Check for updates

Accepted: 19 September 2022 | Published Online 17 October 2022

DOI: 10.1111/1471-0528.17304

BJOG An International Journal of Obstetrics and Gynaecology

RESEARCH ARTICLE

Epidemiology

Exercise during pregnancy for preventing gestational diabetes mellitus and hypertensive disorders: An umbrella review of randomised controlled trials and an updated meta-analysis

Vicente Martínez-Vizcaíno[1,2] | Gema Sanabria-Martínez[1] | Rubén Fernández-Rodríguez[1] | Iván Cavero-Redondo[1,2] | Carlos Pascual-Morena[1] | Celia Álvarez-Bueno[1,3] | José Alberto Martínez-Hortelano[1,4]

[1]Health and Social Research Centre, Universidad de Castilla-La Mancha, Cuenca, Spain

[2]Facultad de Ciencias de la Salud Talca, Universidad Autónoma de Chile, Providencia, Chile

[3]Universidad Politécnica y Artística del Paraguay, Yby Yaú, Paraguay

[4]Facultad de Enfermería, Universidad de Alcalá de Henares, Alcalá de Henares, Spain

Correspondence
Gema Sanabria-Martínez, Universidad de Castilla-La Mancha, Health and Social Research Centre, Cuenca, Spain.
Email: gema.sanabria@uclm.es

Funding information
Consejería de Educación, Cultura y Deportes—Junta de Comunidades de Castilla-La Mancha; FEDER Funds, Grant/Award Number: SBPLY/17/180501/000533

Abstract

Objective: This study aimed to provide, through an umbrella review, an overview of the effect of single exercise interventions during pregnancy on gestational diabetes mellitus (GDM) and hypertensive disorders of pregnancy (HDP). Also, to update the current evidence through an updated meta-analysis.

Design: Umbrella review.

Setting: PubMed, EMBASE, Web of Science, Cochrane database of systematic reviews, Epistemonikos, SPORTDiscus, Clinicaltrials.gov, and PROSPERO register were searched from the database inception until August 2021.

Population: Peer-reviewed systematic reviews and meta-analyses of randomised controlled trials (RCTs) and RCTs samples.

Methods: Random-effects model was used to calculate relative risk with 95% confidence interval in the updated meta-analysis. The reference category was the groups that received usual prenatal care. AMSTAR 2 and the Cochrane Collaboration tool were used to assess the quality and GRADE approach was used to assess the overall certainty of evidence.

Main outcome measures: GDM and HDP relative risk.

Results: Twenty-three systematic reviews and meta-analyses; and 63 RCTs were included. Single exercise interventions reduced the incidence of GDM and HDP in most systematic reviews and meta-analyses. Moreover, exercise interventions during pregnancy decrease the incidence of developing GDM and GH, particularly when they are supervised, have a low to moderate intensity level, and are initiated during the first trimester of pregnancy.

Abbreviations: CG, control group; ES, effect size; GDM, gestational diabetes mellitus; GRADE, Grading of Recommendations Assessment, Development and Evaluation; HDP, hypertensive disorders of pregnancy; IG, intervention group; OR, odds ratio; PA, physical activity; RCT, randomised controlled trials.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2022 The Authors. *BJOG: An International Journal of Obstetrics and Gynaecology* published by John Wiley & Sons Ltd.

Conclusion: Based on the findings, obstetric and physical exercise professionals could recommend exercise interventions during pregnancy as an effective strategy to improve maternal outcomes.

KEYWORDS
aerobic, diabetes, gestation, glucose, hypertension, maternal, motor activity, physical activity, pre-eclampsia, pregnancy

1 | INTRODUCTION

Gestational diabetes mellitus (GDM), defined as 'glucose intolerance and insulin resistance first detected during pregnancy',[1] affects approximately 7% of pregnant women. In more than 50% of cases, GDM may progress to type 2 diabetes mellitus, hypertension and cardiovascular diseases within 5–15 years after pregnancy.[2–6] Additionally, GDM is associated with several maternal and perinatal complications,[7] such as hypertensive disorders of pregnancy (HDP), which include gestational hypertension (GH), pre-eclampsia and eclampsia,[8] affecting 10% of pregnancies.[9] Likewise, HDP are associated with higher life-long cardiovascular risk.[10] Otherwise, fetal overgrowth or macrosomia is one of the fetal complications that occur in up to 45% of GDM pregnancies. These babies have an increased risk of overweight, obesity and type 2 diabetes later in life.[11]

Several studies have suggested that exercise is an effective strategy for preventing and treating diabetes and hypertension in the general population by reducing some of the mechanisms involved in inflammation, oxidative stress and endothelial dysfunction, all of which are pathophysiological mechanisms involved in the genesis of HDP and GDM.[9,12,13] That, in turn, is associated with obesity and physical inactivity.[14] However, the evidence about the effectiveness of exercise in avoiding the development of both disorders during pregnancy is still not consistent. Some reviews reported that physical activity (PA) programmes produced reductions in the prevalence of GDM.[15,16] Regarding the effect of exercise on pre-eclampsia or HDP incidence, some studies did not find protective effect of exercise in the incidence of pre-eclampsia or HDP.[17–20]

Comprehensive evidence synthesis is needed to explore further reasons for these conflicting findings.[21–26] Hence, this umbrella review and updated meta-analysis aimed to provide a comprehensive overview of the effect of exercise interventions during pregnancy on GDM and HDP.

2 | METHODS

This umbrella review of systematic reviews and meta-analyses was registered in PROSPERO (Registration number: CRD42019123410) and was developed according to PRISMA and the Cochrane Collaboration Handbook.[27,28] The review protocol has been published elsewhere.[29]

2.1 | Search methodology

The PubMed, EMBASE, Web of Science, Cochrane database of systematic reviews, Epistemonikos, SPORTDiscus, Clinicaltrials.gov and PROSPERO databases were systematically searched from inception to August 2021 for systematic reviews, meta-analyses and randomised controlled trials (RCTs) aimed at assessing the effect of exercise interventions during pregnancy on GDM and HDP.

The search strategy combined the following relevant terms: (1) patients (pregnant OR pregnancy OR gravid OR gestation* OR maternal); (2) intervention (aerobic OR sport OR exercise OR fitness OR "physical exercise" OR "physical activity" OR "motor activity"); (3) outcome (diabetes OR "diabetes mellitus" OR DM OR "gestational diabetes" OR "glucose intolerance" OR glucose OR insulin OR hyperglycemia OR toxaemia OR preeclampsia OR pre-eclampsia OR eclampsia OR "hypertensive disorders" OR "blood pressure" OR hypertension) (in more detail in Table S1). Additional reviews and RCTs were also identified by screening the references of the included reviews and meta-analyses (Table S2).

The search strategy was conducted independently by two researchers (GSM and JAMH) to avoid any selection bias. Disagreements were solved by consensus, but if discrepancies persisted, a third researcher was consulted (VMV).

2.2 | Study inclusion and exclusion criteria

Systematic reviews and meta-analyses of RCTs written in any language evaluating the effect of exercise interventions during pregnancy on GDM and HDP were selected. Reviews had to contain a quantitative assessment of the exercise effect on GDM and HDP. Diagnostic criteria for GDM varied among studies and were established in each individual trial. The health conditions under HDP were defined by the American College of Obstetricians and Gynecologists (ACOG):[30] pre-eclampsia–eclampsia, chronic hypertension, chronic hypertension with superimposed pre-eclampsia and GH. Participants should be pregnant women with no absolute or relative contraindications to be included in exercise programmes according to the 2020 ACOG recommendations on PA and exercise during pregnancy and postpartum.[31] Moreover, we excluded articles that only included women with a specific disease or with a high incidence of GDM or HDP. Finally, exercise programmes of all exercise

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

types at any level of intensity were included, but when the meta-analysis included studies with an additional intervention with a nutritional or behavioural component, only information from RCTs with exclusive exercise intervention was extracted. Reviews were excluded if women in the control groups (CGs) were not receiving usual prenatal care.

Two researchers (GSM and JAMH) independently assessed for eligibility in duplicate all abstracts and full texts, as recommended by the Cochrane Handbook.[28] Disagreements on study eligibility were discussed with the study team and resolved by consensus.

2.3 | Data extraction

Two researchers (GSM and JAMH) independently extracted data in ad hoc designed forms included in the umbrella review protocol.[29] Potential conflicts were discussed until consensus and a third researcher (VMV) was consulted when agreement was not reached. We collected first author, publication year, years for inclusion, number of RCTs included, intervention group (IG) and CG sample size, sample characteristics, outcomes of interest (GDM, GH, pre-eclampsia), number of cases in each group, pooled risk measure (relative risk or odds ratio [OR]), effect size and its 95% CI of the largest study and overall effect size, the heterogeneity (I^2) and any reported measures of publication bias. For each study, we extracted the first author, publication year, country, recruitment years, IG and CG sample size, intervention characteristics (type of exercise, when exercise intervention started and ended, length, session duration, frequency, intensity and supervision), setting, the outcome of interest, and IG and CG cases.

2.4 | Assessment of risk of bias

The methodological quality of the included reviews and meta-analyses was independently rated using the AMSTAR 2 tool by two researchers (GSM and JAMH). The AMSTAR2 is an instrument to critically assess the risk of bias of systematic reviews that consists of 16 different domains referring to relevant methodological aspects, which are answered with 'yes', 'no', 'cannot answer' and 'partial yes'. The overall quality of the studies was categorised as follows: high, moderate, low or critically low.[32]

Moreover, we assessed the risk of bias (quality) of the RCTs included in the updated meta-analysis using the Cochrane Collaboration risk of bias tool (Table S13), which assesses eight potential sources of bias: random sequence generation, allocation concealment, blinding of participants, evaluator and outcome assessments, incomplete outcome data, missing data, and other.[33]

The certainty of evidence and strength of recommendations from meta-analyses were assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) method.[34] This tool provides a system rate with four categories: 'high', when the systematic review or meta-analysis includes at least two high-quality primary studies; 'moderate', when it includes at least one high-quality or two moderate-quality primary studies; 'low' when it includes only moderate-quality and/or inconsistent results studies; and 'very low', when no medium- to high-quality studies were identified on this topic. Our starting point was 'high', and this grading decreased when we detected risk of bias, inconsistency of results (i.e. I^2 statistics >50%), indirectness of evidence (i.e. differences in intervention), imprecision (i.e. 95% CI includes 1.0) or publication bias (asymmetry in funnel plot). Additionally, the rating was increased if there was a large intervention effect, in case of a dose–response relation or if all plausible biases would decrease the magnitude of the intervention effect.[34] The GRADE assessment was performed independently by two researchers (GSM and JAMH) with discussion and agreement for any discrepancies.

2.5 | Statistical analysis

2.5.1 | Primary analysis

The primary analysis in the umbrella review was focused on one measure per individual study and each outcome. Forest plots were designed to synthesise all pooled estimates regarding the effect of exercise on the outcomes (GDM and HDP).

2.5.2 | Assessment of summary effects and heterogeneity

The summary meta-analytic odds ratio estimates and their corresponding 95% CI for each meta-analysis were displayed graphically using a random-effects model that was calculated by the original studies.[35,36] Additionally, a pooled analysis was performed with the RCTs included in the systematic reviews and meta-analyses. The RCTs identified in the update with the estimates and corresponding 95% CI using the fixed-effects or random-effects model.[35] In our study, the significance level of the p values for Egger's test was set at 0.10. For continuous data, we calculated the mean difference, the incidence difference or the Glass Δ.[37,38] Trial sequence analysis (TSA) was conducted (Tables S20–S22).[39] The heterogeneity between study associations was assessed using the I^2 statistic.[40]

Sensitivity analyses were conducted to assess the robustness of summary estimates and to detect whether any individual study accounted for a large proportion of heterogeneity.

2.5.3 | Subgroup analyses and meta-regression

Subgroup and meta-regression analyses were performed with original study data to examine the influence of some potential mediators on outcomes. For this purpose, the following subgroups were established: (1) body mass index (BMI) categories (>25 kg/m^2 or <25 kg/m^2); (2) pregnancy trimester in which the intervention was initiated (first or second); (3) session duration (>45 min or <45 min) and (4) supervision during the exercise intervention or not.

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

BJOG An International Journal of Obstetrics and Gynaecology

2.5.4 | Small studies effect assessment and excess significance biases

Egger's regression asymmetry test was used to calculate the evidence of small-study effects.[41] Therefore, a p value less than 0.10 was considered to show evidence of small-study effects.[41] Also, we assessed 'p-hacking'[42] and publication bias with PET-PEESE[43,44] and Rucker's analysis.[45]

All statistical analyses and power calculations were performed using STATA V.15.1 software (StataCorp, College Station, TX, USA).

3 | RESULTS

3.1 | Study selection and study characteristics

We retrieved 696 systematic reviews and meta-analyses after removing duplicates. The reasons to exclude studies are provided in Tables S18–S19. Finally, 23 systematic reviews and meta-analyses were included after full-text assessment (Tables 1 and 2), including 63 RCTs (10 485 and 11 192 women in IG and CG, respectively) (Figure S2). Among them, three RCTs published between 2016 and 2019 were not included in any systematic reviews and meta-analyses, which were selected for the meta-analysis update (Figure S3).[46–48] A characteristics summary of the included meta-analyses and RCTs can be found in Tables 1 and 2, and Tables S3 and S4.

3.2 | Risk of bias of included studies

The methodological quality scores of the 23 systematic reviews and meta-analyses assessed by AMSTAR 2 are shown in Table S5. Seven studies scored moderate quality (33%),[18,21,22,49–52] five scored low quality (21%),[26,53–56] and 11 scored critically low methodological quality (53%).[15,17,24,25,57–63] Only six studies provided an a priori protocol register,[18,21,22,26,49,54] and seven reported a list of excluded studies.[18,21,22,24,49,53,64]

According to the GRADE assessment, reviews included were considered low certainty. For the risk of bias, the scores were very serious because of the lack of blinding of participants (Table S6).

3.3 | Synthesis of results

3.3.1 | Gestational diabetes mellitus

Thirteen systematic reviews and meta-analyses found a reduction of GDM incidence in the exercise group[15,21,24,26,27,49–51,53,55,56,59,62,65] and seven did not find

TABLE 1 Meta-analysis of randomised control trials of gestational diabetes mellitus

Reference	Number of RCT	Sample IG/CG	Number of cases IG/CG	Type of measure (RR or OR)	RR/OR and 95% CI of the largest study	RR/OR and 95% CI	I^2 (%)
Aune et al.[24]	12	2015/2030	129/191	RR	0.78 (0.47–1.28)	0.69 (0.50–0.96)	30.2
Bennett et al.[49]	9	1736/1260	111/135	RR	0.70 (0.49–0.99)	0.65 (0.50–0.78)	0
Da Silva et al.[93]	11	1673/1689	NR	RR	0.70 (0.49–0.99)	0.67 (0.49–0.92)	33
Davenport et al.[21]	27	3505/3429	271/380	OR	0.62 (0.40–0.98)	0.62 (0.52–0.75)	0
Di Mascio et al.[56]	4	836/850	20/50	RR	NR	0.41 (0.24–0.68)	NR
Díaz-Burrueco et al.[50]	10	1159/1516	123/204	OR	NR	0.65 (0.43–0.98)	48
Guo et al.[51]	19	Total:5883	NR	RR	0.54 (0.37–0.79)	0.70 (0.59–0.84)	14.9
Han et al.[18]	3	437/389	30/24	RR	1.21 (0.67–2.18)	1.10 (0.66–1.84)	0
Magro-Malosso et al.[57]	7	748/602	40/53	RR	NR	0.61 (0.41–0.90)	NR
Ming et al.[53]	8	1472/1509	88/144	RR	0.70 (0.49–0.99)	0.58 (0.37–0.90)	46
Muhammad et al.[54]	6	314/318	73/101	RR	0.54 (0.37–0.79)	0.78 (0.51–1.19)	49
Nasiri-Amiri et al.[58]	8	727/714	143/196	RR	0.67 (0.47–0.96)	0.76 (0.56–1.03)	50
Rogozinska et al.[26]	27	3153/3015	240/347	OR	NR	0.66 (0.53–0.83)	0
Russo et al.[59]	10	1715/1686	116/159	RR	0.70 (0.49–0.99)	0.74 (0.57–0.97)	12
Sanabria et al.[15]	8	1434/1439	NR	RR	NR	0.69 (0.52–0.91)	0
Doi et al.[55]	11	722/745	100/148	RR	0.54 (0.37–0.79)	0.69 (0.51–0.94)	23.2
Song et al.[60]	10	Total: 4161	NR	RR	0.94 (0.59–1.50)	0.77 (0.54–1.09)	38
Xing et al.[61]	10	794/786	NR	RR	1.30 (0.93. 1.82)	0.71 (0.48–1.04)	63.1
Yin et al.[17]	5	497/450	34/34	RR	1.21 (0.67–2.18)	0.91 (0.57–1.44)	26
Yu et al.[62]	6	651/719	117/181	OR	0.62 (0.40–0.98)	0.59 (0.39–0.88)	46
Zheng et al.[63]	5	550/583	116/168	OR	0.62 (0.40–0.98)	0.62 (0.43–0.89)	37

Abbreviations: CG, control group; IG, intervention group; OR, odds ratio; RCT, randomised controlled trial; RR, relative risk.

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 2 Meta-analysis of randomised control trials of hypertensive disorders of pregnancy

Reference	Number of RCT	Sample IG/CG	Main outcome	Number of cases IG/CG	Type of measure (RR or OR)	RR/OR and 95% CI and of the largest study	RR/OR and 95% CI	I^2 (%)
Davenport et al.[21]	23	2627/2689	GH	61/105	OR	1 (0.46–2.19)	0.61 (0.43–0.85)	0
Magro-Malosso et al.[57]	16	2452/2189	GH	61/100	RR	NR	0.54 (0.40–0.74)	10
Xing et al.[61]	5	428/424	GH	NR	RR	0.74 (0.35–1.55)	0.53 (0.32–0.88)]	3.7
Davenport et al.[21]	16	1719/1603	PE	34/49	OR	0.80 (0.27–2.40)	0.59 (0.37–0.94)	0
Da Silva et al.[93]	4	709/708	PE	NR	RR	0.99 (0.50, 1.96)	0.93 (0.55–1.57)	0
Kramer et al.[64]	1	43/39	PE	7/6/	RR	1.17 (0.44–3.08)	1.17 (0.44–3.08)	NR
Magro-Malosso et al.,[57]	6	1164/1066	PE	26/30	RR	NR	0.79 (0.45–1.38)	0
Xing et al.[61]	5	499/505	PE	NR	RR	NR	1.00 (0.66–1.52)	0
Muhammad et al.[54]	5	324/326	GH and PE	23/30	RR	0.75 (0.36–1.55)	0.77 (0.46–1.30)	0
Rogozinska et al.[26]	20	2513/2359	HDP	106/147	OR	Not reported	0.68 (0.49–0.93)	0

Abbreviations: CG, control group; GH, gestational hypertension; HDP, hypertensive disorders of pregnancy; IG, intervention group; OR, odds ratio; PH, pre-eclampsia; RCT, randomised controlled trial; RR, relative risk.

effect of exercise on the incidence of GDM[18,54,58,60] (Figure 1 and Table S3). Among systematic review and meta-analyses that included women with overweight or obesity,[21,26,49,54,58,61] only one found that exercise reduced GDM incidence (Figure S3 and Table S7).[63]

Regarding the updated meta-analysis, 35 RCTs assessed the effect of exercise on GDM incidence,[46,66–99] whose pooled OR showed a decreased GDM incidence (OR 0.61; 95% CI 0.51–0.74; I^2 = 17.79; IG: n = 4935, CG: n = 5354) (Figure S4). The subgroup analyses (Table S8) showed that GDM incidence was reduced when the exercise intervention was: (1) initiated in the first trimester(OR 0.55; 95% CI 0.44–0.68; I^2 = 23.40; IG: n = 2775, CG: n = 2899); (2) supervised (OR 0.60; 95% CI 0.50–0.72; I^2 = 6.4%; IG: n = 3679, CG: n = 4670) and (3) light to moderate or moderate intensity (OR 0.58; 95% CI 0.39–0.87; I^2 = 0.00%; IG: n = 838, CG: n = 839; and OR 0.56; 95% CI 0.46–0.68; I^2 = 22.56%; IG: n = 2722, CG: n = 2887) (Table S8). Finally, longer exercise intervention did not reduce the GDM incidence more (OR −0.02, 95% CI −0.05 to 0.00; p = 0.06; IG: n = 4539, CG: n = 4936).

3.3.2 | Hypertensive disorders of pregnancy

Eight systematic reviews and meta-analyses assessed the effect of exercise on HDP incidence.[21,22,25,26,50,54,60,64] Three systematic reviews and meta-analyses assessed the effect of exercise interventions on GH incidence,[21,22,61] five on pre-eclampsia incidence,[21,22,25,61,64] three on HDP[22,26,50] and one on GH and pre-eclampsia incidence together (Table S4).[54]

All systematic reviews and meta-analyses reported a GH[21,22,61] and HDP[22,26,50] incidence reduction in the exercise group compared with the CG. The studies that reported the effect of exercise on pre-eclampsia incidence had mixed results: one found a decrease on the pre-eclampsia incidence in the exercise group[21] and four did not find effect.[22,25,61,64] Finally, the only study that reported GH and pre-eclampsia incidence together[54] did not find a decrease in the exercise group (Figure 2).

Among the systematic review and meta-analyses that included women with overweight or obesity,[21,26,54,61] one found a reduction in GH incidence,[61] while the others did not find an effect on GH[21] and HDP[21,26,54,61] (Figure S5 and Table S9).

Regarding the updated meta-analysis of RCTs, 28 of them assessed the effect of exercise on HDP incidence.[47,48,68,70,71,74,77,80,82,83,85–87,89–92,94,97,99–107] Among them, 22 studies assessed the effect of exercise on GH incidence,[67,69,70,72,74,76,87,88,89,90,93,94,96,97,100–104,108–110] 20 on pre-eclampsia incidence,[47,72,74,77,79,82,87,90,92–95,100,101,105–107,111–113] one on HDP incidence[114] and the other RCT reported data on eclampsia (Table S3).[98]

The pooled estimates show that exercise reduced the GH incidence (OR 0.53; 95% CI 0.40–0.71; I^2 = 0.00; IG: n = 2977, CG: n = 3067) (Figure S6). However, exercise did not reduce the incidence of preeclampsia (OR 0.81; 95% CI 0.61–1.07; I^2 = 0.00; IG: n = 2573, CG: n = 2771) (Figure S7). Subgroup

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

BJOG An International Journal of Obstetrics and Gynaecology

Reference	RCTs	Sample IG	Sample CG	Cases GDM IG	Cases GDM CG	OR (95% CI)	I^2(%)	p	AMSTAR-2
Aune et al. 2016	12	2015	2030	129	191	0.69 (0.50, 0.96)	30.2	0.15	red
Bennett et al. 2018	9	1736	1260	111	135	0.65 (0.50, 0.78)	0	0.91	green
Da Silva et al. 2017	11	1673	1689	NR	NR	0.67 (0.49, 0.92)	33	0.14	red
Davenport et al. 2018	27	3505	3429	271	380	0.62 (0.52, 0.75)	0	0.92	green
Di Mascio et al. 2016	4	836	850	20	50	0.41 (0.24, 0.68)	NR	NR	yellow
Díaz-Burrueco et al. 2021	10	1159	1516	123	204	0.65 (0.43, 0.98)	48	0.05	green
Guo et al. 2019	19	5883	NR	NR	NR	0.70 (0.59, 0.84)	14.9	0.3	green
Han et al. 2012	3	437	389	30	24	1.10 (0.66, 1.84)	0	0.37	green
Magro-Malosso et al. 2017	7	748	602	40	53	0.61 (0.41, 0.90)	NR	NR	red
Ming et al 2018	8	1472	1509	88	144	0.58 (0.37, 0.90)	46	0.07	yellow
Muhammad et al. 2020	6	314	318	73	101	0.78 (0.51, 1.19)	49	0.08	yellow
Nasiri-Amiri et al. 2019	8	727	714	143	196	0.76 (0.56, 1.03)	50	0.05	red
Rogozinska et al. 2017	27	3153	3015	240	347	0.66 (0.53, 0.83)	0	NR	yellow
Russo et al. 2015	10	1715	1686	116	159	0.74 (0.57, 0.97)	12	0.33	red
Sanabria et al. 2015	8	1434	1439	NR	NR	0.69 (0.52, 0.91)	0	0.61	red
Song et al. 2016	10	4161	NR	NR	NR	0.77 (0.54, 1.09)	38	0.11	red
Suhail et al. 2020	11	722	745	100	148	0.69 (0.51, 0.94)	23.2	0.02	yellow
Xing et al 2020	10	794	786	NR	NR	0.71 (0.48, 1.04)	63.1	0	red
Yin et al. 2014	5	497	450	34	34	0.91 (0.57, 1.44)	26	0.25	red
Yu et al. 2018	6	651	719	117	181	0.59 (0.39, 0.88)	46	0.11	red
Zheng et al. 2017	5	550	583	116	168	0.62 (0.43, 0.89)	37	0.19	red

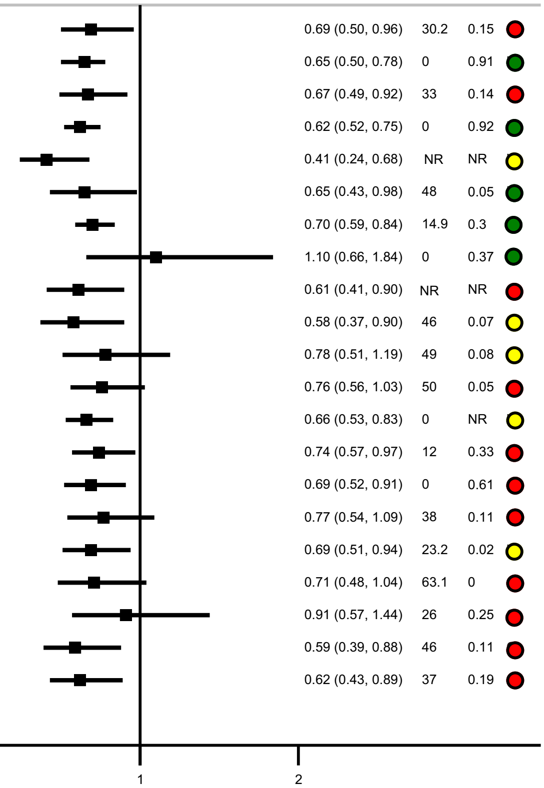

FIGURE 1 Exercise and gestational diabetes mellitus. Systematic review and meta-analyses.

analysis (Table S10) showed lower GH incidence in relation to their counterparts in the CGs in those studies that: (1) included women with all BMI categories (OR 0.50; 95% CI 0.37–0.68; I^2 = 0.00; IG: n = 2145, CG: n = 2332); (2) each session was longer than 45 minutes (OR 0.44; 95% CI 0.31–0.64; I^2 = 0.00; IG: n = 2166, CG: n = 2241); (3) started exercise interventions in the first and second trimester of pregnancy (OR 0.46; 95% CI 0.30–0.69; I^2 = 2.49; IG: n = 1451, CG: n = 1452 versus OR 0.40; 95% CI 0.20–0.79; I^2 = 0.00; IG: n = 1242, CG: n = 1255); (4) exercise was supervised (OR 0.55; 95% CI 0.41–0.73 I^2 = 0.00; IG: n = 2856, CG: n = 2957); and (5) the intensity of the exercise intervention was light to moderate or moderate, (OR 0.44; 95% CI 0.24–0.80; I^2 = 0.00%; IG: n = 657, CG: n = 658 and OR 0.58; 95% CI 0.41–0.81; I^2 = 22.56%; IG: n = 1874, CG: n = 1965). The pre-eclampsia incidence was only reduced when initiated in the first trimester (OR 0.34; 95% CI 0.14–0.87; I^2 = 0.00%; IG: n = 1451, CG: n = 1452) (Table S11). Finally, longer exercise intervention did not reduce more HDP incidence (OR −0.02; 95% CI −0.05 to 0.00; p = 0.17; IG: n = 3266, CG: n = 3544).

Trial sequence analysis

The results of trial sequence analysis are presented in Tables S20–S22 and Figures S8–S10. The required sample size was reached in the main analysis, except for the analysis that assessed the effect of PA intervention on pre-eclampsia.

Additionally, the meta-analysis of blood pressure value showed a reduction in the mean systolic blood pressure among women in the IG (−9.61 mmHg; 95% CI = −11.34 to −7.87 mmHg; I^2 = 93.83%; IG: n = 322, CG: n = 323) (Table S12).

Finally, there was no evidence of 'p-hacking' (Tables S30 and S35, Figures S23–S25) or publication bias according to the analyses that assessed the effect of PA intervention on GDM, or of GH on GDM, GH and pre-eclampsia (Figures S11–S22 and Tables S22–S28).

Sensitivity analyses showed that removing studies one-by-one did not modify the pooled odds ratio estimations or heterogeneity.

4 | DISCUSSION

4.1 | Main findings

Our umbrella review is the first that includes a meta-analysis update to summarise the evidence of the effect of single exercise interventions during pregnancy on GDM and HDP incidence. Based on 21 systematic reviews and meta-analyses, and 54 RCTs, we found that exercise interventions were more effective than standard prenatal care in reducing the incidence of GDM and GH by 39% and 47%, respectively. In contrast, our subgroup analyses showed no effect of exercise on the incidence of HDP in overweight and obese pregnant women or when sessions lasted less than 45 minutes. Meanwhile, our data suggest that exercise is more effective in reducing the GDM and HDP incidence when initiated in the first trimester

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

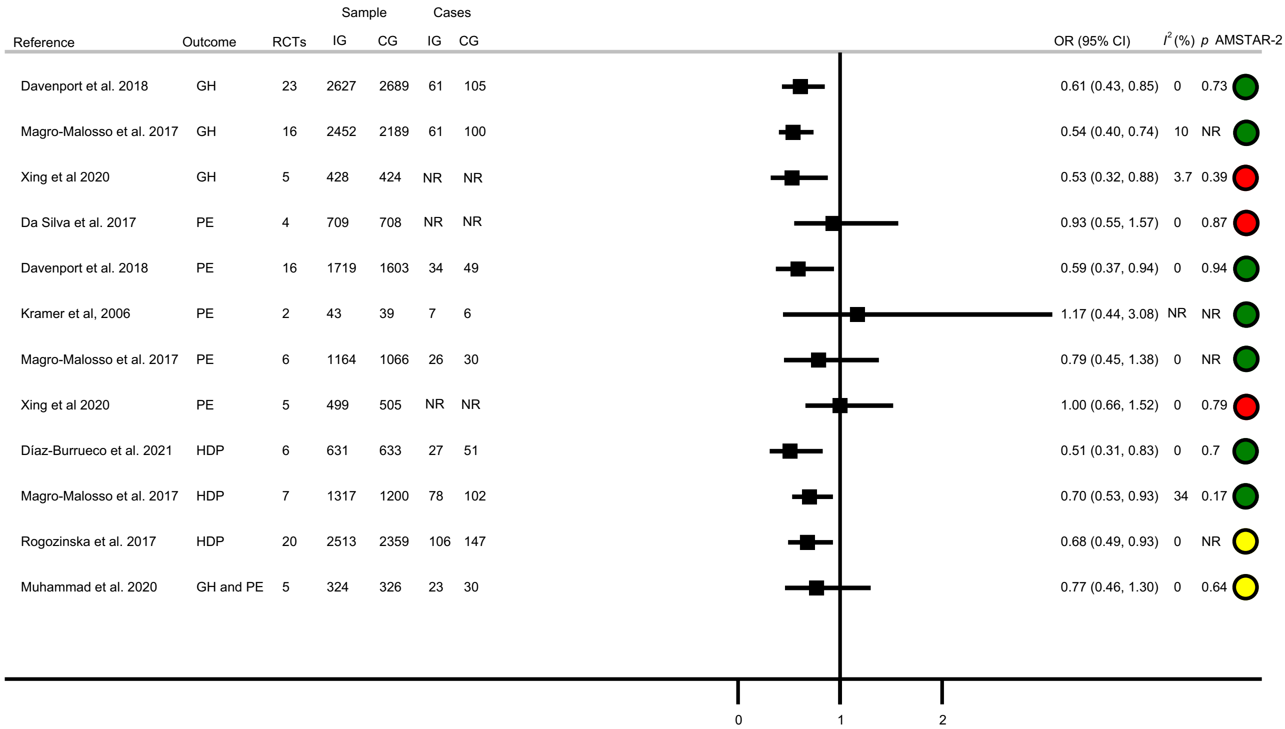

FIGURE 2 Exercise and hypertensive disorders of pregnancy. Systematic reviews and meta-analyses.

of pregnancy, under supervision and with light to moderate intensity, whereas exercise only reduced the incidence of pre-eclampsia when pregnant women started exercise in the first trimester of pregnancy. Trial sequence analysis indicates that additional studies are needed to elucidate the effect of PA interventions on pre-eclampsia incidence.

4.2 | Strengths and limitation

Among the strengths and what the study adds, we provide concrete recommendations about duration, intensity and the best moment to start PA intervention to reduce the incidence of GDM, GH and pre-eclampsia, as well as the need for evidence about the effect of PA on pre-eclampsia incidence.

Although this umbrella provides important insights, some limitations should be noted. First, most RCTs and meta-analyses have methodological shortcomings mainly because blinding is not possible in this type of intervention. Second, many of the reviews included in our umbrella review included the same primary studies, revealing a large overlap between published systematic reviews and meta-analyses (Tables S14–S17). We have conducted the pooled meta-analysis with original studies where each study counted once to avoid multiple contributions of the same studies. Third, we excluded studies that only included women with specific diseases, GDM or HDP. Fourth, an important limitation is that most primary studies did not provide data on the pre-pregnancy PA of participants; consequently, this important confounder was not controlled. Fifth, the included meta-analyses had a broad variety in their primary studies, mainly because of their different included and excluded criteria or the dates for developing, between others. Finally, as a result of the large amount of data, we decided to include only outcomes regarding GDM and HDP of the protocol published.

4.3 | Interpretation

Our estimates of a 39% reduction in the incidence of developing GDM agree with those reported by most systematic reviews and meta-analyses[15,21,24,26,49,53,55,58,61,62,65] and reveal that the reduction in GDM incidence still tends to be significant in most subgroup analyses (Table S8). However, six systematic reviews and meta-analyses included in our umbrella review did not find a reduction in GDM.[17,18,54,57,59,60] Most of these were conducted in pregnant women with obesity and overweight. It is known that exercise interventions are generally less effective in women with a high pre-pregnancy BMI.[49] This could be because the largest RCTs included initiated the intervention at 20 weeks of gestation, when insulin resistance is likely to have already developed.[75]

The updated meta-analysis shows that the incidence of GDM in the IGs is 39% lower than in the CGs. Furthermore, according to a previous systematic reviews and meta-analyses,[21] the incidence of GDM was lower when the intervention started during the first trimester of pregnancy, was supervised, or had a light to moderate level of intensity. In addition, supervision during exercise performance has been highlighted as an important determinant in adherence to exercise interventions, and so it would increase the effectiveness in preventing GDM.[115]

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

ACOG hypothesised that exercise could stimulate placental angiogenesis and improve maternal endothelial function.[116] Subsequent evidence supports that mild and moderate intensity exercise increases angiogenesis without increasing placental oxidative or endoplasmic stress.[117] However, the evidence about the effect of exercise on HDP incidence remains inconsistent.[21,54] Our analyses support, according to previous reports,[22,26] that exercise decreases GH but does not reduce the pre-eclampsia incidence.[22] This could be attributed to differences in the sample characteristics,[54] heterogeneity in the exercise intervention design, or that the number of studies included in the meta-analyses, or their statistical powers, was not sufficient[22] because pre-eclampsia is not a common disorder, occurring in 1.4–4% of all pregnancies.[118]

5 | CONCLUSIONS

In summary, the current evidence supports that exercise has a beneficial effect on the incidence of GDM and GH in non–overweight or obese pregnant women. Furthermore, these benefits are greater when exercise interventions are supervised, have a low to moderate intensity level, and are initiated during the first trimester of pregnancy. Nevertheless, more high-quality intervention studies are needed to accurately evaluate the safety and benefits of exercise programmes for specific pregnant populations, such as women with overweight and obesity, and whether higher intensity exercise interventions result in greater benefits in these groups. In addition, according to our data, to achieve greater benefits, the core of our recommendation for clinicians is that exercise should be supervised, initiated in the first trimester of pregnancy, and lasting more than 45 minutes per session. However, few studies have reported a reduction in HDP among women with overweight and obesity. More studies are needed to test the effectiveness of exercise interventions to reduce the incidence of pre-eclampsia in pregnant women with excess weight.

AUTHOR CONTRIBUTIONS

All authors conceived and designed the study. GSM, JAMH and VMV acquired and collected the data. GSM, JAMH, RFR, CPM, CAB, ICR and VMV analysed the data. All authors drafted and critically revised the manuscript for important intellectual content and gave final approval of the version to be published.

ACKNOWLEDGEMENTS

None.

FUNDING INFORMATION

This study was funded by the Consejería de Educación, Cultura y Deportes—Junta de Comunidades de Castilla-La Mancha and FEDER funds (SBPLY/17/180501/000533). CP-M is supported by a grant from the Universidad de Castilla-La Mancha (2018-CPUCLM-7939).

CONFLICT OF INTEREST

None declared. Completed disclosure of interests form available to view online as supporting information.

DATA AVAILABILITY STATEMENT

The protocol can be accessed on PROSPERO (Registration number: CRD42019123410). The review protocol has also been published.[29] In addition, data can be accessed upon request by e-mailing the corresponding author (gema.sanabria@uclm.es). Reuse only with permission and with citation. The data that support the findings of this study are available in the Supplementary material of this article.

ORCID

Gema Sanabria-Martínez https://orcid.org/0000-0001-7593-6864
Carlos Pascual-Morena https://orcid.org/0000-0003-1154-8752
José Alberto Martínez-Hortelano https://orcid.org/0000-0001-6477-5014

REFERENCES

1. Committee on Practice Bulletins—Obstetric. ACOG practice bulletin no. 190: gestational diabetes mellitus. Obstet Gynecol. 2018;131:e49–64.
2. Casagrande SS, Linder B, Cowie CC. Prevalence of gestational diabetes and subsequent type 2 diabetes among U.S. women. Diabetes Res Clin Pract. 2018;141:200–8.
3. Deputy NP, Kim SY, Conrey EJ, Bullard KM. Prevalence and changes in preexisting diabetes and gestational diabetes among women who had a live birth—United States, 2012-2016. MMWR Morb Mortal Wkly Rep. 2016;67:1201–7.
4. Eades CE, Cameron DM, Evans JMM. Prevalence of gestational diabetes mellitus in Europe: a meta-analysis. Diabetes Res Clin Pract. 2017;129:173–81. https://doi.org/10.1016/j.diabres.2017.03.030
5. Tobias DK, Zhang C, van Dam RM, Bowers K, Hu FB. Physical activity before and during pregnancy and risk of gestational diabetes mellitus: a meta-analysis. Diabetes Care. 2011;34(1):223–9. https://doi.org/10.2337/dc10-1368
6. Lind JM, Hennessy A, McLean M. Cardiovascular disease in women: the significance of hypertension and gestational diabetes during pregnancy. Curr Opin Cardiol. 2014;29:447–53.
7. American Diabetes Association. 2. Classification and diagnosis of diabetes: standards of medical care in diabetes-2020. Diabetes Care. 2020;43:514–31.
8. Kampmann U, Madsen LSG. Gestational diabetes: a clinical update. World J Diabetes. 2015;6:1065–72.
9. Magee LA, Pels A, Helewa M, Rey E, von Dadelszen P, SOGC Hypertension Guideline Committee. Evaluation, and management of the hypertensive disorders of pregnancy: executive summary. J Obstet Gynaecol Can. 2014;36:575–6.
10. Lane-Cordova AD, Khan SS, Grobman WA, Greenland P, Shah SJ. Long-term cardiovascular risks associated with adverse pregnancy outcomes. J Am Coll Cardiol. 2019;73:2106–16.
11. Kc K, Shakya S, Zhang H. Gestational diabetes mellitus and macrosomia: a literature review. Ann Nutr Metab. 2015;66(2):14–20. https://doi.org/10.1159/000371628
12. Sibai BM, Ross MG. Hypertension in gestational diabetes mellitus: pathophysiology and long-term consequences. J Matern Neonatal Med. 2010;23:229–33.
13. Thompson D, Berger H, Feig D, Gagnon R, Kader T, Keely E, et al. Diabetes and pregnancy. Can J Diabetes. 2013;37:S168–83. https://doi.org/10.1016/j.jcjd.2013.01.044

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

14. Padayachee C, Coombes JS. Exercise guidelines for gestational diabetes mellitus. World J Diabetes. 2015;6(8):1033–44. https://doi.org/10.4239/wjd.v6.i8.1033
15. Sanabria-Martínez G, García-Hermoso A, Poyatos-León R, Álvarez-Bueno C, Sánchez-López M, Martínez-Vizcaíno V. Effectiveness of physical activity interventions on preventing gestational diabetes mellitus and excessive maternal weight gain: a meta-analysis. BJOG. 2015;122(9):1167–74. https://doi.org/10.1111/1471-0528.13429
16. Du MC, Ouyang YQ, Nie XF, Huang YRS. Effects of physical exercise during pregnancy on maternal and infant outcomes in overweight and obese pregnant women: a meta-analysis. Birth. 2018;46:211–21.
17. Yin Y, Li X, Tao T, Luo BR, Liao SJ. Physical activity during pregnancy and the risk of gestational diabetes mellitus: a systematic review and meta-analysis of randomised controlled trials. Br J Sports Med. 2014;48(4):290–5. https://doi.org/10.1136/bjsports-2013-092596
18. Han S, Middleton P, Crowther CA. Exercise for pregnant women for preventing gestational diabetes mellitus. Cochrane Database Syst Rev. 2012;(7):CD009021. https://doi.org/10.1002/14651858.CD009021.pub2
19. Rudra CB, Sorensen TK, Luthy DA, Williams MA. A prospective analysis of recreational physical activity and preeclampsia risk. Med Sci Sports Exerc. 2008;40:1581–8.
20. Vollebregt KC, Wolf H, Boer K, van der Wal MF, Vrijkotte TG, Bonsel GJ. Does physical activity in leisure time early in pregnancy reduce the incidence of preeclampsia or gestational hypertension? Acta Obstet Gynecol Scand. 2010;89:261–7.
21. Davenport MH, Ruchat S-M, Poitras VJ, et al. Prenatal exercise for the prevention of gestational diabetes mellitus and hypertensive disorders of pregnancy: a systematic review and meta-analysis. Br J Sports Med. 2018;52(21):1367–75. https://doi.org/10.1136/bjsports-2018-099355
22. Magro-Malosso ER, Saccone G, Di Tommaso M, Roman A, Berghella V. Exercise during pregnancy and risk of gestational hypertensive disorders: a systematic review and meta-analysis. Acta Obstet Gynecol Scand. 2017;96(8):921–31. https://doi.org/10.1111/aogs.13151
23. Poyatos-Leon R, Garcia-Hermoso A, Sanabria-Martinez G, Alvarez-Bueno C, Cavero-Redondo I, Martinez-Vizcaino V. Effects of exercise-based interventions on postpartum depression: a meta-analysis of randomized controlled trials. Birth. 2017;44(3):200–8. https://doi.org/10.1111/birt.12294
24. Aune D, Sen A, Henriksen T, Saugstad OD, Tonstad S. Physical activity and the risk of gestational diabetes mellitus: a systematic review and dose-response meta-analysis of epidemiological studies. Eur J Epidemiol. 2016;31(10):967–97. https://doi.org/10.1007/s10654-016-0176-0
25. Silva S, Ricardo LI, Evenson KR, Hallal PC. Leisure-time physical activity in pregnancy and maternal-child health: a systematic review and meta-analysis of randomized controlled trials and cohort studies. Sports Med. 2017;47(2):295–317. https://doi.org/10.1007/s40279-016-0565-2
26. Rogozinska E, Marlin N, Betran AP, Astrup A, Barakat R, Bogaerts A, et al. 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. https://doi.org/10.1136/bmj.j3119
27. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg. 2010;8(5):336–41. https://doi.org/10.1016/j.ijsu.2010.02.007
28. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions. Version 6.2, 2021. Part 1, Chapter V: Overviews of Reviews. *Handbook*. 2011;2:649.
29. Sanabria-Martínez G, Poyatos-León R, Notario-Pacheco B, Álvarez-Bueno C, Cavero-Redondo I, Martinez-Vizcaino V. Effects of physical exercise during pregnancy on mothers' and neonates' health: a protocol for an umbrella review of systematic reviews and meta-analysis of randomised controlled trials. BMJ Open. 2019;9(9):e030162. https://doi.org/10.1136/bmjopen-2019-030162
30. American College of Obstetricians and Gynecologists. Task force on hypertension in pregnancy. Hypertension in pregnancy. Obstet Gynecol. 2013;122(5):1122–31. https://doi.org/10.1097/01.AOG.0000437382.03963.88
31. ACOG Committee opinion N 804. Physical activity and exercise during pregnancy and the postpartum period. Obstet Gynecol. 2020;135(4):e178–88. https://doi.org/10.1097/AOG.0000000000003772
32. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358:j4008. https://doi.org/10.1136/bmj.j4008
33. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928.
34. Guyatt GH. GrADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ. 2008;336:924–6. https://doi.org/10.1136/bmj.39489.470347.AD
35. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7(3):177–88. https://doi.org/10.1016/0197-2456(86)90046-2
36. Lau J, Ioannidis JPA, Schmid CH. Quantitative synthesis in systematic reviews. Ann Intern Med. 1997;127(9):820–6. https://doi.org/10.7326/0003-4819-127-9-199711010-00008
37. Fusar-Poli P, Radua J. Ten simple rules for conducting umbrella reviews. Evid Based Ment Health. 2018;21(3):95–100. https://doi.org/10.1136/ebmental-2018-300014
38. Chinn S. A simple method for converting an odds ratio to effect size for use in meta-analysis. Stat Med. 2000;19(22):3127–31. https://doi.org/10.1002/1097-0258(20001130)19:22<3127::AID-SIM784>3.0.CO;2-M
39. Brok J, Thorlund K, Gluud C, Wetterslev J. Trial sequential analysis reveals insufficient information size and potentially false positive results in many meta-analyses. J Clin Epidemiol. 2008;61(8):763–9.
40. Deeks JJ, Higgins JP, Altman DG. Analysing data and undertaking meta-analyses. In: Higgins JPT, Green S, editors. Cochrane handbook for systematic reviews of interventions. Chichester, UK: John Wiley & Sons, Ltd; 2008. p. 243–96. https://doi.org/10.1002/9780470712184.ch9
41. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629–34. https://doi.org/10.1136/BMJ.315.7109.629
42. Simonsohn U, Nelson LD, Simmons JP. P-curve: a key to the file-drawer. J Exp Psychol Gen. 2014;143(2):534.
43. Stanley TD. Meta-regression methods for detecting and estimating empirical effects in the presence of publication selection. Oxf Bull Econ Stat. 2008;70(1):103–27.
44. Stanley TD, Doucouliagos H. Meta-regression approximations to reduce publication selection bias. Res Synth Methods. 2014;5(1):60–78.
45. Rücker G, Schwarzer G, Carpenter JR, Binder H, Schumacher M. Treatment-effect estimates adjusted for small-study effects via a limit meta-analysis. Biostatistics. 2011;12(1):122–42.
46. 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):1951–9. https://doi.org/10.1016/j.mayocp.2019.01.050
47. Taniguchi C, Sato C. Home-based walking during pregnancy affects mood and birth outcomes among sedentary women: a randomized controlled trial. Int J Nurs Pract. 2016;22(5):420–6. https://doi.org/10.1111/ijn.12453
48. Khoram S, Loripoor M, Pirhadi M, Beigi M. The effect of walking on pregnancy blood pressure disorders in women susceptible to

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

pregnancy hypertension: a randomized clinical trial. J Educ Health Promot. 2019;8(1):95. https://doi.org/10.4103/jehp.jehp_378_18
49. Bennett CJ, Walker RE, Blumfield ML, Gwini SM, Ma J, Wang F, et al. Interventions designed to reduce excessive gestational weight gain can reduce the incidence of gestational diabetes mellitus: a systematic review and meta-analysis of randomised controlled trials. Diabetes Res Clin Pract. 2018;141:69–79. https://doi.org/10.1016/j.diabres.2018.04.010
50. Díaz-Burrueco JR, Cano-Ibáñez N, Martín-Peláez S, Khan KS, Amezcua-Prieto C. Effects on the maternal-fetal health outcomes of various physical activity types in healthy pregnant women. A systematic review and meta-analysis. Eur J Obstet Gynecol Reprod Biol. 2021;262:203–15. https://doi.org/10.1016/j.ejogrb.2021.05.030
51. Guo X-Y, Shu J, Fu X-H, Chen XP, Zhang L, Ji MX, et al. Improving the effectiveness of lifestyle interventions for gestational diabetes prevention: a meta-analysis and meta-regression. BJOG. 2019;126(3):311–20. https://doi.org/10.1111/1471-0528.15467
52. Kramer MS. Regular aerobic exercise during pregnancy. Cochrane Database Syst Rev. 2000;(2):CD000180. https://doi.org/10.1002/14651858.CD000180
53. Ming WK, Ding W, Zhang CJP, Zhong L, Long Y, Li Z, et al. The effect of exercise during pregnancy on gestational diabetes mellitus in normal-weight women: a systematic review and meta-analysis. BMC Pregnancy Childbirth. 2018;18(1):440. https://doi.org/10.1186/s12884-018-2068-7
54. Muhammad HFL, Pramono A, Rahman MN. The safety and efficacy of supervised exercise on pregnant women with overweight/obesity: a systematic review and meta-analysis of randomized controlled trials. Clin Obes. 2020;11:e12428. https://doi.org/10.1111/cob.12428
55. Doi SAR, Furuya-Kanamori L, Toft E, Musa OAH, Mohamed AM, Clark J, et al. Physical activity in pregnancy prevents gestational diabetes: a meta-analysis. Diabetes Res Clin Pract. 2020;168:108371. https://doi.org/10.1016/j.diabres.2020.108371
56. Di Mascio D, Magro-Malosso ER, Saccone G, Marhefka GD, Berghella V. Exercise during pregnancy in normal-weight women and risk of preterm birth: a systematic review and meta-analysis of randomized controlled trials. Am J Obstet Gynecol. 2016;215(5):561–71. https://doi.org/10.1016/j.ajog.2016.06.014
57. Magro-Malosso ER, Saccone G, Di Mascio D, Di Tommaso M, Berghella V. Exercise during pregnancy and risk of preterm birth in overweight and obese women: a systematic review and meta-analysis of randomized controlled trials. Acta Obstet Gynecol Scand. 2017;96(3):263–73. https://doi.org/10.1111/aogs.13087
58. Nasiri-Amiri F, Sepidarkish M, Shirvani MA, Habibipour P, Tabari NSM. The effect of exercise on the prevention of gestational diabetes in obese and overweight pregnant women: a systematic review and meta-analysis. Diabetol Metab Syndr. 2019;11:72. https://doi.org/10.1186/s13098-019-0470-6
59. Russo LM, Nobles C, Ertel KA, Chasan-Taber L, Whitcomb BW. Physical activity interventions in pregnancy and risk of gestational diabetes mellitus: a systematic review and meta-analysis. Obstet Gynecol. 2015;125(3):576–82. https://doi.org/10.1097/AOG.0000000000000691
60. Song C, Li J, Leng J, Ma RC, Yang X. Lifestyle intervention can reduce the risk of gestational diabetes: a meta-analysis of randomized controlled trials. Obes Rev. 2016;17(10):960–9. https://doi.org/10.1111/obr.12442
61. Xing Y, Wang X, Zhang W, Jiang H. The effect of exercise on maternal complications and birth outcomes in overweight or obese pregnant women: a meta-analysis. Ann Palliat Med. 2020;9(6):4103–12. https://doi.org/10.21037/apm-20-2097
62. Yu Y, Xie R, Shen C, Shu L. Effect of exercise during pregnancy to prevent gestational diabetes mellitus: a systematic review and meta-analysis. J Matern Fetal Neonatal Med. 2018;31(12):1632–7. https://doi.org/10.1080/14767058.2017.1319929
63. Zheng J, Wang H, Ren M. Influence of exercise intervention on gestational diabetes mellitus: a systematic review and meta-analysis. J Endocrinol Invest. 2017;40(10):1027–33. https://doi.org/10.1007/s40618-017-0673-3
64. Kramer MS, McDonald SW. Aerobic exercise for women during pregnancy. Cochrane Database Syst Rev. 2006;2006(3):CD000180. https://doi.org/10.1002/14651858.CD000180.pub2
65. da Silva SG, da Silva BGC, Coll CVN, Domingues MR, Evenson KR, Hallal PC. Effects of an exercise intervention on gestational weight gain. Med Sci Sports Exerc. 2016;48:644. https://doi.org/10.1249/01.mss.0000486931.59434.ce
66. Barakat R, Lucia A, Ruiz JR. Resistance exercise training during pregnancy and newborn's birth size: a randomised controlled trial. Int J Obes (Lond). 2009;33(9):1048–57. https://doi.org/10.1038/ijo.2009.150
67. Callaway LK, Colditz PB, Byrne NM, Lingwood BE, Rowlands IJ, Foxcroft K, et al. Prevention of gestational diabetes: feasibility issues for an exercise intervention in obese pregnant women. Diabetes Care. 2010;33(7):1457–9. https://doi.org/10.2337/dc09-2336
68. Cordero Y, Mottola MF, Vargas J, Blanco M, Barakat R. Exercise is associated with a reduction in gestational diabetes mellitus. Med Sci Sports Exerc. 2015;47(7):1328–33. https://doi.org/10.1249/MSS.0000000000000547
69. Daly N, Farren M, McKeating A, O'Kelly R, Stapleton M, Turner MJ. A medically supervised pregnancy exercise intervention in obese women: a randomized controlled trial. Obstet Gynecol. 2017;130(5):1001–10. https://doi.org/10.1097/AOG.0000000000002267
70. Garnæs KK, Mørkved S, Salvesen Ø, Moholdt T. Exercise training in pregnancy for women with Bmi ≥ 28. A randomized controlled trial. Med Sci Sports Exerc. 2016;48:931–2. https://doi.org/10.1249/01.mss.0000487788.31806.bb
71. Guelfi KJ, Ong MJ, Crisp NA, Fournier PA, Wallman KE, Grove JR, et al. Regular exercise to prevent the recurrence of gestational diabetes mellitus: a randomized controlled trial. Obstet Gynecol. 2016;128:819–27. https://doi.org/10.1097/AOG.0000000000001632
72. Hui AL, Back L, Ludwig S, Gardiner P, Sevenhuysen G, Dean HJ, 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. https://doi.org/10.1186/1471-2393-14-331
73. Ko CW, Napolitano PG, Lee SP, Schulte SD, Ciol MA, Beresford SAA. 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. https://doi.org/10.1055/s-0033-1334455
74. 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):462–71. https://doi.org/10.1249/MSS.0000000000000141
75. Nobles C, Marcus BH, Stanek EJ 3rd, Braun B, Whitcomb BW, Manson JE, et al. The effect of an exercise intervention on gestational weight gain: the behaviors affecting baby and you (B.A.B.Y.) study: a randomized controlled trial. Am J Health Promot. 2018;32(3):736–44. https://doi.org/10.1177/0890117117732409
76. Okido MM, Valeri FL, Martins WP, Ferreira CHJ, Duarte G, Cavalli RC. Assessment of foetal wellbeing in pregnant women subjected to pelvic floor muscle training: a controlled randomised study. Int Urogynecol J. 2015;26(10):1475–81. https://doi.org/10.1007/s00192-015-2719-4
77. 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):656–61. https://doi.org/10.1136/bjsports-2011-090009
78. Oostdam N, van Poppel MN, Wouters MG, Eekhoff EM, Bekedam DJ, Kuchenbecker WK, 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):1098–107. https://doi.org/10.1111/j.1471-0528.2012.03366.x
79. Petrella E, Malavolti M, Bertarini V, Pignatti L, Neri I, Battistini NC, et al. Gestational weight gain in overweight and obese women

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

enrolled in a healthy lifestyle and eating habits program. J Matern Neonatal Med. 2014;27(13):1348–52. https://doi.org/10.3109/14767058.2013.858318
80. Renault KM, Nørgaard K, Nilas L, Carlsen EM, Cortes D, Pryds O, et al. The treatment of obese pregnant women (TOP) study: a randomized controlled trial of the effect of physical activity intervention assessed by pedometer with or without dietary intervention in obese pregnant women. Am J Obstet Gynecol. 2014;210(2):134.e1–9. https://doi.org/10.1016/j.ajog.2013.09.029
81. Cordero Rodríguez Y, Puente MP, De M, Abad M, Santaella MP, Carballo RB. Can moderate physical exercise during pregnancy act as a factor in preventing gestational diabetes. Rev Int Cienc Deporte. 2012;8(27):3–19. https://doi.org/10.5232/ricyde2012.02701
82. 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):1388–97. https://doi.org/10.1016/j.mayocp.2013.07.020
83. Seneviratne SN, Jiang Y, Derraik J, McCowan L, Parry GK, Biggs JB, 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):588–97. https://doi.org/10.1111/1471-0528.13738
84. Simmons D, Devlieger R, van Assche A, Jans G, Galjaard S, Corcoy R, et al. Effect of physical activity and/or healthy eating ongdm risk: the Dali lifestyle study. J Clin Endocrinol Metab. 2017;102(3):903–13. https://doi.org/10.1210/jc.2016-3455
85. Stafne SN, Salvesen KÅ, Romundstad PR, Eggebø TM, Carlsen SM, Mørkved S. Regular exercise during pregnancy to prevent gestational diabetes: a randomized controlled trial. Obstet Gynecol. 2012;119(1):29–36. https://doi.org/10.1097/AOG.0b013e3182393f86
86. Tomić V, Sporiš G, Tomić J, Milanović Z, Zigmundovac-Klaić D, Pantelić S. The effect of maternal exercise during pregnancy on abnormal fetal growth. Croat Med J. 2013;54(4):362–8. https://doi.org/10.3325/cmj.2013.54.362
87. Ussher M, Lewis S, Aveyard P, Manyonda I, West R, Lewis B, et al. The London exercise and pregnant smokers (LEAP) trial: a randomised controlled trial of physical activity for smoking cessation in pregnancy with an economic evaluation. Health Technol Assess. 2015;19(84):1–135. https://doi.org/10.3310/hta19840
88. 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 Neonatal Med. 2012;25(11):2372–6. https://doi.org/10.3109/14767058.2012.696165
89. Vinter CA, Jensen DM, Ovesen P, Beck-Nielsen H, Jørgensen JS. The LiP (lifestyle in pregnancy) study: a randomized controlled trial of lifestyle intervention in 360 obese pregnant women. Diabetes Care. 2011;34(12):2502–7. https://doi.org/10.2337/dc11-1150
90. Wang C, Wei Y, Zhang X, Zhang Y, Xu Q, Sun Y, et al. A randomized clinical trial of exercise during pregnancy to prevent gestational diabetes mellitus and improve pregnancy outcome in overweight and obese pregnant women. Am J Obstet Gynecol. 2017;216(4):340–51. https://doi.org/10.1016/j.ajog.2017.01.037
91. 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):2263–9. https://doi.org/10.1249/MSS.0b013e318267ad67
92. Rakhshani A, Nagarathna R, Mhaskar R, Mhaskar A, Thomas A, Gunasheela S. The effects of yoga in prevention of pregnancy complications in high-risk pregnancies: a randomized controlled trial. Prev Med. 2012;55(4):333–40. https://doi.org/10.1016/j.ypmed.2012.07.020
93. da Silva SG, Hallal PC, Domingues MR, Bertoldi AD, Silveira MFD, Bassani D, 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. https://doi.org/10.1186/s12966-017-0632-6
94. 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):630–6. https://doi.org/10.1136/bjsports-2012-091788
95. 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. https://doi.org/10.4278/ajhp.130131-QUAN-56
96. Barakat R, Pelaez M, Montejo R, Refoyo I, Coteron J. Exercise throughout pregnancy does not cause preterm delivery: a randomized, controlled trial. J Phys Act Health. 2014;11(5):1012–7. https://doi.org/10.1123/jpah.2012-0344
97. Barakat R, Pelaez M, Cordero Y, Perales M, Lopez C, Coteron J, et al. Exercise during pregnancy protects against hypertension and macrosomia: randomized clinical trial. Am J Obstet Gynecol. 2016;214(5):649.e1–8. https://doi.org/10.1016/j.ajog.2015.11.039
98. 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. *Brazilian*. J Phys Ther. 2019;23(2):148–55. https://doi.org/10.1016/j.bjpt.2018.11.005
99. Bisson M, Alméras N, Dufresne SS, Robitaille J, Rhéaume C, Bujold E, 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. https://doi.org/10.1371/journal.pone.0137742
100. Haakstad LAH, 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):116–25. https://doi.org/10.3109/13625187.2011.560307
101. 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):2080–8. https://doi.org/10.1210/jc.2009-2255
102. Murtezani A, Paçarada M, Ibraimi Z, Nevzati A, Abazi N. The impact of exercise during pregnancy on neonatal outcomes: a randomized controlled trial. J Sports Med Phys Fitness. 2014;54(6):802–8.
103. Pelaez M, Gonzalez-Cerron S, Montejo R, Barakat R. Pelvic floor muscle training included in a pregnancy exercise program is effective in primary prevention of urinary incontinence: a randomized controlled trial. NeurourolUrodyn. 2014;33(1):67–71. https://doi.org/10.1002/nau.22381
104. Perales M, Mateos S, Vargas M, Sanz I, Lucia A, Barakat R. Fetal and maternal heart rate responses to exercise in pregnant women. A randomized controlled trial. Arch Med Deport. 2015;32(6):361–7.
105. de Oliveria Melo AS, Silva JLP, Tavares JS, Barros VO, Leite DFB, Amorim MMR. Effect of a physical exercise program during pregnancy on uteroplacental and fetal blood flow and fetal growth: a randomized controlled trial. Obstet Gynecol. 2012;120(2):302–10. https://doi.org/10.1097/AOG.0b013e31825de592
106. Erkkola R. The influence of physical training during pregnancy on physical work capacity and circulatory parameters. Scand J Clin Lab Invest. 1976;36(8):747–54. https://doi.org/10.3109/00365517609081933
107. Kasawara KT, Burgos CSG, do Nascimento SL, Ferreira NO, Surita FG, Silva JLPE. Maternal and perinatal outcomes of exercise in pregnant women with chronic hypertension and/or previous preeclampsia: a randomized controlled trial. ISRN Obstet Gynecol. 2013;2013:1–8. https://doi.org/10.1155/2013/857047
108. Barakat R, Ruiz JR, Stirling JR, Zakynthinaki M, Lucia A. Type of delivery is not affected by light resistance and toning exercise training during pregnancy: a randomized controlled trial. Am J Obstet Gynecol. 2009;201(6):590.e1–6. https://doi.org/10.1016/j.ajog.2009.06.004
109. 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.e1–7. https://doi.org/10.1016/j.ajog.2011.01.043
110. 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. https://doi.org/10.1371/journal.pmed.1002079
111. Collings CA, Curet LB, Mullin JP. Maternal and fetal responses to a maternal aerobic exercise program. Am J Obstet Gynecol. 1983;145(6):702–7. https://doi.org/10.1016/0002-9378(83)90576-8

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

112. Elden H, Ostgaard HC, Fagevik-Olsen M, Ladfors L, Hagberg H. Treatments of pelvic girdle pain in pregnant women: adverse effects of standard treatment, acupuncture and stabilising exercises on the pregnancy, mother, delivery and the fetus/neonate. BMC Complement Altern Med. 2008;8(1):1–13. https://doi.org/10.1186/1472-6882-8-34
113. Kordi R, Abolhasani M, Rostami M, Hantoushzadeh S, Mansournia MA, Vasheghani-Farahani F. Comparison between the effect of lumbopelvic belt and home based pelvic stabilizing exercise on pregnant women with pelvic girdle pain; A randomized controlled trial. J Back Musculoskelet Rehabil. 2013;26(2):133–9. https://doi.org/10.3233/BMR-2012-00357
114. Bhartia N, Jain S, Shankar N, Rajaram S, Gupta M. Effects of antenatal yoga on maternal stress and clinical outcomes in north Indian women: a randomised controlled trial. J Indian Assoc Clin Med. 2019;1(20):10–4.
115. Choi J, Fukuoka Y, Lee JH. The effects of physical activity and physical activity plus diet interventions on body weight in overweight or obese women who are pregnant or in postpartum: a systematic review and meta-analysis of randomized controlled trials. Prev Med. 2013;56(6):351–64. https://doi.org/10.1016/j.ypmed.2013.02.021
116. ACOG. The American College of Obstetricians and Gynecologists (ACOG) Practice Bulletin No. 202. Obstet Gynecol. 2019;133(1):e1–e25. https://doi.org/10.1097/AOG.0000000000003018
117. Hardy DB, Mu X, Marchiori KS, Mottola MF. Exercise in pregnancy increases placental angiogenin without changes in oxidative or endoplasmic reticulum stress. Med Sci Sports Exerc. 2021;53:1846–54. https://doi.org/10.1249/MSS.0000000000002647
118. Roberts CL, Ford JB, Algert CS, Antonsen S, Chalmers J, Cnattingius S, et al. Population-based trends in pregnancy hypertension and pre-eclampsia: an international comparative study. BMJ Open. 2011;1(1):e000101. https://doi.org/10.1136/bmjopen-2011-000101

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Martínez-Vizcaíno V, Sanabria-Martínez G, Fernández-Rodríguez R, Cavero-Redondo I, Pascual-Morena C, Álvarez-Bueno C, et al. Exercise during pregnancy for preventing gestational diabetes mellitus and hypertensive disorders: An umbrella review of randomised controlled trials and an updated meta-analysis. BJOG. 2023;130(3):264–275. https://doi.org/10.1111/1471-0528.17304

14710528, 2023, 3, Downloaded from https://obgyn.onlinelibrary.wiley.com/doi/10.1111/1471-0528.17304 by Cochrane Chile, Wiley Online Library on [21/03/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License