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Impact of exercise on maternal gestational weight gain

An updated meta-analysis of randomized controlled trials

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Abstract

Background: Clinical evidence indicates that women will benefit from regular physical activity during pregnancy. This study aimed to summarize and update the evidence on the effect of exercise on maternal gestational weight gain (GWG).

Methods: We conducted a systematic literature search of Pubmed, Embase, and Cochrane Library from inception until July, 2018 for randomized controlled trials (RCTs) that investigate the effect of physical exercises on the maternal GWG compared with that of no physical exercises or conventional medical care. We extracted data from eligible trials for study characteristics, interventions, patients' baseline characteristics and outcomes for the study populations of interest. We conducted meta-analyses using random effects models.

Results: From 844 citations, 23 RCTs including 4462 pregnant women met the inclusion criteria. Meta-analysis indicated that compared with that in women having conventional medical care, GWG was significantly decreased in pregnant women with physical exercise [weighted mean difference (WMD) −1.02, 95% CI −1.35 to −0.70; $P<.01$; $I^2=48.4\%$]. Women appeared to benefit more for gestational weight control for exercise frequency of 3 times per week (WMD −1.22, 95% CI −1.55 to −0.90; $I^2=40.3\%$) and exercise duration of 30 to 45 minutes each time (WMD −1.32, 95% CI −1.79 to −0.85; $I^2=1.5\%$).

Conclusion: This meta-analysis provides indications that exercise intervention can reduce maternal GWG for pregnant women, especially for those with exercise frequency of 3 times per week and duration of 30 to 45 minutes each time.

Abbreviations: CI = confidence interval, GWG = gestational weight gain, MeSH = Medical Subject Heading, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses, RCT = randomized controlled trials, WMD = weighted mean difference.

Keywords: exercise, gestational weight gain, meta-analysis, pregnancy

1. Introduction

Excessive gestational weight gain (GWG) is a common issue among pregnant women, accounting for approximately 50% of all pregnant women in the USA.[1] Excessive GWG has also been reported to increase the risk of poor prognosis for pregnancy outcomes, including gestational diabetes, hypertension, pre-eclampsia, preterm birth and cesarean delivery, which could result in detrimental consequences for both mothers and infants' health.[2–5] Nehring et al found that excessive GWG increased the risk of childhood overweight by nearly 30%.[6] A cohort study by Ensenauer et al also demonstrated that excessive GWG was associated with an increased risk of infant overweight as well as abdominal adiposity, and even offspring cognition.[7] However, few reports have found certain interventions with consistent results for the prevention of excessive GWG for both the mother and the infant.

Recent randomized controlled trials (RCTs) and meta-analyses summarized the effects of physical activity during pregnancy on maternal and infant prognosis with controversial findings. Streuling et al found that physical activity during pregnancy could significantly restrict GWG with 12 RCTs.[8] Moreover, a recent meta-analysis by Silva et al found that exercise programs during pregnancy could reduce the risk of excessive weight gain, gestational diabetes, delivering a preterm infant or a baby large for gestational age, while no effects of exercise during pregnancy was found on pre-eclampsia, preterm birth, or birth weight.[9] Nevertheless, some of the RCTs found no effects[10,11] and even harm at early stage of pregnancy with increased risk of miscarriage.[53] Price et al showed no significant difference on weight gain from 12-week gestation to the last prenatal visit between the exercise group and the control group.[12] In addition, there is a lack of high-quality evidence regarding the effects of exercise characteristics (including frequency, intensity, duration, type, and volume) on maternal GWG based on guidelines from all

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around the world mainly including European, American and Asian countries.[47,48] Therefore, based on high-quality RCTs, we aimed to collect and reassess all the evidence regarding whether physical exercise and its characteristics can have an effect on maternal GWG.

2. Methods

2.1. Search strategy

A systematic review and meta-analysis was conducted based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for meta-analyses of RCTs.[13] Both of the patient informed consent and the ethical approval were not required because this study was a meta-analysis based on previously published data. We searched relevant trials using the following terms: (exercise or exercise therapy or physical activity or cycling or swimming or dancing or walk or yoga or tai chi) and (pregnancy or pregnant) and (randomized controlled trial or controlled clinical trial or randomized or placebo or randomly or trial) as keywords or text words or the Medical Subject Headings (MeSH) terms published on Pubmed, Embase and Cochrane Library from initial to July, 2018. The initial search was conducted by 2 senior research authors and we applied no language restrictions. We restricted studies to RCT, controlled clinical trials or meta-analyses with original data. We also hand searched bibliographies of included trials. Detailed search strategies of the searched online databases are provided in Supplementary materials, http://links.lww.com/MD/D85.

2.2. Study selection

Three authors (J.W., D.W., and X.L.) independently assessed trials for eligibility. Disagreements between the authors on the inclusion or exclusion of the trials were resolved by discussion, or

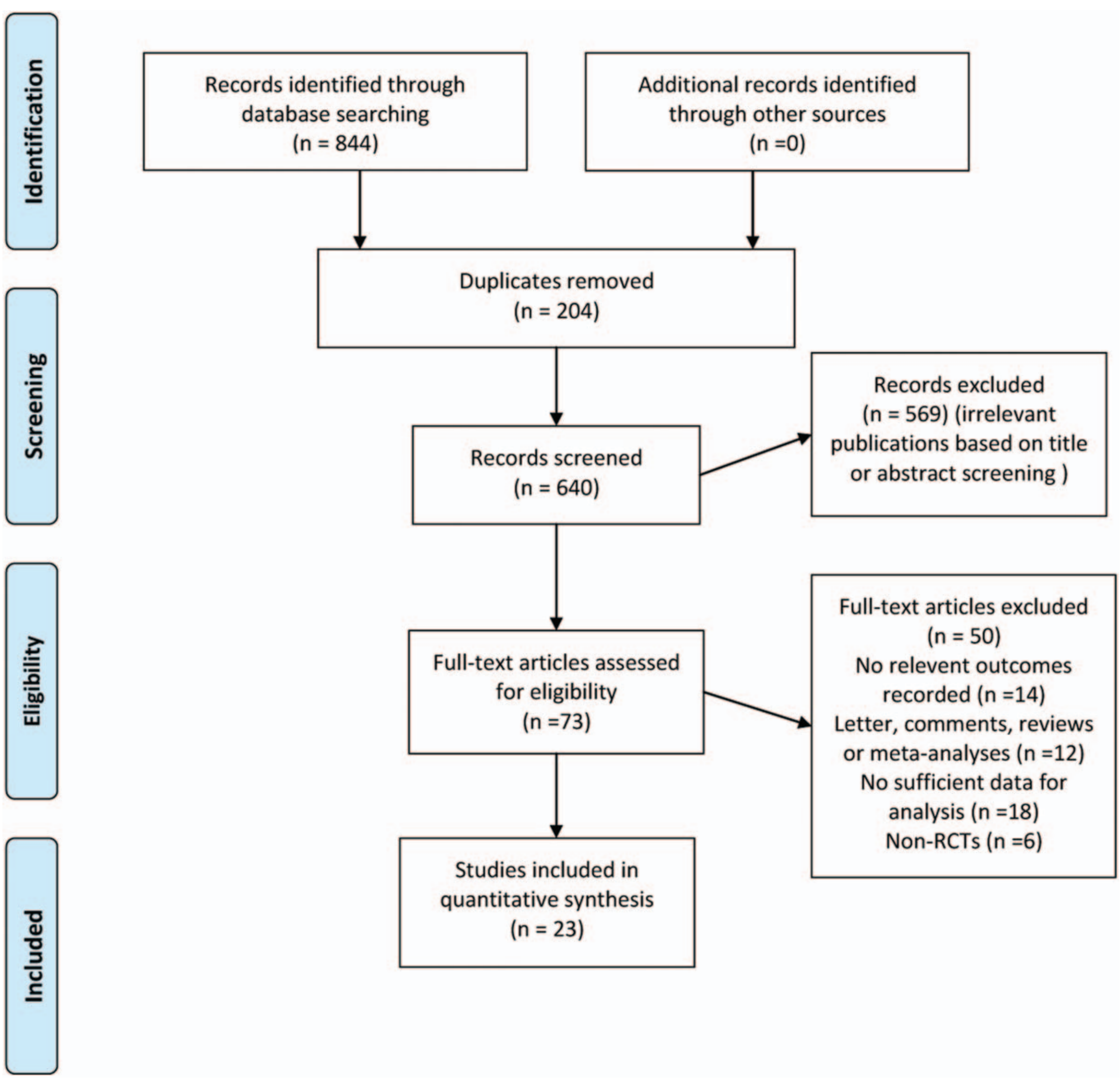

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for systematic review phases of exercise on maternal gestational weight gain.

when necessary, consultation with a senior author. The studies were eligible for inclusion if they satisfied the following criteria,

(1) published as RCTs;
(2) pregnant women having physical activity such as aerobic exercises, strength training, walking, cycling, or weight training compared with conventional medical care;
(3) studies were included if they reported outcome of maternal GWG during pregnant period. We excluded non RCTs such as cohort studies.

2.3. Data extraction and quality assessment

For each included study, 3 authors (J.W., D.W., and X.L.) independently extracted data from the trials' original texts and available supplementary materials, http://links.lww.com/MD/D85 using a predesigned data abstraction form. One author (Y.L.) entered the data into an excel datasheet, and the other authors checked these entries. The variables for abstraction were: first author of the study, the publication year, research country, sample size of the trial and control group, intervention applied,

Table 1

Characteristics of studies satisfying search inclusion criteria.

Source	Region	Sample size	Type of exercise intervention	Gestational period (weeks)	Exercise frequency (times/week)	Exercise duration (min)	Intensity	Jadad score
Wang et al., 2017	China	265	Stationary cycling exercise	<12+6	3	30-60	Moderate	3
da Silva et al., 2017	Brazil	612	Aerobic exercises, strength training, and stretching	16-20	3	60	Moderate	3
Perales et al., 2016	Spain	166	Muscle resistance, aerobic exercises, stretching	9–11 to end of third trimester	3	55–60	Light to moderate	3
Taniguchi et al., 2016	Japan	107	Home-based walking	30 to delivery	3 or more	30	Moderate	3
Barakat et al., 2014	Spain	290	Muscle resistance, aerobic dance, lumbar and pelvic floor muscle training	8–10 to 38–39	3	55–60	Moderate	3
Barakat et al., 2014	Spain	200	Muscle resistance, aerobic exercises, stretching, pelvic floor muscle training	9–13 to 39–40	3	55–60	Light to moderate	3
Barakat et al., 2013	Spain	428	Aerobic exercises, muscle strength and flexibility	10–12 to 38–39	3	50–55	Moderate	3
Ruiz et al., 2013	Spain	962	Aerobic exercises, muscle resistance and stretching	9 to 38–39	3	50–55	Light to moderate	3
Barakat et al., 2012	Spain	83	Aerobic land activities and aquatic exercises	6–9 to 38–39	3	35–45	Light to moderate	3
Price et al., 2012	USA	62	Walking, cycling, and weight training	12–14 to 36–delivery	4	45–60	Moderate	3
Rodriguez et al., 2012	Spain	55	Land and water aerobic exercises, muscle resistance, stretching	6–10 to 38–39	3	50	Moderate	2
Barakat et al., 2011	Spain	67	Muscular resistance, aerobic dance, pelvic floor muscle training	6–9 to 38–39	3	35–45	Light	3
Haakstad and Bo, 2011	Norway	105	Aerobic dance, strength training, advice to extra activities	12–24 to 36–38	2	60	Moderate	4
Hopkins et al., 2011	New Zealand	84	Stationary cycling	20–36	5	40	Moderate	3
Ramírez-Vélez et al., 2011	Colombia	50	Aerobic exercises, stretching	16–20 to 32–36	3	45	Moderate	3
Cavalcante et al., 2009	Brazil	70	Aquatic aerobic exercises	16–20 to delivery	3	50	Moderate	3
Barakat et al., 2009	Spain	142	Muscular strength and resistance training	12–13 to 38–39	3	35–40	Light to moderate	3
Sedaghati et al., 2007	Iran	90	Cycling	Second to third trimester	3	45	Moderate	1
Garshasbi et al., 2005	Iran	212	Aerobic exercises, resistance training	17–22 to 29–39	3	60	Light to moderate	2
Polley et al., 2002	USA	110	Stressed modest exercise	<20	Not reported	Not reported	Moderate	2
Marquez-Sterling et al., 2000	USA	15	Stationary aerobic cycling, walking and rowing	Not reported	3	60	Moderate	2
Clapp et al., 2000	USA	46	Stationary walking, step aerobics, stair stepper	Not reported	3 to 5	20	Moderate	2
Kihlstrand et al., 1999	Sweden	240	Water gymnastics	15–18 to delivery	1	60	Not reported	2

gestational period of the subjects, frequency, duration, and intensity of intervention.

The methodological quality of trials was assessed using the Jadad ranking score system to ascertain risk of trial bias.[14] The score system assesses the risk of bias in aspects of the method of randomization, double-blindness, the withdrawals, and dropouts of participants. A Jadad score of between 0 and 5 could be obtained based on these aspects, with higher score representing good methodological quality and lower score representing poor methodological quality.

2.4. Statistical analyses

We performed all meta-analyses using the Dersimonian–Laird random-effects model in Stata Software (version 12.0; StataCorp LP, College Station, TX). The Cochran chi-square test and the I^2 statistic were used to measure inter-trial heterogeneity.[15] We defined an I^2 statistic more than 50% as significant heterogeneity.[16] Summary data for continuous outcomes such as maternal GWG measured with the same scale were presented as weighted mean differences (WMDs) with 95% confidence intervals (CIs). Subgroup analyses were tested to further examine potential sources of between-trial heterogeneity in terms of some trial variables including trial region, sample size, gestational period, intervention frequency, duration and intensity, and Jadad score. Begg test and Egger linear regression method were quantified to assess publication bias.[17,18] When necessary, the trim-and-fill method was applied to adjust the pooled estimates to assess the possible effect of publication bias.[19] We also conducted sensitivity analysis to investigate the influence of each study on the pooled estimate. All statistical analyses were 2-sided. We considered a P value <.05 as significant difference.

3. Results

Our original search identified 844 original titles, of which 73 were considered potentially relevant for full-text review. After full text review, 23 primary RCTs published between 1999 and 2017 investigating exercise and maternal GWG contributed to the quantitative synthesis.[10–12,20–37]Figure 1 gives the detailed process for study selection of this meta-analysis.

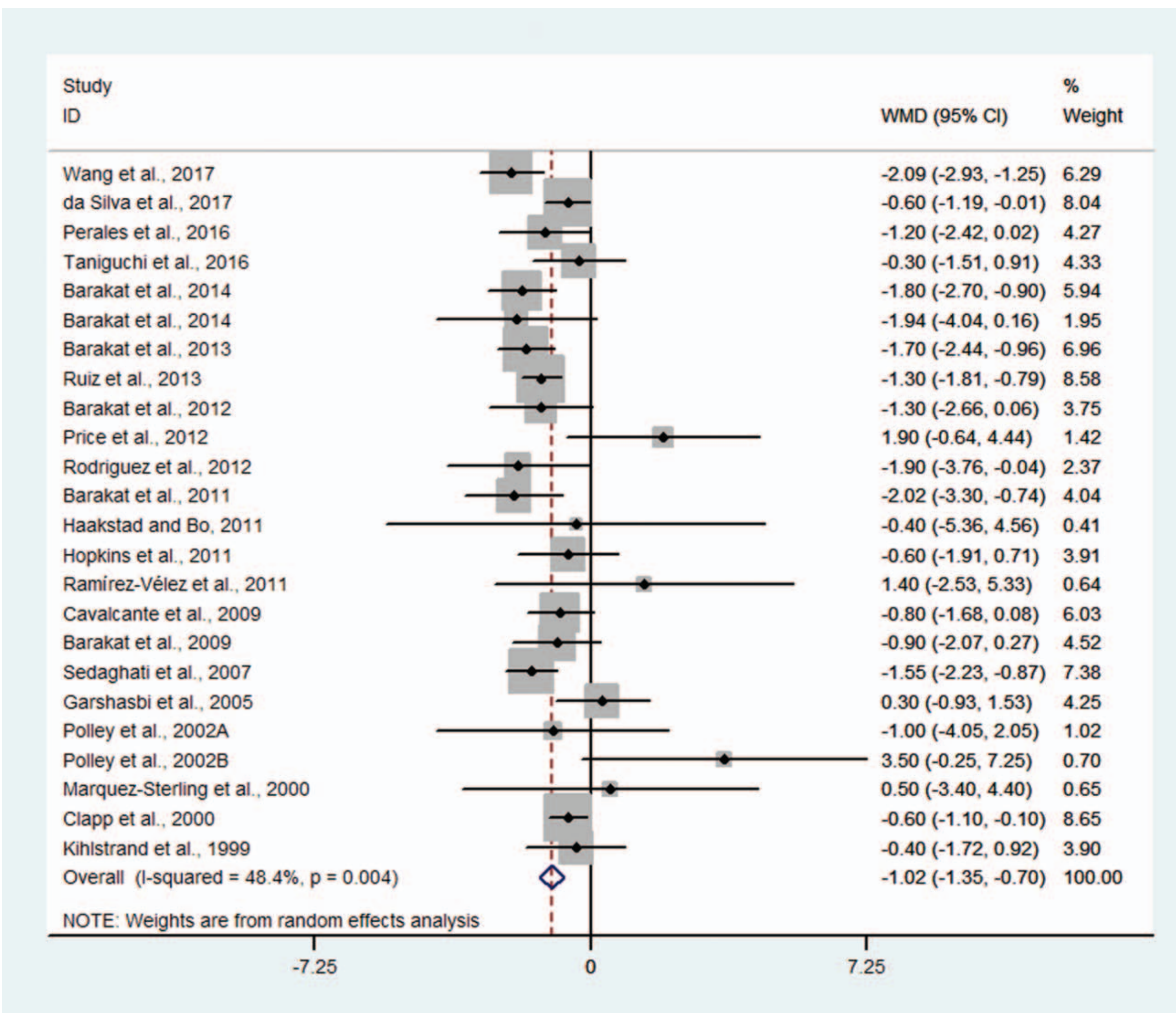

Figure 2. Forest plot for effect of exercise on maternal gestational weight gain.

3.1. Demographics

The 23 RCTs included a total of 4462 pregnant women, of whom 2128 had been randomized to certain physical exercise program and 2334 to standard antenatal care and normal daily activities. Eleven of the trials were conducted in Europe, 4 in the USA, 4 in Asia and 3 in South America. Physical exercise was administered from the 1st to the 3rd gestational trimester in 4 trials, from the 2nd to the 3rd gestational trimester in 12 trials and from the 2nd trimester to delivery in 3 trials. The frequency of physical exercise ranged from once to twice to 4 to 5 times per week. For risk of bias, 16 trials had higher Jadad score (3–4 points) and 7 had lower Jadad score (1–2 points). Table 1 summarizes the main characteristics of the trials included in the analysis of the main outcome.

3.2. GWG

Meta-analysis from 23 RCTs indicated that compared with that in women having conventional medical care, GWG was significantly decreased in pregnant women with physical exercise (WMD −1.02, 95% CI −1.35 to −0.70), with moderate heterogeneity among trials (I^2=48.4%) (Fig. 2). Subgroup analyses stratified by some baseline features such as trial region, sample size, gestational period, intervention frequency, duration and intensity, and Jadad score were also conducted. The results did not substantially alter compared with that of the primary analysis in most of the subgroups (Table 2).

3.3. Sample size

Subgroup analysis by sample size showed that GWG was decreased moderately for trials with small sample size (<200) (WMD −0.87, 95% CI −1.29 to −0.46; I^2=33.3%); similar finding was also obtained for trials with large sample size (≥200) (WMD −1.21, 95% CI −1.72 to −0.69; I^2=64.2%). No statistically significant difference was found for inter-study heterogeneity (P=.109).

3.4. Trial region and ethnicity

Eleven, 4 and 4 trials were conducted in Europe, the USA, and Asia, respectively. Meta-analysis showed that GWG was decreased significantly for trials conducted in Europe (WMD −1.41, 95% CI −1.72 to −1.11; I^2=0%), Asia (WMD −1.01,

Table 2

Pooled WMD for the main effect estimates by subgroups of randomized controlled trials defined by characteristic of study participants and study design.

Variable	WMD	95%CI	Degree of heterogeneity (I^2 statistics; %)	*P* value	No. of included Studies	*P* for interaction
Total (Random-effect)	−1.02	−1.35 to −0.70	48.4	.004	23	NA
(Fixed-effect)	−1.06	−1.26 to −0.86	48.4	.004	23	NA
Sample size						.109
<200	−0.87	−1.29 to −0.46	33.3	.096	15	
≥200	−1.21	−1.72 to −0.69	64.2	.007	8	
Trial region						.003
Europe	−1.41	−1.72 to −1.11	0	.802	11	
USA	0.45	−1.09 to 2.00	51.4	.083	4	
Asia	−1.01	−2.00 to −0.01	77.0	.005	4	
Ethnicity						.014
White	−1.19	−1.49 to −0.89	12.8	.313	14	
East Asian	−1.25	−3.00 to 0.50	82.4	.017	2	
South American	−0.63	−1.12 to −0.15	0	.555	3	
Middle Eastern	−0.70	−2.51 to 1.11	85.0	.010	2	
Gestational period						.012
1st to 3rd trimester	−1.42	−1.85 to −0.98	0	.721	4	
2nd to 3rd trimester	−1.19	−1.64 to −0.75	49.6	.026	12	
2nd trimester to delivery	0.06	−1.15 to 1.27	51.4	.083	4	
Frequency (times/week)						.021
1–2	−0.40	−1.67 to 0.87	0	1.000	2	
3	−1.22	−1.55 to −0.90	40.3	.044	17	
4–5	0.40	−2.00 to 2.81	66.0	.087	2	
Duration (minutes)						.032
⩽30	−0.56	−1.02 to −0.09	0	.654	2	
30–45	−1.32	−1.79 to −0.85	1.5	.407	6	
50–60	−0.99	−1.42 to −0.57	45.7	.036	13	
Intensity						.357
Light	−2.02	−3.30 to −0.74	–	–	1	
Light to moderate	−1.05	−1.54 to −0.55	22	.268	6	
Moderate	−0.98	−1.42 to −0.53	57.1	.003	15	
Jadad score						.058
1–2	−0.64	−1.34 to 0.07	54.9	.030	7	
3–4	−1.17	−1.53 to −0.82	41.1	.044	16	

P for interaction: *P* values from the test of homogeneity between strata.
CI=confidence interval, NA=not available, WMD=weighted mean difference.

95% CI −2.00 to −0.01; I^2 = 77.0%), and South America (WMD −0.63, 95% CI −1.12 to −0.15; I^2 = 0%). We did not find GWG significantly decreased for trials conducted in the USA (WMD 0.45, 95% CI −1.09 to 2.00; I^2 = 51.4%). Significant difference for inter-study heterogeneity was indicated (P = .003). We also observed that GWG was decreased significantly across ethnic groups including white (WMD −1.19, 95% CI −1.49 to −0.89; I^2 = 12.8%) and South American (WMD −0.63, 95% CI −1.12 to −0.15; I^2 = 0) while not for East Asian (WMD −1.25, 95% CI −3.00 to 0.50; I^2 = 82.4%) or Middle Eastern (WMD −0.70, 95% CI −2.51 to 1.11; I^2 = 85.0%). There was statistically significant difference for inter-study heterogeneity (P = .014).

3.5. Gestational period

Three gestational periods were involved in conducting physical activity including the 1st to the 3rd gestational trimester, the 2nd to the 3rd gestational trimester and the 2nd trimester to delivery. Subgroup analyses showed that GWG was decreased significantly for women having physical activity from the 1st to the 3rd gestational trimester (WMD −1.42, 95% CI-1.85 to −0.98; I^2 = 0%) and the 2nd to the 3rd gestational trimester (WMD −1.19, 95% CI −1.64 to −0.75; I^2 = 49.6%). However, women who had physical activity from the 2nd trimester to delivery did not show decreased GWG (WMD 0.06, 95% CI −1.15 to 1.27; I^2 = 51.4%). There was statistically significant difference for inter-study heterogeneity (P = .012).

3.6. Frequency of exercise

Women in 17 trials had physical exercise 3 time per week, showing significantly decreased GWG (WMD −1.22, 95% CI −1.55 to −0.90; I^2 = 40.3%) compared with those having conventional medical care, while women having physical activity once to twice or 4 to 5 times per week did not show significant decreased GWG, with pooled WMD being −0.40 (95% CI −1.67 to 0.87) and 0.40 (95% CI −2.00 to 2.81), respectively (Fig. 4). Statistically significant difference for inter-study heterogeneity (P = .021) was noted.

3.7. Duration of exercise

Meta-analysis stratified by duration of exercise indicated that GWG was decreased significantly in trials with women's duration of exercise ranging from 30 to 45 minutes (WMD −1.32, 95% CI −1.79 to −0.85; I^2 = 1.5%) and 50 to 60 minutes (WMD −0.99, 95% CI −1.42 to −0.57; I^2 = 45.7%); similar result was also noted for trial with women's duration of exercise ≤30 minutes (WMD −0.56, 95% CI −1.02 to −0.09; I^2 = 1.5%) (Fig. 5). We found statistically significant difference for inter-study heterogeneity (P = .032).

3.8. Intensity of exercise

We conducted subgroup analysis stratified by intensity of exercise. The results showed that GWG was decreased significantly in trials with light (WMD −2.02, 95% CI −3.30 to −0.74), moderate to light (WMD −1.05, 95% CI −1.54 to −0.55; I^2 = 22.0%) and moderate intensity of exercise (WMD −0.98, 95% CI −1.42 to −0.53; I^2 = 57.1%). There was no statistically significant difference for inter-study heterogeneity (P = .357).

3.9. Methodological quality

Significant decreased GWG was observed in trials with high methodological quality (Jadad score 3 to 4) (WMD −1.17, 95%

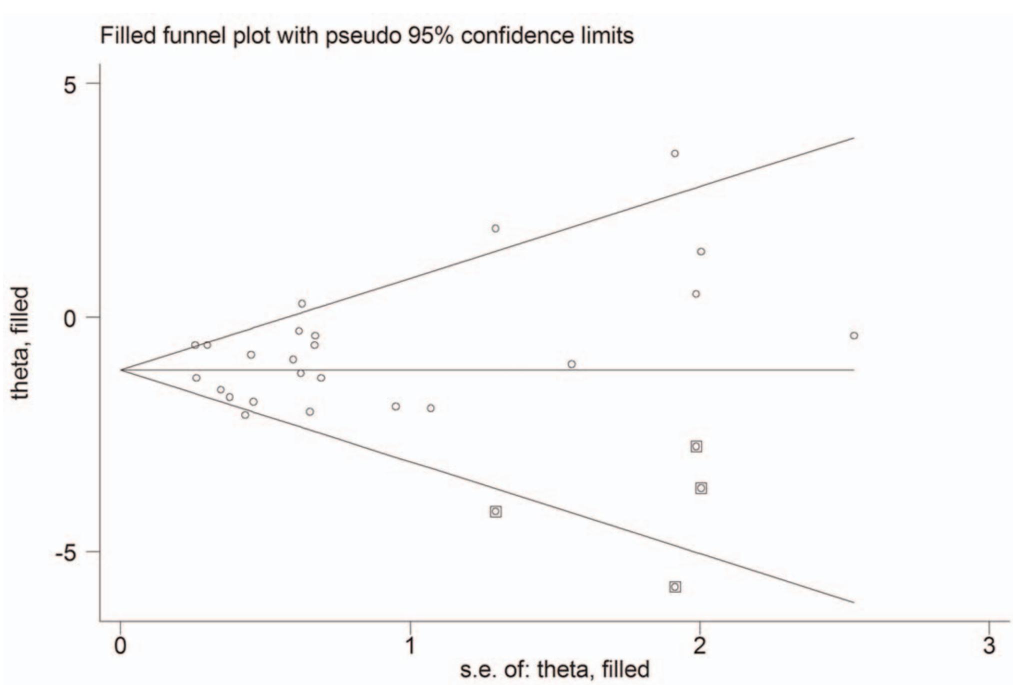

Figure 3. The trimmed funnel plot for effect of exercise on maternal gestational weight gain.

CI −1.53 to −0.82; I^2=41.1%), while not in trial with low methodological quality (Jadad score 1–2) (WMD −0.64, 95% CI −1.34 to 0.07; I^2=54.9%). No statistically significant difference for inter-study heterogeneity was indicated (P=.058).

3.10. Publication bias and sensitivity analyses

There seemed to be an asymmetry in the funnel plot (Fig. 3). However, the Begg (P=.189) and Egger test (P=.203) seemed to indicate no evident publication bias. Moreover, we also used the trim-and-fill method to further identify and adjust for funnel plot asymmetry. The adjusted random effects summary WMD of −1.13 (95% CI, −1.48 to −0.77) was consistent with the primary analysis, further confirming the robustness of the result. We also conducted sensitivity analysis by excluding one trial at each time and recalculating the summary estimate for the remaining trials to investigate the effect of each trial on the overall estimate. No significant alteration in the overall estimate when any one of the included trials was excluded. For subgroup analysis based on ethnicity, we noted that the summary WMD yielded −0.84, 95% CI −1.37 to −0.31 for other European countries except Spain, which was similar to that of the main analysis.

4. Discussion

Body weight is a significant concern for pregnant women across the spectrum of the gestational period.[38–41] Physical activity or regular exercise, one of the most generally recommended means to improve physical conditioning during pregnancy, has identified beneficial effects on both maternal and fetal health that are reported by numerous clinical trials.[42,43] Recent evidence has shown that pregnant women with regular exercise such as aerobic exercises, muscle strength, and flexibility are effective in reducing glycemic level in women with gestation diabetes mellitus (GDM) and other gestation-related conditions.[25,26,32,33] This systematic review sought to evaluate the effectiveness of regularly exercise in maternal GWG.

In this systematic review and meta-analysis, compared with conventional medical care, exercise or physical activity was

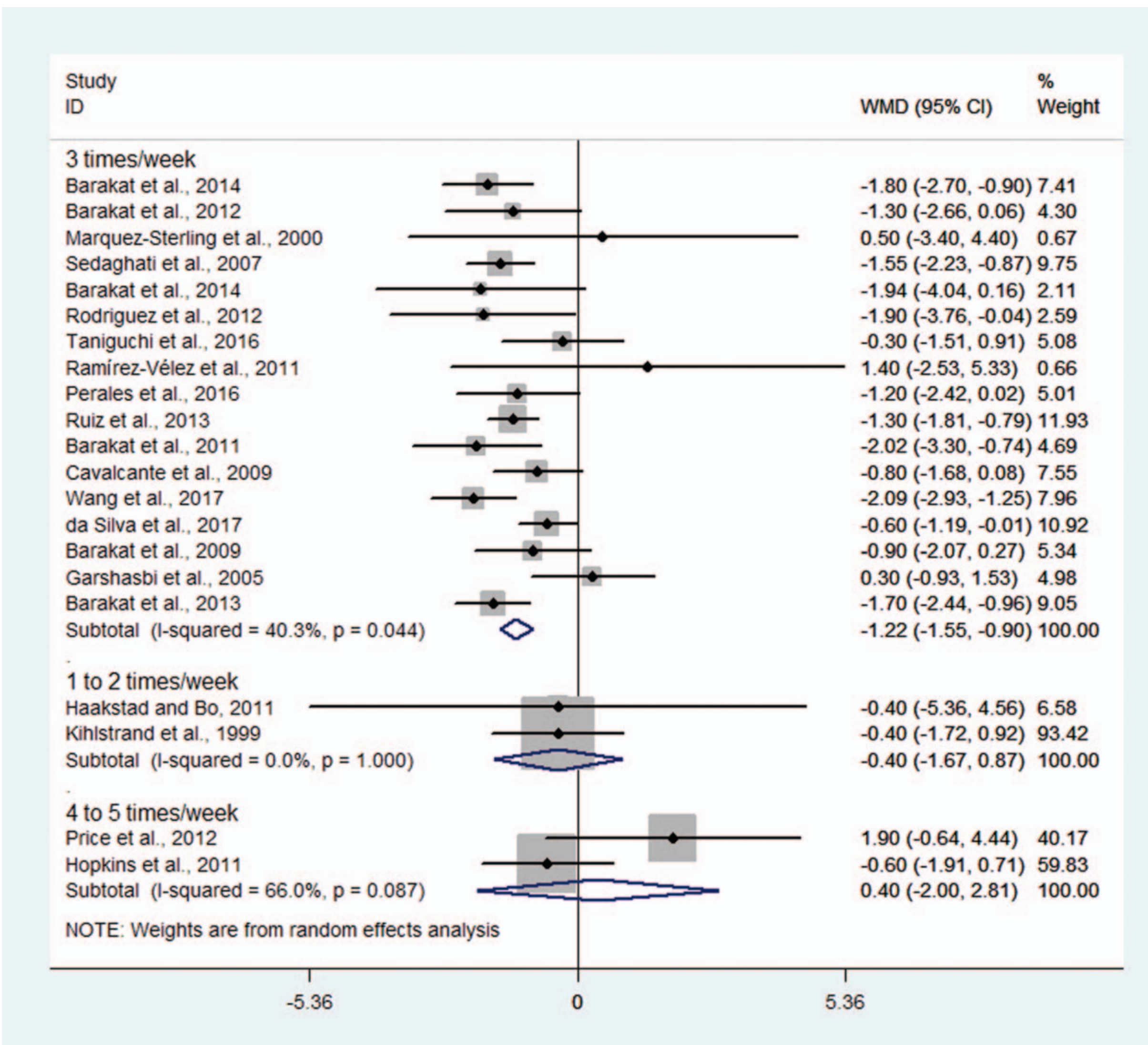

Figure 4. Forest plot for subgroup analyses by exercise frequency.

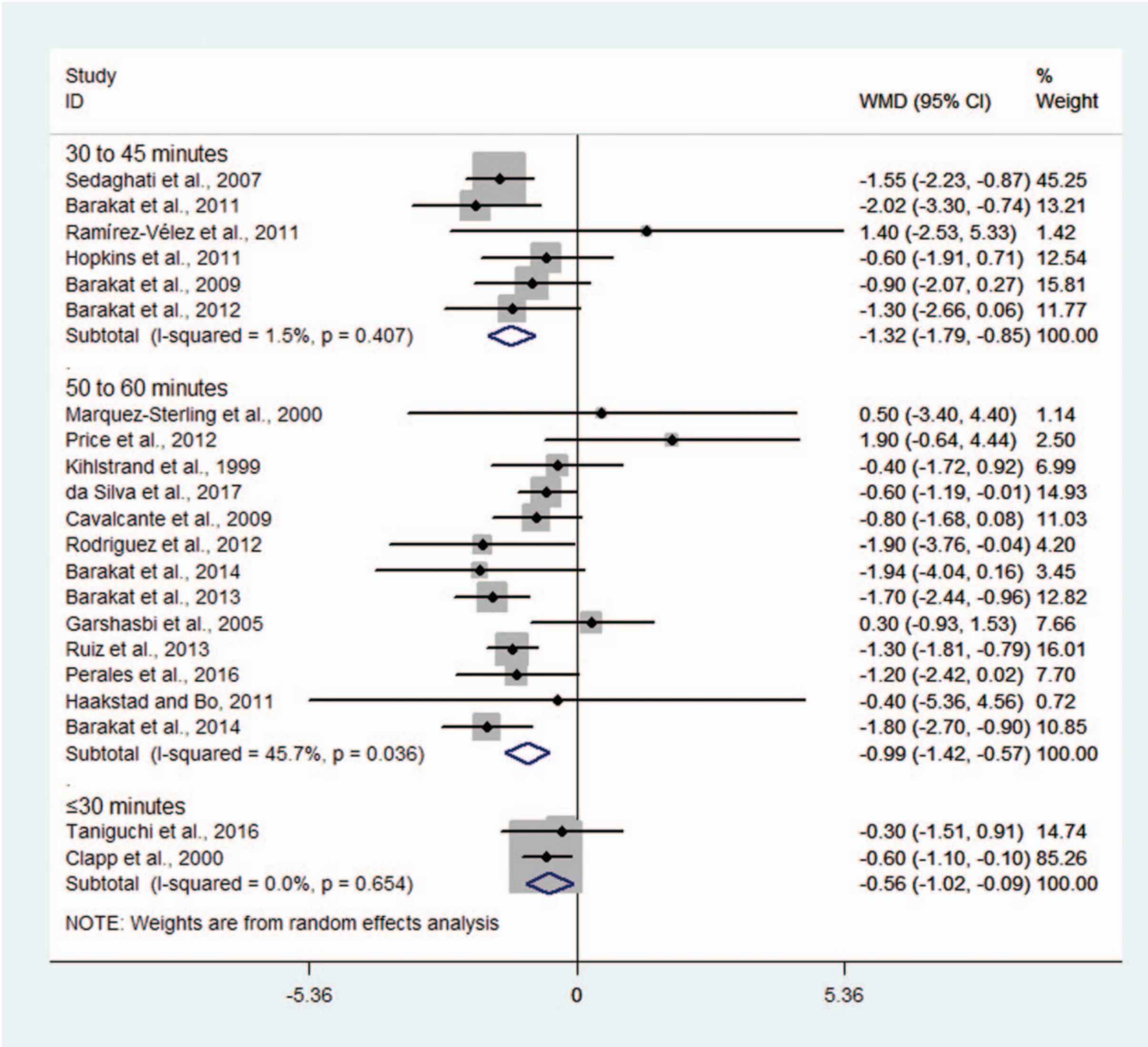

Figure 5. Forest plot for subgroup analyses by exercise duration.

associated with reduced maternal GWG. This effect seems consistent across different subgroups in terms of trial region, sample size, gestational period, intervention frequency, duration and intensity, and Jadad score. Though the real mechanisms have not been identified, it has been proposed that exercise not only attenuates the increase in insulin resistance in the population of overweight-obese pregnant women, but significantly lowers glucose concentrations in the fasted and postprandial state.[20,44] In the acute or chronic conditions of a body, exercise during pregnancy can suppress peripheral insulin resistance in the same way as the non-pregnant women, probably through exercise-induced increase in muscle insulin sensitivity.[54,55] Moreover, some hormones have also been proposed to play a pivotal role in nutrient partitioning during pregnancy, either directly through placental regulation of maternal metabolism or indirectly through regulation of maternal body composition changes, such as leptin and free fatty acids.[28]

Six previous systematic review and meta-analyses have reported the effect of exercises on maternal weight gain, among which 5 yielded beneficial effects, resulting in a significant reduction in GWG from 0.70 to 1.14 kg.[9,45,49–52] The other narrative review also concluded that exercise may help in the control of maternal weight gain.[45] Compared with these 6 studies, we included a larger number of studies with high-quality evidence (21 RCTs with a total of 4245 pregnant women) and conducted more thorough subgroup analyses. It provided more reliable estimates of effects on association between physical activity and maternal GWG, and subgroup analysis further investigated and raised the possibility of differential effects of different subgroup hypotheses, though these findings could have low credibility.[46]

Strengths of our study include a systematic and rigorous literature search to the identification of RCTs regarding this topic. We also conducted a number of preplanned subgroup analyses to explore for differences in effect estimates. Furthermore, we used the Jadad approach to assess the quality of evidence that indicated convincing evidence that physical activity could reduce GWG.

There are limitations to our study. First, studies might selectively report data regarding exercise on GWG in their full publications, which might have led to risk of selection bias; we tried to mitigate this risk by checking the registered records of the included studies on ClinicalTrials.gov for unreported data. Second, in order to assess the effects of different frequency, duration, and intensity of exercise on GWG, subgroup analyses based on patient-level data should preferably be performed. However, due to the nature of study-level data rather than patient-level data, we could not conduct more detailed analyses. For example, as the timing of exercise was unavailable in most of the included trials, we could not conduct further subgroup analysis based on this. Therefore, future trials are proposed on this aspect to further demonstrate the effect of the timing of exercise on GWG. Third, based on aggregate data, this meta-analysis shares the possible limitations of the original clinical trials. Differences in the enrolled populations (one trial enrolled exclusively overweight and obese pregnant women) and varied interventions of physical exercise might lead to statistical heterogeneity in the overall estimates. Finally, though sensitivity analyses indicated that exclusion of any one of the studies did not substantially change the pooled estimate, and the adjusted estimate yielded from the trim-and-fill model were in line with the initial findings, suggesting that the result of this meta-analysis was robust. However, we should interpret it cautiously considering the common existence of publication bias and incomplete statistical methods to test the publication bias.

In summary, the results of this meta-analysis suggest that exercise intervention can reduce maternal GWG for pregnant women. This effect is almost independent of trial region and other study characteristics. However, future trials should focus on the frequency, duration, intensity and type of physical exercise to further examine this effect.

Author contributions

Conceptualization: Danting Wen.
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Software: Danting Wen, Yingjie Liu.
Supervision: Danting Wen.
Validation: Danting Wen, Xiaofei Liu, Yingjie Liu.
Visualization: Danting Wen, Xiaofei Liu.
Writing – original draft: Danting Wen.
Writing – review & editing: Danting Wen.

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