 to −0.49)	76.3	.22
No	76	−1.24 (−1.55 to −0.93)	80.2	
Length of session				
High	5	−1.42 (−2.42 to −0.43)	58.9	.72
Moderate	47	−1.09 (−1.39 to −0.79)	64.1	
Low	24	−0.94 (−1.47 to −0.41)	76.8	
NA	23	−1.55 (−2.17 to −0.94)	91.0	

(continued)

Table 3. Association of Lifestyle Intervention TIDieR Component Subgroups With GWGs (continued)

TIDieR intervention component	Studies (No.)	GWG, MD (95% CI), kg[a]	I^2 (%)	*P* value for subgroup differences
Tailoring				
Tailored	74	−1.07 (−1.34 to −0.80)	78.1	.56
Not tailored or NA	25	−1.34 (−1.86 to −0.81)	83.5	
Compliance				
High	34	−1.18 (−1.55 to −0.82)	72.2	.88
Low	15	−0.99 (−1.70 to −0.28)	82.4	
Insufficient data to calculate	50	−1.17 (−1.58 to −0.76)	81.0	
Attrition				
High	15	−0.67 (−1.28 to −0.07)	59.6	.22
Low	57	−1.15 (−1.44 to −0.85)	86.0	
Insufficient data to calculate	27	−1.49 (−2.19 to −0.80)	84.1	

Abbreviations: GWG, gestational weight gain; MD, mean difference; NA: not available; TIDieR, Template for Intervention Description and Replication.

[a] For all MDs, the reference group was the control group (ie, usual care).

Association Between Characteristics of Diet With Physical Activity Interventions and GWG

Of 16 diet with physical activity interventions (eTable 2 in Supplement 1), most were delivered by allied health staff (13 studies [81.3%]),[26,43,60,69,75,76,80,84,85,87,89,99,102] using an individual format (9 studies [56.2%])[77,91,98,101,103,114,116,117] and face-to-face mode (10 studies [62.5%]),[40,51,52,57,63,77,91,98,101,103] with no significant differences across subgroups of facilitator, delivery format, or mode found. Interventions were mostly delivered in early pregnancy (11 studies [68.7%])[57,63,77,83,91,98,103,112,114,116,117] and in a clinical setting (10 studies [62.5%]).[51,57,63,77,91,98,103,112,114,116] Most studies involved interventions with a low (6 studies [37.5%])[57,77,91,98,112,116] to moderate (7 studies [43.7%])[40,52,63,101,103,114,117] number of sessions, low (7 studies [43.7%])[48,63,64,101,103,114,117] to moderate (5 studies [31.2%])[40,51,91,98,116] length, and low (5 studies [31.2%])[40,48,52,77,114] to moderate (7 studies [43.7%])[51,57,64,101,112,116,117] duration; 6 studies (37.5%) reported having ongoing support.[52,63,64,103,112,116] In most studies, attrition was low (9 studies [56.2%])[40,48,57,64,101,103,112,114,117] and adherence was not reported (8 studies [50.0%]).[40,57,63,91,98,103,112,114] Intervention theoretical underpinning, delivery setting, number and length of sessions, duration of intervention, provision of ongoing support, tailoring, adherence, and attrition were not associated with differences in GWG reduction.

Association of Physical Activity Intervention Characteristics and GWG

Of 42 physical activity interventions (eTable 3 in Supplement 1), most were delivered in a group format (35 studies [83.3%])[23-25, 27-32, 34-39, 41, 42, 44, 46, 47, 49, 50, 53, 55, 56, 58, 59, 61, 62, 65, 66, 70-73] by allied health staff (30 studies [71.4%])[25, 27, 30-32, 35-39, 41, 44, 46, 47, 49, 53, 55, 56, 58, 61, 65, 66, 70, 72, 73, 81, 92, 93, 97, 104] and all in face-to-face mode (42 studies [100%]),[23-25, 27-32, 34-39, 41, 42, 44, 46, 47, 49, 53, 55, 56, 58, 59, 61, 62, 65, 66, 70-73, 79, 81, 92-94, 97, 104] with no significant difference by intervention format, facilitator, or mode found. Interventions mostly commenced in early pregnancy (27 studies [64.3%])[24, 31, 32, 35, 38, 39, 42, 44, 46, 47, 50, 53, 55, 56, 58, 59, 62, 65, 66, 70-72, 79, 92-94, 104] and occurred in a clinical setting (26 studies [61.9%]),[23, 24, 28, 29, 32, 34, 35, 37-39, 41, 42, 44, 47, 53, 55, 56, 58, 59, 62, 66, 70-72, 93, 94] with no association with efficacy. Most studies involved interventions with a high number of sessions (35 studies [83.3%]),[24, 25, 27-32, 34-36, 38, 39, 41, 42, 44, 46, 47, 49, 53, 55, 56, 59, 61, 62, 65, 66, 70-73, 79, 92, 104] moderate length (34 studies [81.0%]),[23, 25, 27-32, 35-39, 41, 42, 44, 46, 47, 53, 55, 58, 66, 70, 79, 81, 92] and high duration (20 studies [47.6%])[32, 35, 38, 39, 42, 44, 46, 47, 53, 55, 58, 59, 65, 66, 70-72, 93, 94]; 4 studies (9.5%)[23,49,93,97] reported having ongoing support. In most studies, attrition was low (23 studies [54.8%])[32, 35-39, 44, 46, 50, 53, 55, 61, 62, 65, 66, 70, 72, 73, 81, 92-94, 104] and reported adherence was high (21 studies [50.0%]).[28, 32, 35, 38, 39, 42, 44, 46, 47, 50, 55, 62, 65, 66, 70, 72, 73, 79, 81, 93, 104] Theoretical underpinning, provision of resources or ongoing support, number and length of sessions, duration of intervention, tailoring, attrition, and adherence were not associated with GWG.

Association of Mixed Intervention Characteristics and GWG

Of 28 mixed interventions (eTable 4 in Supplement 1), most were delivered in an individual format (23 studies [82.1%])[21, 22, 74, 78, 82, 83, 86, 88, 90, 95, 96, 100, 105-111, 113, 115, 118, 119] and face-to-face mode (19 studies [67.9%]),[21, 22, 33, 45, 67, 68, 74, 78, 82, 83, 86, 88, 90, 95, 96, 100, 105-107] with no significant difference in GWG reduction by subgroup. Intervention facilitator and prior training were not associated with the efficacy of interventions. Interventions were mostly delivered in early pregnancy (19 studies [67.9%])[21, 22, 33, 45, 54, 67, 68, 78, 82, 83, 86, 88, 95, 100, 105, 106, 111, 113, 118] and in a clinical setting (19 studies [67.9%]).[21, 22, 33, 45, 54, 67, 68, 78, 82, 86, 88, 90, 95, 105, 106, 108, 109, 111, 118] Most studies involved interventions with a low number of sessions (17 studies [60.7%])[21, 22, 33, 45, 67, 68, 78, 82, 83, 86, 88, 90, 106, 107, 109, 119] and moderate duration (15 studies [53.6%])[33, 45, 82, 83, 86, 90, 96, 100, 106, 107, 110, 111, 113, 115, 119]; 11 studies (39.3%)[21,22,54,67,74,83,95,96,115,118,119] reported having ongoing support. Most interventions were tailored (22 studies [78.6%]).[21, 22, 33, 45, 54, 67, 74, 82, 83, 86, 88, 90, 95, 105, 106, 108-111, 113, 115, 118] In most studies, attrition was low (19 studies [67.9%])[21, 22, 33, 54, 67, 68, 78, 86, 88, 90, 95, 100, 106-109, 111, 113, 115] but adherence was not reported (20 studies [71.4%]).[21, 33, 67, 68, 74, 78, 82, 83, 86, 88, 90, 95, 100, 105, 107-111, 119] Theoretical underpinning, commencement time and setting of intervention, number and length of sessions, duration of intervention, having ongoing support, tailoring, and attrition were not associated with a difference in GWG reduction; however, a high adherence level was associated with a higher efficacy (MD, −0.96 kg; 95%CI, −1.68 to −0.23 kg) compared with a low adherence (MD, <0.01 kg; 95% CI, −0.05 to 0.05 kg; $P < .001$).

Discussion

The association of excess GWG with adverse maternal and neonatal outcomes has now been well established, as has the efficacy associated with lifestyle interventions, and population-based strategies to optimize GWG during pregnancy are recommended by the US Prevention Task Force.[5] Despite supporting evidence for the cost-effectiveness of implementing interventions in antenatal care,[8] little translation has been achieved to date, with a lack of clinical implementation-based research a critical remaining barrier. This is compounded by a lack of understanding of exactly what should be implemented and how. In this meta-analysis, we extended our recent systematic review[6] to evaluate the association of intervention type with efficacy in reduced GWG. We also evaluated the potential association of specific pragmatic components of intervention design with efficacy, underpinned by the TIDieR framework, enabling exploration of efficacy of lifestyle interventions by who, what, when, where, and how much,[14] which are important for informing implementation. In line with the CFIR, efficacious components have the potential to be considered core, or essential, to intervention design compared with less effective components that could be considered amenable according to contextual needs. Subgroup analysis by intervention type (diet, physical activity, diet with physical activity, and mixed interventions) found potential differences in characteristics by facilitator, delivery style, intensity level, and duration, which may provide significant insight to inform future implementation design of lifestyle interventions in antenatal care settings.

Our previous systematic review and meta-analysis[6] built on several seminal reviews in the field to date, evaluating 117 RCTs to evaluate the association of antenatal lifestyle interventions with efficacy in optimized GWG and reduced risk of adverse maternal and neonatal outcomes. Differential effects were noted when analyzed by intervention type, with the greatest change in GWG found with diet (MD, −2.63 kg), followed by diet with physical activity (−1.35 kg), physical activity (−1.04 kg), and mixed interventions (−0.74 kg).[6] Associated reductions in risk of adverse maternal and neonatal outcomes were demonstrated with diet interventions, while diet with physical activity and physical activity interventions were associated with reduced risk of maternal outcomes, and mixed interventions were associated with optimized GWG only.[6] For a broad population health benefit to be realized, a vital next step is the pragmatic translation of interventions into routine care settings. Cost-effectiveness support implementation,[7,8] with a 2022 study[8] finding that for every A $1 (US $0.67) invested in implementation of structured diet and physical activity interventions, projected return was up to 5 times as high, with cost savings largely associated with reduced incidence of adverse outcomes. To enhance feasibility of implementation, a critical remaining gap is defining exactly what intervention components and strategies are associated with the greatest effectiveness in optimized GWG, nuanced to intervention type. This enables specificity in ensuring that the most effective characteristics are incorporated while enabling less efficacious characteristics to be modified according to local contextual factors related to resources, time, and cost. In turn, this may be associated with positive downstream cost-effectiveness and feasibility outcomes, particularly in resource-poor settings that may benefit greatly from population health initiatives.

Dietary interventions were associated with the greatest change in GWG, and on analysis, those delivered by allied health staff using a face-to-face mode and individual delivery format were associated with increased efficacy compared with group delivery. Interventions incorporating a moderate number of sessions (6-20 sessions) were also associated with optimized GWG, compared with a lower number of sessions (1-5 sessions). Dietary interventions need to consider pregnancy-specific barriers, including nausea, aversions, cravings and fatigue,[121] widespread inadequate consumption of recommended fruit and vegetable servings, and increased availability of convenience foods, all of which may compromise diet quality.[122] Given the complexity of individual barriers to optimal dietary composition, including environment, accessibility, sociodemographic factors, cultural practices, parity, and pregnancy-specific barriers, an individual delivery format may be more effective, as suggested by our findings, to maximize adherence to dietary advice or prescription that is difficult and complex to address in group-based formats. Peripheral and adaptable elements examined in this study, including intervention tailoring, behavioral and theoretical underpinning, session duration, and provision of ongoing support, were not found to be associated with a reduction in GWG. This is encouraging, suggesting the potential association of brief but frequent contact with a health professional with optimized GWG without the need for support between visits. In this study, dietary interventions were more prescriptive in nature, so it is perhaps not surprising that we found no evidence for the association of behavioral or theoretical underpinning with a change in GWG in dietary interventions. Key remaining questions include efficacy in clinical populations and delivery in routine care compared with highly select trial populations, as well as nuanced evidence on optimal time and intensity. Overall, our findings suggest that interventions delivered individually by an allied health professional and including 6 or more sessions may be considered as key components for dietary interventions.

Diet with physical activity, physical activity, and mixed interventions were associated with less effectiveness in optimizing GWG compared with dietary interventions. While no significant components were identified, for physical activity interventions, commencing in earlier pregnancy (ie, <20 weeks gestation), longer-duration interventions, and delivery by an allied health professional may be associated with more effectively optimized GWG. This is aligned to the well-accepted finding that physical activity interventions alone are associated with less reduction in weight compared with dietary interventions.[123] These findings suggest that a longer intervention duration (ie, >20 weeks) commencing in early pregnancy may be advisable.

Mixed interventions were more likely to be focused on behavior change, commonly including goal setting, feedback, and monitoring and shaping knowledge. Behavior change is an iterative process, involving problem-solving and development of skills in self-management and self-efficacy, and an immediate association with weight change is less likely. Given that skills in behavior change require practice,[124] commencing interventions earlier in pregnancy and over a longer duration may be considered relevant to GWG. In this study, we found that mixed interventions commencing at less than 20 weeks' gestation and with longer duration and session length delivered in a group format were associated with lower GWG. Previous research found that a group format was associated with improved peer support.[125] This may be particularly important during pregnancy to offer support directly related to the experience of pregnancy, which may not be available in a pregnant individual's immediate social support network. In physical activity and mixed interventions, low attrition was associated with reduced GWG, which may have been related to the lower change in outcome associated with these intervention types compared with dietary interventions, which were associated with a greater change in GWG with fewer contact points.

Strengths and Limitations

The strengths of this study include building on a robust systematic review and meta-analysis and intervention categorization spanning 30 years of research across 5 continents and involving 34 546 pregnant individuals in various settings and population groups. We informed our evaluation using established rigorous frameworks for identifying intervention characteristics (ie, the TIDieR framework) and for informing implementation design (ie, the CFIR). Eligibility criteria included usual care as the comparator group, which may increase generalizability to clinical settings.

This study also has several limitations, including a moderate to high risk of bias across most studies as previously reported[6] and a lack in reporting of quality assurance measures, such as adherence or fidelity.[120] There was also a lack of understanding of reach and capacity for implementation of lifestyle interventions in pregnancy, as previously reported.[120] Included studies did not report against the TIDieR framework, so extraction of some components required subjective interpretation. In particular, there was limited information relating to gestational age at the completion of intervention or length of sessions (ie, minutes per hour), tailoring, adherence, or attrition rates, all of which limited our interpretative ability for the efficacy of these components in GWG reduction. As previously reported, significant publication bias was found against small studies reporting efficacy,[6] which may have artificially increased the effect size. However our previous sensitivity analysis demonstrated negligible association with GWG efficacy, with studies deemed to be at low risk of bias.[6] Subgroup analyses examining pooled effects by intervention type may have been underpowered.[126]

Conclusions

This meta-analysis of randomized antenatal lifestyle interventions may advance the field by defining core and adaptable intervention components to underpin pragmatic implementation in routine pregnancy care as a critical next step to leverage the established efficacy and cost-effectiveness of interventions to optimize GWG and maternal and neonatal outcomes. We report broadly that lifestyle intervention delivery by an allied health professional appeared important with intervention content focused on diet and physical activity. Among dietary interventions, which were found to be associated with the greatest decrease in GWG in our previous study,[6] those with an individual delivery format and moderate intensity were associated with the greatest change in GWG in this study. Physical activity and mixed behavioral interventions were beneficial but associated with less change in GWG; they therefore may benefit from earlier commencement and a longer duration for a more effective association with GWG reduction. These findings suggest that future pragmatic research should focus on testing and evaluating components to inform implementation in varied antenatal care settings, including those with limited resources, to optimize population benefit for pregnant individuals and the next generation.

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REFERENCES

1. Fryar CD, Carroll MD, Afful J. Prevalence of overweight, obesity, and severe obesity among adults aged 20 and over: United States, 1960–1962 through 2017–2018. National Center for Health Statistics. Accessed May 11, 2023. https://www.cdc.gov/nchs/data/hestat/obesity-adult-17-18/obesity-adult.htm

2. Rasmussen K, Yaktine AL; US Institute of Medicine; National Research Council Committee to Reexamine IOM Pregnancy Weight Guidelines, eds. *Weight Gain During Pregnancy: Reexamining the Guidelines*. National Academies Press; 2009.

3. Goldstein RF, Abell SK, Ranasinha S, et al. Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. *JAMA*. 2017;317(21):2207-2225. doi:10.1001/jama.2017.3635

4. Hill B, Skouteris H, Boyle JA, et al. Health in preconception, pregnancy and postpartum global alliance: international network pregnancy priorities for the prevention of maternal obesity and related pregnancy and long-term complications. *J Clin Med*. 2020;9(3):822. doi:10.3390/jcm9030822

5. Cantor AG, Jungbauer RM, McDonagh M, et al. Counseling and behavioral interventions for healthy weight and weight gain in pregnancy: evidence report and systematic review for the US Preventive Services Task Force. *JAMA*. 2021;325(20):2094-2109. doi:10.1001/jama.2021.4230

6. Teede HJ, Bailey C, Moran LJ, et al. Association of antenatal diet and physical activity-based interventions with gestational weight gain and pregnancy outcomes: a systematic review and meta-analysis. *JAMA Intern Med*. 2022; 182(2):106-114. doi:10.1001/jamainternmed.2021.6373

7. Bailey C, Skouteris H, Harrison CL, et al. A Comparison of the Cost-Effectiveness of Lifestyle Interventions in Pregnancy. *Value Health*. 2022;25(2):194-202. doi:10.1016/j.jval.2021.07.013

8. Lloyd M, Teede H, Bailey C, Callander E, Ademi Z. Projected return on investment from implementation of a lifestyle intervention to reduce adverse pregnancy outcomes. *JAMA Netw Open*. 2022;5(9):e2230683-e2230683. doi:10.1001/jamanetworkopen.2022.30683

9. Harrison CL, Skouteris H, Boyle J, Teede HJ. Preventing obesity across the preconception, pregnancy and postpartum cycle: implementing research into practice. *Midwifery*. 2017;52:64-70. doi:10.1016/j.midw.2017.06.003

10. Hill B, Skouteris H, Savaglio M, Harrison CL. Optimising weight gain in pregnancy: key challenges and solutions for maternal obesity prevention. *Public Health Res Pract*. 2022;32(3):3232222. doi:10.17061/phrp3232222

11. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implement Sci*. 2009;4(1):50-50. doi:10.1186/1748-5908-4-50

12. Lim S, Liang X, Hill B, Teede H, Moran LJ, O'Reilly S. A systematic review and meta-analysis of intervention characteristics in postpartum weight management using the TIDieR framework: a summary of evidence to inform implementation. *Obes Rev*. 2019;20(7):1045-1056. doi:10.1111/obr.12846

13. Lim S, Hill B, Pirotta S, O'Reilly S, Moran L. What are the most effective behavioural strategies in changing postpartum women's physical activity and healthy eating behaviours: a systematic review and meta-analysis. *J Clin Med*. 2020;9(1):237. doi:10.3390/jcm9010237

14. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*. 2014;348:g1687. doi:10.1136/bmj.g1687

15. Ruifrok AE, Rogozinska E, van Poppel MNM, et al; i-WIP (International Weight Management in Pregnancy) Collaborative Group. Study protocol: differential effects of diet and physical activity based interventions in pregnancy on maternal and fetal outcomes–individual patient data (IPD) meta-analysis and health economic evaluation. *Syst Rev*. 2014;3:131-131. doi:10.1186/2046-4053-3-131

16. Thangaratinam S, Rogozińska E, Jolly K, et al. Effects of interventions in pregnancy on maternal weight and obstetric outcomes: meta-analysis of randomised evidence. *BMJ*. 2012;344:e2088. doi:10.1136/bmj.e2088

17. International Weight Management in Pregnancy (i-WIP) Collaborative Group. Effect of diet and physical activity based interventions in pregnancy on gestational weight gain and pregnancy outcomes: meta-analysis of individual participant data from randomised trials. *BMJ*. 2017;358:j3119. doi:10.1136/bmj.j3119

18. UN Conference on Trade and Development. Composition criteria of economic groups. Accessed May 11, 2023. https://unctadstat.unctad.org/EN/Classifications.html

19. Harris RJ, Deeks JJ, Altman DG, Bradburn MJ, Harbord RM, Sterne JAC. Metan: fixed- and random-effects meta-analysis. *Stata J*. 2008;8(1):3-28. doi:10.1177/1536867X0800800102

20. Deeks JJ, Higgins JPT, Altman DG. Chapter 10: analysing data and undertaking meta-analyses. In: Higgins JPT, Thomas J, Chandler J, et al, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Version 6.3. Cochrane; 2022. Accessed May 11, 2023. http://www.training.cochrane.org/handbook

21. Jing W, Huang Y, Liu X, Luo B, Yang Y, Liao S. The effect of a personalized intervention on weight gain and physical activity among pregnant women in China. *Int J Gynaecol Obstet*. 2015;129(2):138-141. doi:10.1016/j.ijgo.2014.11.014

22. Okesene-Gafa KAM, Li M, McKinlay CJD, et al. Effect of antenatal dietary interventions in maternal obesity on pregnancy weight-gain and birthweight: Healthy Mums and Babies (HUMBA) randomized trial. *Am J Obstet Gynecol*. 2019;221(2):152.e1-152.e13. doi:10.1016/j.ajog.2019.03.003

23. Kihlstrand M, Stenman B, Nilsson S, Axelsson O. Water-gymnastics reduced the intensity of back/low back pain in pregnant women. *Acta Obstet Gynecol Scand*. 1999;78(3):180-185.

24. Clapp JF III, Kim H, Burciu B, Lopez B. Beginning regular exercise in early pregnancy: effect on fetoplacental growth. *Am J Obstet Gynecol*. 2000;183(6):1484-1488. doi:10.1067/mob.2000.107096

25. Marquez-Sterling S, Perry AC, Kaplan TA, Halberstein RA, Signorile JF. Physical and psychological changes with vigorous exercise in sedentary primigravidae. *Med Sci Sports Exerc*. 2000;32(1):58-62. doi:10.1097/00005768-200001000-00010

26. Bechtel-Blackwell DA. Computer-assisted self-interview and nutrition education in pregnant teens. *Clin Nurs Res*. 2002;11(4):450-462. doi:10.1177/105477302237456

27. Prevedel TTS, Calderon IdMP, De Conti MH, Consonni EB, Rudge MVC. Maternal and perinatal effects of hydrotherapy in pregnancy. Repercussões maternas e perinatais da hidroterapia na gravidez. *Rev Bras Ginecol Obstet*. 2003;25:53-59. doi:10.1590/S0100-72032003000100008

28. Garshasbi A, Faghih Zadeh S. The effect of exercise on the intensity of low back pain in pregnant women. *Int J Gynaecol Obstet*. 2005;88(3):271-275. doi:10.1016/j.ijgo.2004.12.001

29. Santos IA, Stein R, Fuchs SC, et al. Aerobic exercise and submaximal functional capacity in overweight pregnant women: a randomized trial. *Obstet Gynecol*. 2005;106(2):243-249. doi:10.1097/01.AOG.0000171113.36624.86

30. Sedaghati P, Ziaee V, Ardjmand A. The effect of an ergometric training program on pregnants' weight gain and low back pain. *Gazz Med Ital*. 2007;166(6):209-213.

31. Baciuk EP, Pereira RI, Cecatti JG, Braga AF, Cavalcante SR. Water aerobics in pregnancy: cardiovascular response, labor and neonatal outcomes. *Reprod Health*. 2008;5:10. doi:10.1186/1742-4755-5-10

32. Barakat R, Stirling JR, Lucia A. Does exercise training during pregnancy affect gestational age: a randomised controlled trial. *Br J Sports Med*. 2008;42(8):674-678. doi:10.1136/bjsm.2008.047837

33. Guelinckx I, Devlieger R, Mullie P, Vansant G. Effect of lifestyle intervention on dietary habits, physical activity, and gestational weight gain in obese pregnant women: a randomized controlled trial. *Am J Clin Nutr*. 2010;91(2): 373-380. doi:10.3945/ajcn.2009.28166

34. Khaledan A, Mirdar S, Motahari-Tabari N, Ahmad SM. Effect of an Aerobic Exercise Program on Fetal Growth in Pregnant Women. *Hayat*. 2010;16(1):55-64.

35. Barakat R, Pelaez M, Montejo R, Luaces M, Zakynthinaki M. Exercise during pregnancy improves maternal health perception: a randomized controlled trial. *Am J Obstet Gynecol*. 2011;204(5):402.e1-402.e7. doi:10.1016/j.ajog.2011.01.043

36. Haakstad LA, Bø K. Effect of regular exercise on prevention of excessive weight gain in pregnancy: a randomised controlled trial. *Eur J Contracept Reprod Health Care*. 2011;16(2):116-125. doi:10.3109/13625187.2011.560307

37. Nascimento SL, Surita FG, Parpinelli MÂ, Siani S, Pinto e Silva JL. The effect of an antenatal physical exercise programme on maternal/perinatal outcomes and quality of life in overweight and obese pregnant women: a randomised clinical trial. *BJOG*. 2011;118(12):1455-1463. doi:10.1111/j.1471-0528.2011.03084.x

38. Barakat R, Cordero Y, Coteron J, Luaces M, Montejo R. Exercise during pregnancy improves maternal glucose screen at 24-28 weeks: a randomised controlled trial. *Br J Sports Med*. 2012;46(9):656-661. doi:10.1136/bjsports-2011-090009

39. Barakat R, Pelaez M, Lopez C, Montejo R, Coteron J. Exercise during pregnancy reduces the rate of cesarean and instrumental deliveries: results of a randomized controlled trial. *J Matern Fetal Neonatal Med*. 2012;25(11): 2372-2376. doi:10.3109/14767058.2012.696165

40. Hui A, Back L, Ludwig S, et al. Lifestyle intervention on diet and exercise reduced excessive gestational weight gain in pregnant women under a randomised controlled trial. *BJOG*. 2012;119(1):70-77. doi:10.1111/j.1471-0528.2011.03184.x

41. Oostdam N, van Poppel MN, Wouters MG, et al. No effect of the FitFor2 exercise programme on blood glucose, insulin sensitivity, and birthweight in pregnant women who were overweight and at risk for gestational diabetes: results of a randomised controlled trial. *BJOG*. 2012;119(9):1098-1107. doi:10.1111/j.1471-0528.2012.03366.x

42. Price BB, Amini SB, Kappeler K. Exercise in pregnancy: effect on fitness and obstetric outcomes-a randomized trial. *Med Sci Sports Exerc*. 2012;44(12):2263-2269. doi:10.1249/MSS.0b013e318267ad67

43. Walsh JM, McGowan CA, Mahony R, Foley ME, McAuliffe FM. Low glycaemic index diet in pregnancy to prevent macrosomia (ROLO study): randomised control trial. *BMJ*. 2012;345:e5605. doi:10.1136/bmj.e5605

44. Barakat R, Pelaez M, Lopez C, Lucia A, Ruiz JR. Exercise during pregnancy and gestational diabetes-related adverse effects: a randomised controlled trial. *Br J Sports Med*. 2013;47(10):630-636. doi:10.1136/bjsports-2012-091788

45. Bogaerts AF, Devlieger R, Nuyts E, Witters I, Gyselaers W, Van den Bergh BR. Effects of lifestyle intervention in obese pregnant women on gestational weight gain and mental health: a randomized controlled trial. *Int J Obes (Lond)*. 2013;37(6):814-821. doi:10.1038/ijo.2012.162

46. Ruiz JR, Perales M, Pelaez M, Lopez C, Lucia A, Barakat R. Supervised exercise-based intervention to prevent excessive gestational weight gain: a randomized controlled trial. *Mayo Clin Proc*. 2013;88(12):1388-1397. doi:10.1016/j.mayocp.2013.07.020

47. Barakat R, Perales M, Bacchi M, Coteron J, Refoyo I. A program of exercise throughout pregnancy: is it safe to mother and newborn? *Am J Health Promot*. 2014;29(1):2-8. doi:10.4278/ajhp.130131-QUAN-56

48. Hui AL, Back L, Ludwig S, et al. Effects of lifestyle intervention on dietary intake, physical activity level, and gestational weight gain in pregnant women with different pre-pregnancy body mass index in a randomized control trial. *BMC Pregnancy Childbirth*. 2014;14:331. doi:10.1186/1471-2393-14-331

49. Ko CW, Napolitano PG, Lee SP, Schulte SD, Ciol MA, Beresford SA. Physical activity, maternal metabolic measures, and the incidence of gallbladder sludge or stones during pregnancy: a randomized trial. *Am J Perinatol*. 2014;31(1):39-48. doi:10.1055/s-0033-1334455

50. Kong KL, Campbell CG, Foster RC, Peterson AD, Lanningham-Foster L. A pilot walking program promotes moderate-intensity physical activity during pregnancy. *Med Sci Sports Exerc*. 2014;46(3):462-471. doi:10.1249/MSS.0000000000000141

51. Vesco KK, Karanja N, King JC, et al. Efficacy of a group-based dietary intervention for limiting gestational weight gain among obese women: a randomized trial. *Obesity (Silver Spring)*. 2014;22(9):1989-1996. doi:10.1002/oby.20831

52. Gesell SB, Katula JA, Strickland C, Vitolins MZ. Feasibility and initial efficacy evaluation of a community-based cognitive-behavioral lifestyle intervention to prevent excessive weight gain during pregnancy in Latina women. *Matern Child Health J*. 2015;19(8):1842-1852. doi:10.1007/s10995-015-1698-x

53. Perales M, Refoyo I, Coteron J, Bacchi M, Barakat R. Exercise during pregnancy attenuates prenatal depression: a randomized controlled trial. *Eval Health Prof*. 2015;38(1):59-72. doi:10.1177/0163278714533566

54. Poston L, Bell R, Croker H, et al; UPBEAT Trial Consortium. Effect of a behavioural intervention in obese pregnant women (the UPBEAT study): a multicentre, randomised controlled trial. *Lancet Diabetes Endocrinol*. 2015;3(10):767-777. doi:10.1016/S2213-8587(15)00227-2

55. Barakat R, Pelaez M, Cordero Y, et al. Exercise during pregnancy protects against hypertension and macrosomia: randomized clinical trial. *Am J Obstet Gynecol*. 2016;214(5):649.e1-649.e8. doi:10.1016/j.ajog.2015.11.039

56. Garnæs KK, Mørkved S, Salvesen Ø, Moholdt T. Exercise training and weight gain in obese pregnant women: a randomized controlled trial (ETIP trial). *PLoS Med*. 2016;13(7):e1002079. doi:10.1371/journal.pmed.1002079

57. Koivusalo SB, Rönö K, Klemetti MM, et al. Gestational diabetes mellitus can be prevented by lifestyle intervention: the Finnish gestational diabetes prevention study (RADIEL): a randomized controlled trial. *Diabetes Care*. 2016;39(1):24-30. doi:10.2337/dc15-0511

58. Perales M, Calabria I, Lopez C, Franco E, Coteron J, Barakat R. Regular exercise throughout pregnancy is associated with a shorter first stage of labor. *Am J Health Promot*. 2016;30(3):149-154. doi:10.4278/ajhp.140221-QUAN-79

59. Wang C, Wei Y, Zhang X, et al. Effect of regular exercise commenced in early pregnancy on the incidence of gestational diabetes mellitus in overweight and obese pregnant women: a randomized controlled trial. *Diabetes Care*. 2016;39(10):e163-e164. doi:10.2337/dc16-1320

60. Assaf-Balut C, García de la Torre N, Durán A, et al. A Mediterranean diet with additional extra virgin olive oil and pistachios reduces the incidence of gestational diabetes mellitus (GDM): a randomized controlled trial: the St. Carlos GDM prevention study. *PLoS One*. 2017;12(10):e0185873. doi:10.1371/journal.pone.0185873

61. da Silva SG, Hallal PC, Domingues MR, et al. A randomized controlled trial of exercise during pregnancy on maternal and neonatal outcomes: results from the PAMELA study. *Int J Behav Nutr Phys Act*. 2017;14(1):175. doi:10.1186/s12966-017-0632-6

62. Daly N, Farren M, McKeating A, O'Higgins A, Mullaney L, Turner MJ. 34: Effect of a randomized controlled trial of an intensive medically supervised exercise program designed to improve maternal glucose control on gestational weight gain. *Am J Obstet Gynecol*. 2017;216(1)(suppl):S24. doi:10.1016/j.ajog.2016.11.926

63. Peaceman AM, Kwasny MJ, Gernhofer N, Vincent E, Josefson JL, Van Horn L. 2: MOMFIT: a randomized clinical trial of an intervention to prevent excess gestational weight gain in overweight and obese women. *Am J Obstet Gynecol*. 2017;216(1)(suppl):S2-S3. doi:10.1016/j.ajog.2016.11.003

64. Sagedal LR, Øverby NC, Bere E, et al. Lifestyle intervention to limit gestational weight gain: the Norwegian Fit for Delivery randomised controlled trial. *BJOG*. 2017;124(1):97-109. doi:10.1111/1471-0528.13862

65. Bacchi M, Mottola MF, Perales M, Refoyo I, Barakat R. Aquatic activities during pregnancy prevent excessive maternal weight gain and preserve birth weight: a randomized clinical trial. *Am J Health Promot*. 2018;32(3):729-735. doi:10.1177/0890117117697520

66. Barakat R, Franco E, Perales M, López C, Mottola MF. Exercise during pregnancy is associated with a shorter duration of labor. a randomized clinical trial. *Eur J Obstet Gynecol Reprod Biol*. 2018;224:33-40. doi:10.1016/j.ejogrb.2018.03.009

67. Kennelly MA, Ainscough K, Lindsay KL, et al. Pregnancy exercise and nutrition with smartphone application support: a randomized controlled trial. *Obstet Gynecol*. 2018;131(5):818-826. doi:10.1097/AOG.0000000000002582

68. Kiani Asiabar A, Amin Shokravi F, Hajifaraji M, Zayeri F. The effect of an educational intervention in early pregnancy with spouse's participation on optimal gestational weight gain in pregnancy: a randomized controlled trial. *Health Educ Res*. 2018;33(6):535-547. doi:10.1093/her/cyy040

69. Anleu E, Reyes M, Araya B M, Flores M, Uauy R, Garmendia ML. Effectiveness of an intervention of dietary counseling for overweight and obese pregnant women in the consumption of sugars and energy. *Nutrients*. 2019; 11(2):385. doi:10.3390/nu11020385

70. Barakat R, Refoyo I, Coteron J, Franco E. Exercise during pregnancy has a preventative effect on excessive maternal weight gain and gestational diabetes. a randomized controlled trial. *Braz J Phys Ther*. 2019;23(2): 148-155. doi:10.1016/j.bjpt.2018.11.005

71. Brik M, Fernández-Buhigas I, Martin-Arias A, Vargas-Terrones M, Barakat R, Santacruz B. Does exercise during pregnancy impact on maternal weight gain and fetal cardiac function: a randomized controlled trial. *Ultrasound Obstet Gynecol*. 2019;53(5):583-589. doi:10.1002/uog.20147

72. Pelaez M, Gonzalez-Cerron S, Montejo R, Barakat R. Protective effect of exercise in pregnant women including those who exceed weight gain recommendations: a randomized controlled trial. *Mayo Clin Proc*. 2019;94(10): 1951-1959. doi:10.1016/j.mayocp.2019.01.050

73. Rodríguez-Blanque R, Aguilar-Cordero MJ, Marín-Jiménez AE, Núñez-Negrillo AM, Sánchez-López AM, Sánchez-García JC. Influence of a water-based exercise program in the rate of spontaneous birth: a randomized clinical trial. *Int J Environ Res Public Health*. 2020;17(3):795. doi:10.3390/ijerph17030795

74. Briley C, Flanagan NL, Lewis N. In-home prenatal nutrition intervention increased dietary iron intakes and reduced low birthweight in low-income African-American women. *J Am Diet Assoc*. 2002;102(7):984-987. doi:10.1016/S0002-8223(02)90225-7

75. Khoury J, Henriksen T, Christophersen B, Tonstad S. Effect of a cholesterol-lowering diet on maternal, cord, and neonatal lipids, and pregnancy outcome: a randomized clinical trial. *Am J Obstet Gynecol*. 2005;193(4): 1292-1301. doi:10.1016/j.ajog.2005.05.016

76. Wolff S, Legarth J, Vangsgaard K, Toubro S, Astrup A. A randomized trial of the effects of dietary counseling on gestational weight gain and glucose metabolism in obese pregnant women. *Int J Obes (Lond)*. 2008;32(3): 495-501. doi:10.1038/sj.ijo.0803710

77. Asbee SM, Jenkins TR, Butler JR, White J, Elliot M, Rutledge A. Preventing excessive weight gain during pregnancy through dietary and lifestyle counseling: a randomized controlled trial. *Obstet Gynecol*. 2009;113(2 Pt 1):305-312. doi:10.1097/AOG.0b013e318195baef

78. Jeffries K, Shub A, Walker SP, Hiscock R, Permezel M. Reducing excessive weight gain in pregnancy: a randomised controlled trial. *Med J Aust*. 2009;191(8):429-433. doi:10.5694/j.1326-5377.2009.tb02877.x

79. Ong MJ, Guelfi KJ, Hunter T, Wallman KE, Fournier PA, Newnham JP. Supervised home-based exercise may attenuate the decline of glucose tolerance in obese pregnant women. *Diabetes Metab*. 2009;35(5):418-421. doi:10.1016/j.diabet.2009.04.008

80. Thornton YS, Smarkola C, Kopacz SM, Ishoof SB. Perinatal outcomes in nutritionally monitored obese pregnant women: a randomized clinical trial. *J Natl Med Assoc*. 2009;101(6):569-577. doi:10.1016/S0027-9684(15)30942-1

81. Hopkins SA, Baldi JC, Cutfield WS, McCowan L, Hofman PL. Exercise training in pregnancy reduces offspring size without changes in maternal insulin sensitivity. *J Clin Endocrinol Metab*. 2010;95(5):2080-2088. doi:10.1210/jc.2009-2255

82. Huang TT, Yeh CY, Tsai YC. A diet and physical activity intervention for preventing weight retention among Taiwanese childbearing women: a randomised controlled trial. *Midwifery*. 2011;27(2):257-264. doi:10.1016/j.midw.2009.06.009

83. Phelan S, Phipps MG, Abrams B, Darroch F, Schaffner A, Wing RR. Randomized trial of a behavioral intervention to prevent excessive gestational weight gain: the Fit for Delivery Study. *Am J Clin Nutr*. 2011;93(4): 772-779. doi:10.3945/ajcn.110.005306

84. Quinlivan JA, Lam LT, Fisher J. A randomised trial of a four-step multidisciplinary approach to the antenatal care of obese pregnant women. *Aust N Z J Obstet Gynaecol*. 2011;51(2):141-146. doi:10.1111/j.1479-828X.2010.01268.x

85. Korpi-Hyövälti E, Schwab U, Laaksonen DE, Linjama H, Heinonen S, Niskanen L. Effect of intensive counselling on the quality of dietary fats in pregnant women at high risk of gestational diabetes mellitus. *Br J Nutr*. 2012;108(5):910-917. doi:10.1017/S0007114511006118

86. Althuizen E, van der Wijden CL, van Mechelen W, Seidell JC, van Poppel MN. The effect of a counselling intervention on weight changes during and after pregnancy: a randomised trial. *BJOG*. 2013;120(1):92-99. doi:10.1111/1471-0528.12014

87. Deveer R, Deveer M, Akbaba E, et al. The effect of diet on pregnancy outcomes among pregnant with abnormal glucose challenge test. *Eur Rev Med Pharmacol Sci*. 2013;17(9):1258-1261.

88. Harrison CL, Lombard CB, Strauss BJ, Teede HJ. Optimizing healthy gestational weight gain in women at high risk of gestational diabetes: a randomized controlled trial. *Obesity (Silver Spring)*. 2013;21(5):904-909. doi:10.1002/oby.20163

89. Di Carlo C, Iannotti G, Sparice S, et al. The role of a personalized dietary intervention in managing gestational weight gain: a prospective, controlled study in a low-risk antenatal population. *Arch Gynecol Obstet*. 2014;289(4):765-770. doi:10.1007/s00404-013-3054-y

90. Dodd JM, Turnbull D, McPhee AJ, et al; LIMIT Randomised Trial Group. Antenatal lifestyle advice for women who are overweight or obese: LIMIT randomised trial. *BMJ*. 2014;348:g1285. doi:10.1136/bmj.g1285

91. Petrella E, Malavolti M, Bertarini V, et al. Gestational weight gain in overweight and obese women enrolled in a healthy lifestyle and eating habits program. *J Matern Fetal Neonatal Med*. 2014;27(13):1348-1352. doi:10.3109/14767058.2013.858318

92. Bisson M, Alméras N, Dufresne SS, et al. A 12-week exercise program for pregnant women with obesity to improve physical activity levels: an open randomised preliminary study. *PLoS One*. 2015;10(9):e0137742. doi:10.1371/journal.pone.0137742

93. Dekker Nitert M, Barrett HL, Denny KJ, McIntyre HD, Callaway LK; BAMBINO group. Exercise in pregnancy does not alter gestational weight gain, MCP-1 or leptin in obese women. *Aust N Z J Obstet Gynaecol*. 2015;55(1):27-33. doi:10.1111/ajo.12300

94. Ronnberg AK, Ostlund I, Fadl H, Gottvall T, Nilsson K. Intervention during pregnancy to reduce excessive gestational weight gain—a randomised controlled trial. *BJOG*. 2015;122(4):537-544. doi:10.1111/1471-0528.13131

95. Aşcı Ö, Rathfisch G. Effect of lifestyle interventions of pregnant women on their dietary habits, lifestyle behaviors, and weight gain: a randomized controlled trial. *J Health Popul Nutr*. 2016;35:7. doi:10.1186/s41043-016-0044-2

96. McCarthy EA, Walker SP, Ugoni A, Lappas M, Leong O, Shub A. Self-weighing and simple dietary advice for overweight and obese pregnant women to reduce obstetric complications without impact on quality of life: a randomised controlled trial. *BJOG*. 2016;123(6):965-973. doi:10.1111/1471-0528.13919

97. Seneviratne SN, Jiang Y, Derraik J, et al. Effects of antenatal exercise in overweight and obese pregnant women on maternal and perinatal outcomes: a randomised controlled trial. *BJOG*. 2016;123(4):588-597. doi:10.1111/1471-0528.13738

98. Bruno R, Petrella E, Bertarini V, Pedrielli G, Neri I, Facchinetti F. Adherence to a lifestyle programme in overweight/obese pregnant women and effect on gestational diabetes mellitus: a randomized controlled trial. *Matern Child Nutr*. 2017;13(3):e12333. doi:10.1111/mcn.12333

99. Sewell DA, Hammersley VS, Robertson A, et al. A pilot randomised controlled trial investigating a Mediterranean diet intervention in pregnant women for the primary prevention of allergic diseases in infants. *J Hum Nutr Diet*. 2017;30(5):604-614. doi:10.1111/jhn.12469

100. Cahill AG, Haire-Joshu D, Cade WT, et al. Weight control program and gestational weight gain in disadvantaged women with overweight or obesity: a randomized clinical trial. *Obesity (Silver Spring)*. 2018;26(3):485-491. doi:10.1002/oby.22070

101. Phelan S, Wing RR, Brannen A, et al. Randomized controlled clinical trial of behavioral lifestyle intervention with partial meal replacement to reduce excessive gestational weight gain. *Am J Clin Nutr*. 2018;107(2):183-194. doi:10.1093/ajcn/nqx043

102. H Al Wattar B, Dodds J, Placzek A, et al; ESTEEM study group. Mediterranean-style diet in pregnant women with metabolic risk factors (ESTEEM): a pragmatic multicentre randomised trial. *PLoS Med*. 2019;16(7):e1002857. doi:10.1371/journal.pmed.1002857

103. Buckingham-Schutt LM, Ellingson LD, Vazou S, Campbell CG. The Behavioral Wellness in Pregnancy study: a randomized controlled trial of a multi-component intervention to promote appropriate weight gain. *Am J Clin Nutr*. 2019;109(4):1071-1079. doi:10.1093/ajcn/nqy359

104. Clark E, Isler C, Strickland D, et al. Influence of aerobic exercise on maternal lipid levels and offspring morphometrics. *Int J Obes (Lond)*. 2019;43(3):594-602. doi:10.1038/s41366-018-0258-z

105. Daley A, Jolly K, Jebb SA, et al. Effectiveness of a behavioural intervention involving regular weighing and feedback by community midwives within routine antenatal care to prevent excessive gestational weight gain: POPS2 randomised controlled trial. *BMJ Open*. 2019;9(9):e030174. doi:10.1136/bmjopen-2019-030174

106. Kunath J, Günther J, Rauh K, et al. Effects of a lifestyle intervention during pregnancy to prevent excessive gestational weight gain in routine care—the cluster-randomised GeliS trial. *BMC Med*. 2019;17(1):5. doi:10.1186/s12916-018-1235-z

107. Arthur C, Di Corleto E, Ballard E, Kothari A. A randomized controlled trial of daily weighing in pregnancy to control gestational weight gain. *BMC Pregnancy Childbirth*. 2020;20(1):223. doi:10.1186/s12884-020-02884-1

108. Polley BA, Wing RR, Sims CJ. Randomized controlled trial to prevent excessive weight gain in pregnant women. *Int J Obes Relat Metab Disord*. 2002;26(11):1494-1502. doi:10.1038/sj.ijo.0802130

109. Jackson RA, Stotland NE, Caughey AB, Gerbert B. Improving diet and exercise in pregnancy with Video Doctor counseling: a randomized trial. *Patient Educ Couns*. 2011;83(2):203-209. doi:10.1016/j.pec.2010.05.019

110. Herring SJ, Cruice JF, Bennett GG, Rose MZ, Davey A, Foster GD. Preventing excessive gestational weight gain among African American women: a randomized clinical trial. *Obesity (Silver Spring)*. 2016;24(1):30-36. doi:10.1002/oby.21240

111. Smith K, Lanningham-Foster L, Welch A, Campbell C. Web-based behavioral intervention increases maternal exercise but does not prevent excessive gestational weight gain in previously sedentary women. *J Phys Act Health*. 2016;13(6):587-593. doi:10.1123/jpah.2015-0219

112. Sun Y, Zhao H. The effectiveness of lifestyle intervention in early pregnancy to prevent gestational diabetes mellitus in Chinese overweight and obese women: a quasi-experimental study. *Appl Nurs Res*. 2016;30:125-130. doi:10.1016/j.apnr.2015.10.006

113. Willcox JC, Wilkinson SA, Lappas M, et al. A mobile health intervention promoting healthy gestational weight gain for women entering pregnancy at a high body mass index: the txt4two pilot randomised controlled trial. *BJOG*. 2017;124(11):1718-1728. doi:10.1111/1471-0528.14552

114. Chan RS-M, Tam W-H, Ho IC-H, et al. Randomized trial examining effectiveness of lifestyle intervention in reducing gestational diabetes in high risk Chinese pregnant women in Hong Kong. *Sci Rep*. 2018;8(1):13849. doi:10.1038/s41598-018-32285-6

115. Olson CM, Groth SW, Graham ML, Reschke JE, Strawderman MS, Fernandez ID. The effectiveness of an online intervention in preventing excessive gestational weight gain: the e-moms roc randomized controlled trial. *BMC Pregnancy Childbirth*. 2018;18(1):148. doi:10.1186/s12884-018-1767-4

116. Ferrara A, Hedderson MM, Brown SD, et al. A telehealth lifestyle intervention to reduce excess gestational weight gain in pregnant women with overweight or obesity (GLOW): a randomised, parallel-group, controlled trial. *Lancet Diabetes Endocrinol*. 2020;8(6):490-500. doi:10.1016/S2213-8587(20)30107-8

117. Chao AM, Srinivas SK, Studt SK, Diewald LK, Sarwer DB, Allison KC. A pilot randomized controlled trial of a technology-based approach for preventing excess weight gain during pregnancy among women with overweight. *Front Nutr*. 2017;4:57. doi:10.3389/fnut.2017.00057

118. Hawkins M, Hosker M, Marcus BH, et al. A pregnancy lifestyle intervention to prevent gestational diabetes risk factors in overweight Hispanic women: a feasibility randomized controlled trial. *Diabet Med*. 2015;32(1):108-115. doi:10.1111/dme.12601

119. Simmons D, Devlieger R, van Assche A, et al. Effect of physical activity and/or healthy eating on GDM Risk: the DALI lifestyle study. *J Clin Endocrinol Metab*. 2017;102(3):903-913. doi:10.1210/jc.2016-3455

120. Bahri Khomami M, Teede HJ, Enticott J, O'Reilly S, Bailey C, Harrison CL. Implementation of antenatal lifestyle interventions into routine care: secondary analysis of a systematic review. *JAMA Netw Open*. 2022;5(10):e2234870. doi:10.1001/jamanetworkopen.2022.34870

121. Asim M, Ahmed ZH, Nichols AR, et al. What stops us from eating: a qualitative investigation of dietary barriers during pregnancy in Punjab, Pakistan. *Public Health Nutr*. 2022;25(3):760-769. doi:10.1017/S1368980021001737

122. Schwedhelm C, Lipsky LM, Temmen CD, Nansel TR. Eating patterns during pregnancy and postpartum and their association with diet quality and energy intake. *Nutrients*. 2022;14(6):1167. doi:10.3390/nu14061167

123. Howell S, Kones R. "Calories in, calories out" and macronutrient intake: the hope, hype, and science of calories. *Am J Physiol Endocrinol Metab*. 2017;313(5):E608-E612. doi:10.1152/ajpendo.00156.2017

124. Gardner B, Lally P, Wardle J. Making health habitual: the psychology of 'habit-formation' and general practice. *Br J Gen Pract*. 2012;62(605):664-666. doi:10.3399/bjgp12X659466

125. Moore SE, McMullan M, McEvoy CT, McKinley MC, Woodside JV. The effectiveness of peer-supported interventions for encouraging dietary behaviour change in adults: a systematic review. *Public Health Nutr*. 2019;22(4):624-644. doi:10.1017/S1368980018003294

126. Cuijpers P, Griffin JW, Furukawa TA. The lack of statistical power of subgroup analyses in meta-analyses: a cautionary note. *Epidemiol Psychiatr Sci*. 2021;30:e78. doi:10.1017/S2045796021000664

SUPPLEMENT 1.

eFigure. Diagram of Systematic Search
eTable 1. Subgroup Analyses of 13 Diet Interventions in Pregnant Individuals on Gestational Weight Gain and Intervention Component
eTable 2. Subgroup Analyses of 16 Diet With Physical Activity Interventions in Pregnant Individuals on Gestational Weight Gain and Intervention Components
eTable 3. Subgroup Analyses of 42 Physical Activity Interventions in Pregnant Individuals on Gestational Weight Gain and Intervention Components
eTable 4. Subgroup Analyses of 28 Mixed Interventions in Pregnant Individuals on Gestational Weight Gain and Intervention Components

SUPPLEMENT 2.

Data Sharing Statement