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Systematic review

# Effectiveness of physical activity interventions on preventing gestational diabetes mellitus and excessive maternal weight gain: a meta-analysis

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**Background** It is commonly accepted that pregnancy-related physiological changes (circulatory, respiratory, and locomotor) negatively influence the daily physical activity of pregnant women.

**Objectives** The aim of this study is to conduct a meta-analysis of randomised controlled trials (RCTs) for assessing the effectiveness of physical exercise interventions during pregnancy to prevent gestational diabetes mellitus and excessive maternal weight gain.

**Search strategy** Keywords were used to conduct a computerised search in six databases: Cochrane Library Plus, Science Direct, EMBASE, PubMed, Web of Science, and ClinicalTrials.gov.

**Selection criteria** Healthy pregnant women who were sedentary or had low levels of physical activity were selected for RCTs that included an exercise programme.

**Data collection and analysis** Two independent reviewers extracted data and assessed the quality of the included studies. Of 4225 articles retrieved, 13 RCTs (2873 pregnant women) met the inclusion criteria. Pooled relative risk (RR) or weighted mean differences (WMDs) (depending on the outcome measure) were calculated using a random-effects model.

**Main results** Overall, physical exercise programmes during pregnancy decreased the risk of gestational diabetes mellitus (RR = 0.69; $P = 0.009$), particularly when the exercise programme was performed throughout pregnancy (RR = 0.64; $P = 0.038$). Furthermore, decreases were also observed in maternal weight (WMD = −1.14 kg; 95% CI −1.50 to −0.78; $P < 0.001$). No serious adverse effects were reported.

**Conclusion** Structured moderate physical exercise programmes during pregnancy decrease the risk of gestational diabetes mellitus and diminish maternal weight gain, and seem to be safe for the mother and the neonate; however, further studies are needed to establish recommendations.

**Keywords** Exercise, gestational diabetes mellitus, maternal weight gain, physical activity, pregnancy.

**Tweetable abstract** Exercise programmes decreased the risk of gestational diabetes mellitus and excessive weight gain.

**Linked article** This article is commented on by L Poston, p. 1175 in this issue. To view this mini commentary visit http://dx.doi.org/10.1111/1471-0528.13446.

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## Introduction

Gestational diabetes mellitus (GDM) is one of most frequent complications of pregnancy.[1] It has been associated with serious disorders such as pre-eclampsia, hypertension, preterm birth, and a higher frequency of induced and caesarean deliveries.[2,3] Also, it has been related to a higher risk for perinatal morbidity, impaired glucose tolerance, and type–II diabetes after pregnancy.[4–8] Finally, the offspring are at an increased risk of becoming overweight or obese,[9] and of developing type–I or -II diabetes later in life.[10]

Meanwhile, pregnancy for most women is associated with greater weight gain than recommended.[11] It is known that excessive maternal weight gain (MWG) is a risk factor for hypertension, GDM, pre-eclampsia, caesarean delivery, macrosomia, stillbirth, and perinatal complications.[12–14] Moreover, it is also independently associated with postpartum weight retention and higher body mass index in offspring during childhood, adolescence, and early adulthood.[15–18] Indeed, an excessive MWG has been described as an important contributor to increased obesity among women.[12–19]

Pregnant women were traditionally advised to reduce their levels of physical activity (PA), and even to stop working, because of the belief that PA could reduce placental circulation and, as a consequence, increase the risk of disorders such as miscarriages, preterm deliveries, and intrauterine growth retardation;[20] however, during the last two decades a growing interest in the potential beneficial effects of PA during pregnancy for both mother and offspring has emerged.[21] Several authors have reported that PA may account for some improvements in maternal and fetal outcomes.[22–26] Thus, it has been suggested that PA during pregnancy might reduce excessive MWG and the incidence of GDM.[27] Therefore, in 2002, and reaffirmed in 2009, the American College of Obstetricians and Gynecologists (ACOG) recommended at least 30 minutes of moderate-intensity PA on most if not all days of the week for pregnant women.[21] In the absence of contraindications, pregnant women should be encouraged to engage in a range of recreational activities that appear to be safe.[28]

The influence of PA on preventing GDM and excessive MWG is still a controversial issue, however, as a 2012 Cochrane review did not find significant differences in frequency of GDM and weight in late pregnancy between pregnant women engaged in exercise programmes and those who did not exercise.[29] Consequently, clinicians are reluctant to recommend PA to pregnant women.

The aim was to conduct a meta-analysis of randomised controlled clinical trials (RCTs) focused on assessing the effectiveness of physical exercise programmes during pregnancy to prevent GDM and excessive MWG.

## Methods

This meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement.[30]

### Data sources and searches

Studies were identified in six databases: Cochrane Library Plus, Science Direct, EMBASE, PubMed, Web of Science, and ClinicalTrials.gov. In addition, we manually searched the references of published studies. The search strategy applied was (pregnancy OR gravid) AND (aerobic OR exercise OR fitness OR 'physical exercise' OR 'physical activity' OR 'motor activity') AND (effectiveness OR 'program evaluation' OR 'gestational diabetes' OR insulin OR glucose OR 'maternal weight gain' OR 'gestational weight gain' OR 'labor' OR 'delivery'). Studies included were RCTs that aimed to assess the influence of PA on pregnant women, published from January 1990 to May 2014. Language restrictions were applied and only papers written in Spanish and English language were selected. Repeated publications for the same studies and data were excluded. The search was conducted from 2 to 12 May 2014.

### Study selection

First, record titles were independently evaluated by two investigators (GS and RP), and in the same way selected abstracts were also evaluated. When abstracts did not provide enough information to decide upon inclusion or exclusion, they were extracted for full-text evaluation. Some reviewers independently determined which study could be selected. Disagreements were solved by consensus between them, but if disagreements persisted, a third reviewer solved the conflict (CA). Authors were contacted for clarification about the women included when there was a suspicion of double counting because more than one RCT were included in the meta-analysis from the same author, they were contacted for clarification.

The criteria for inclusion were: (1) population – sedentary healthy women or those with low levels of PA (exercising <20 minutes on <3 days per week), with uncomplicated and singleton pregnancies; (2) type of study – RCT, in which the control group received no type of physical exercise; (3) type intervention – physical exercise programmes that included low to moderate intensity exercises; and (4) evaluation pregnancy outcomes: GDM and/or MWG. No restrictions on frequency, duration, or type of training were made.

Finally, the exclusion criteria were: (1) women at high risk of preterm delivery; (2) women involved in any other trial; (3) women with any contraindication for exercise, as advised by an obstetrician; and (iv) women who were not planning to give birth at the same obstetrics hospital department in which the medical control of the pregnancy was performed.

### Data extraction and quality assessment

The two reviewers extracted the following data from each included article: (1) characteristics of participants (number, age, and obstetric characteristics); (2) intervention features (type, duration, frequency, and intensity of physical exercise intervention); (3) target of the study; (4) strengths and weakness of each RCT; and (5) results of outcomes: GDM (%) and MWG (kg). A request for missing data was sent to each of the corresponding or first authors.

Risk of bias was evaluated according to the PRISMA recommendation.[30]

The quality assessment was performed using the Jadad scale.[31] This scale includes five items to be assessed as iyes' or 'no', depending on whether the clinical trials met quality criteria in the following areas: randomisation, random method, double blind, double-blinded method, description of adherence, and drop-outs.

### Data synthesis and analysis

The relative risk (RR) and 95% confidence intervals (95% CIs) were calculated for GDM. Weighted mean differences (WMDs) and 95% confidence intervals (CIs) were calculated for maternal weight.[32] The random-effects model (DerSimonian–Laird approach) was selected to summarise the pooled WMD and RR. Cochran's Q–statistic was applied to assess the heterogeneity of the studies,[33] and the percentage of total variation across the studies as a result of heterogeneity was determined using $I^2$. The magnitude of the heterogeneity or inconsistency was classed as follows: (1) small, $I^2 < 25\%$; (2) medium, $I^2 = 25–50\%$; and (3) large, $I^2 > 50\%$.[34] The sensitivity analysis was assessed, deleting each study from the model, and the pooled analyses were conducted without this study. To test publication bias the funnel plot and the Egger test were used.[35]

Finally, the following subgroup analyses were prespecified: duration of exercise intervention (throughout pregnancy or from second trimester to end of pregnancy), type of exercise (aerobic or combined aerobic, strength, and flexibility), research group (the studies of Barakat et al. versus other studies), location (studies conducted in Europe versus other studies), intensity level of exercise (very light to light versus moderate), and studies with low adherence versus studies with high adherence.

## Results

### Study selection

The search strategy retrieved 4225 references. Of these, 3983 references were excluded based on the title, leaving 242 as potentially relevant references (Figure 1). Of these, 210 were excluded after abstracts were reviewed, and 32 were evaluated and selected for a more detailed evaluation of the full published version. Then, 19 studies were excluded because they did not meet the inclusion criteria: four papers were not RCTs, two consisted of perineal exercise interventions, two collected variables not investigated in the current study, four included previously active women in their intervention groups, and seven were duplicate publications. Finally, 13 RCTs were included in the meta-analysis.[36–48] Five studies had been also published in other additional articles.[40,44–47,49–54]

Barakat authored several studies included in this meta-analysis.[38–41,43,46] Thus, we verified that the samples used did not include the same participants in either study; this issue was confirmed as they had different characteristics, were conducted in different locations, and at different times. Furthermore, an author from these studies was contacted to clarify the origin of some samples.

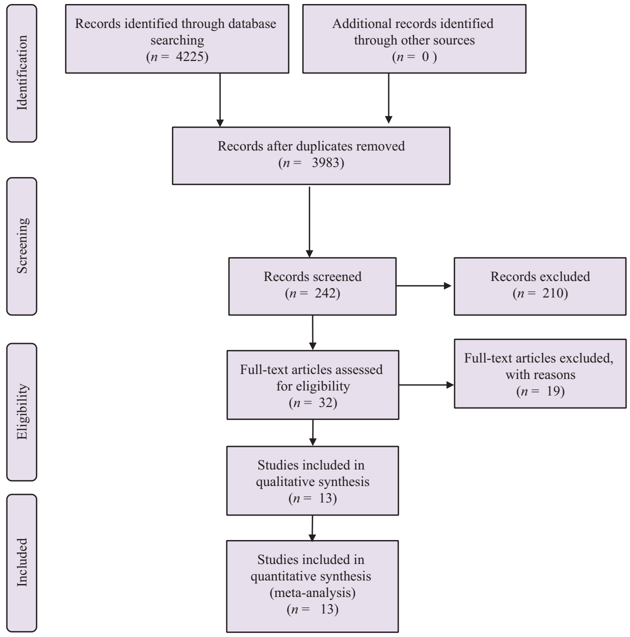


**Figure 1.** Flow diagram of the study selection process.

### Subjects

The total sample included 2873 women: 1434 in the intervention group (IG) and 1439 in the control group (CG). Every woman had a healthy pregnancy, which was nullipara or multipara, with a singleton pregnancy and without maternal or fetal disease, and uncomplicated pregnancy evolution. Only three studies reported ethnicity, involving white women.[39–41]

### Study characteristics and intervention

Table S1 summarises the study characteristics.[36–48] The studies were gathered from several countries: seven in Spain, but in different health centres or hospitals;[36,38–41,43,46] one in Croatia;[37] one in Brazil;[47] one in Norway;[44] one in New Zealand;[45] and two in the USA.[42,48] In all of them, women in CG were given the usual prenatal care.

### Exercise programmes

There was a wide variety in the type of exercises including: aerobic exercises,[36–45,47] resistance, toning, flexibility, and strength exercises,[36,38–41,43,46] weight training,[42,48] and strength exercises with muscles of the pelvic floor and those involved in labour in the last trimester of pregnancy.[38,41,43,44] Some exercise programmes were conducted throughout pregnancy,[36–38,40,41,43,48] whereas others were used from the second trimester to the end of pregnancy.[39,42,44–47]

 

The frequencies of the sessions were: two,[44] three,[36–41,43,46,47] four,[42] or five sessions per week.[45,48] The sessions lasted between 15 and 60 minutes. Intensity levels were categorised as very light,[43] light to moderate,[36,38,41,46] and moderate.[37,39,40,42,44,45,47,48] These categories were established according to the Borg scale,[55] with scoring of perceived exertion,[36–40,42,44] heart rate,[36–41,43,46,47] a questionnaire to assess metabolic equivalents of task (METs),[37,45] and by aerobic capacity ($VO_{2max}$).[45,48] All programmes were supervised, except for one that was conducted using a home-based programme.[45]

## Outcome measures

All RCTs measured at least one of the pregnancy outcomes: GDM,[36–42,46] MWG,[36–48] or both.[36–42,46]

There are several diagnostic and screening criteria to GDM. Some of the included RCTs applied World Health Organization (WHO)[56] diagnostic criteria,[39,46] other RCTs used American Diabetes Association (ADA)[1] diagnostic criteria,[37,40–42] and finally there were two studies that did not report on this issue.[36,38] None of the RCTs reported GDM in previous pregnancies.

On the other hand, the weight data collections were very different. Four studies reported that maternal weights were obtained from the medical reports.[38,39,41,43] Three studies reported that MWG was calculated on the basis of weight measured at the first prenatal visit and weight measured at the last visit before delivery through standard procedures.[36,40,46] Price et al.[42] collected maternal weight before each exercise test at 12–14, 18–20, and at 30–32 weeks of gestation. Cavalcante et al.[47] evaluated it three times during pregnancy, at 18–20, 22–26, and 32–36 weeks of gestation. Finally, only two studies reported that they measured pregnancy weight with an electronic balance beam scale.[44,48]

## Adherence, drop-outs, and adverse effects

Regarding the adherence rate, in most of the studies included the adherence rate was high (>85%),[36–41,43,44,46,48] one study reported an adherence rate of 75%,[45] and another reported an adherence of 65–70%.[47] Among the main reasons for leaving programmes were the logistical difficulties of regular attendance, such as scheduling conflicts and transportation issues.[42] Regarding drop-outs, in five studies the rate was below 10%,[37,41,43,46,47] in another seven the rate was 10–20%,[36,38–40,44,45,48] and one study had a rate of 26%.[42] The main reasons for drop-outs were discontinued intervention,[37,38,40,45,47,48] threat of premature delivery,[36–46,48] persistent bleeding,[36,39,46] pregnancy-induced hypertension,[38–40,43–46] and moving to another hospital.[36,39,46] In the same way, the studies did not report data on adverse effects attributable to interventions. Overall, the studies reported no adverse outcomes, except for two studies that reported two and three preterm deliveries in the IG and CG, respectively.[46,48]

## Quality (risk of bias) assessment

Among the included studies, 11 satisfied three of the quality criteria (randomisation, random method, and description of adherence and drop-outs),[36–44,47,48] and two studies satisfied two of the quality criteria (randomisation and random method; randomisation and description of adherence and drop-out).[45,46] None of the studies was double blinded (Table S1). Finally, only four studies used the intention-to-treat analysis.[36,42,44,47]

## Synthesis of results

Figures 2 and 3 display the results of all of the included studies in both comparison groups. The RR and WMD (95% confidence intervals) values were estimated for each study. The data analysis showed a decreased risk of GDM (RR = 0.69; 95% CI 0.52–0.91; $P = 0.009$) and a diminished MWG (WMD = −1.14 kg; 95% CI −1.50 to −0.78; $P < 0.001$) in the exercise group.

There was no heterogeneity in the individual risk estimates for gestational diabetes ($I^2 = 0\%$; $P = 0.614$), and there was medium heterogeneity between studies for maternal weight ($I^2 = 26\%$; $P = 0.185$). Similarly, there was no

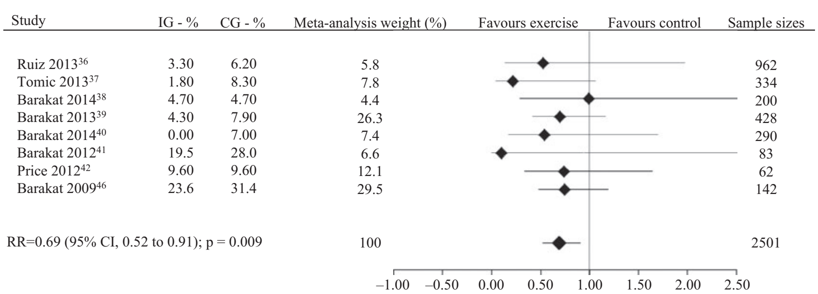


**Figure 2.** Prevention of gestational diabetes mellitus in intervention and control groups using the random-effects model; CG, control group; IG, intervention group, SD, standard deviation.

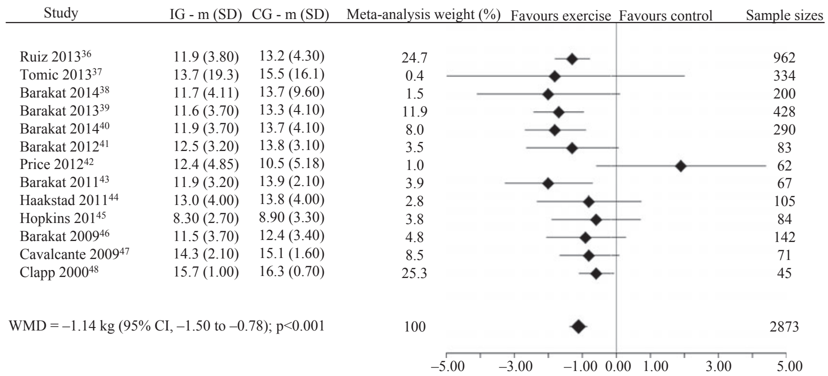


**Figure 3.** Prevents excessive maternal weight gain (kg) in intervention and control groups using the random-effects model; CG, control group; IG, intervention group.

significant publication bias, as evidenced by the funnel plot asymmetry and Egger test ($P = 0.998$ and $P = 0.054$, in MWG and GDM, respectively).

Finally, the summary estimates were consistent when analyses were repeated using a fixed-effects model. When each study was deleted from the model once, the results remained significant across all of the analyses.

Regarding subgroup analyses by the duration of intervention, a lower rate of GDM in IG was observed when exercise was conducted throughout pregnancy (RR = 0.64; 95% CI 0.36–0.98; $P = 0.038$; $I^2 = 0\%$); however, similar decreases in MWG were also observed when exercise was conducted throughout pregnancy (WMD = −1.16 kg; 95% CI −1.47 to −0.85; $P < 0.001$; $I^2 = 0\%$) and from the second trimester (WMD = −1.03 kg; 95% CI −1.48 to −0.59; $P < 0.001$; $I^2 = 46\%$). Regarding the type of exercise, decreases in maternal weight were observed for both types of aerobic exercise (WMD = −0.81 kg; 95% CI −1.42 to −0.20; $P < 0.001$; $I^2 = 0\%$), and combined (WMD = −1.18 kg; 95% CI −1.46 to −0.90; $P < 0.001$; $I^2 = 54\%$). Moreover, there was a lower risk of GDM with combined exercises (RR = 0.69; 95% CI 0.48–0.99; $P = 0.043$; $I^2 = 0\%$). Finally, other subgroup analyses were conducted (studies of Barakat et al.[36,38–41,43,46] versus others;[37,42,44,45,47,48] studies conducted in Europe[36–41,43,44,46] versus others;[42,45,47,48] very light to light PA intensity studies[36,38,41,43,46] versus moderate PA intensity studies;[37,39,40,42,44,45,47,48] studies with low adherence[45,47] versus studies with high adherence[36–41,43,44,46,48]), and noteworthy differences between subgroups were not found (data not shown).

# Discussion

## Main findings

The influence of PA on pregnancy outcomes has been widely debated. To our knowledge, this meta-analysis is the first aimed to provide evidence regarding the benefits of structured physical exercise programmes during pregnancy for preventing GDM, as well as for avoiding excessive weight gain. In this sense, our results show that physical exercise during pregnancy reduces the risk of GDM and also slightly reduces the MWG. Furthermore, the benefits of the programmes for decreasing the risk of GDM and excessive MWG are greater when begun in early pregnancy, and include a combination of aerobic, toning, resistance, strength, and flexibility exercises.

## Strengths and limitations

The main strength of our study over the two previous meta-analyses is that it includes well-designed RCTs with relatively large samples of pregnant women. In addition, the pre-specified subgroup analyses by the duration of exercise interventions (throughout pregnancy or from the second trimester to the end of pregnancy) and type of exercise (aerobic or combined aerobic, strength, and flexibility) improved the clinical significance of the findings. Also, other subgroup analyses were conducted (the studies by Barakat et al. versus other studies; studies conducted in Europe versus other studies; very light to light PA intensity studies versus moderate PA studies; and studies with low adherence versus studies with high adherence), and the results remained significant in all analyses.

There are several limitations of the present study. First, data extraction was non-blinded, which is a potential source of bias. The general quality of the studies was medium,[36–44,47,48] and low,[45,46] reflecting the increased risk of bias in some studies. Second, none of the studies assessed the daily PA performed by the subjects outside of the programmes (recall or accelerometer). Third, pregnant women who participated in these studies were volunteers, so they may have maintained higher levels of compliance than the general population of pregnant women. Fourth, six studies did not offer data about the number of nulliparous and multiparous women in the IG and CG.[36,39,48] Fifth, the diagnostic criteria for GDM were different. Sixth, only two studies provided information about nutritional habits during pregnancy.[36–39] Finally, although several RCTs were carried out by the same authors – a circumstance that could influence the variability in estimating WMD and RR – these studies reported different characteristics, were carried out in different times and locations.[36,38–41,43,46]

### Interpretation

The effectiveness of physical exercise during pregnancy on preventing both GDM and excessive MWG remains controversial. In fact, a 2012 Cochrane review concluded that there was not enough evidence to support that PA decreases the risk of GDM or improves insulin sensitivity during pregnancy.[29] In this regard, an earlier review has also reported no effects of exercise on preventing pregnancy-impaired glucose tolerance.[57] As the authors of these Cochrane reviews recognise, the lack of evidence could be attributed to weaknesses in the design or sample size of the published studies.[29,57] In this sense our meta-analysis includes some recently published well-designed RCTs with a larger number of participants in which physical activity intervention programmes that were reproducible and standardised.[36–40] Furthermore, Stafne et al.[58] found no evidence that a PA programme during the second half of pregnancy decreased the risk of GDM or improved insulin resistance. Conversely, a meta-analysis reported that higher levels of PA before pregnancy or in early pregnancy are associated with a lower risk of GDM,[59] and some observational studies have described that PA in pregnancy decreases insulin resistance and might help to decrease the incidence of GDM.[60,61]

Our meta-analysis provides evidence that physical exercise during pregnancy is associated with a 31% reduction in risk of gestational diabetes, and also reveals that when the exercise programme is conducted throughout pregnancy, the reduction in risk of gestational diabetes is even greater (36%). These results could be linked with the fact that physical exercise in these programmes was initiated before the normal increase in insulin resistance that occurs with advancing gestation,[62] so that chronic changes in the regulation of skeletal muscle glucose uptake had already been adopted when this increased resistance was reached; therefore, women might have better conditions to handle the metabolic stress of pregnancy.[63] Additionally, the reduction in risk of GDM is greater when the intervention includes combined exercises (31%). This finding could be because resistance training contributes to blood glucose uptake without altering the muscle capacity to respond to insulin, and aerobic exercise enhances its uptake via a greater insulin action.[64] Two meta-analyses of RCTs have suggested a significant effect of physical exercise on reducing excessive MWG in pregnancy.[27,65] Conversely, two other reviews did not report any significant effect of physical activity on maternal weight reduction.[29,57] In addition, it has also been suggested that the influence of exercise may be different depending on gestational age.[66] In this sense, our meta-analysis provides evidence that exercise during pregnancy is successful in reducing excessive MWG (WMD = −1.14 kg), and that the effectiveness is more apparent throughout pregnancy (WMD = −1.16 kg). But the greatest reduction was produced with combined exercise programmes (WMD = −1.18 kg).

## Conclusion

In summary, our analyses allow us to conclude that regular moderate-intensity exercise training during pregnancy is associated with both a lower incidence of GDM and less MWG during this period. Also, our data support that practicing physical exercise from early pregnancy is associated with a higher reduction of GDM. Consequently, our study has important clinical and public health implications, because it provides support for the recommendation to advise mothers to engage in PA programmes as an effective and safe strategy to experience healthier pregnancies because they will have less risk of GDM and they will avoid excessive weight gain and, as a consequence, improve the health status of their offspring.

### Disclosure of interests

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

### Contribution to authorship

GS and RP conceived the idea for the review, developed the search strategy, selected and retrieved relevant papers, made the final decisions regarding the inclusion/exclusion of all papers, designed the data extraction tool, carried out data extraction, checking of data, and quality assessments, and wrote the article. CA selected and retrieved relevant papers and carried out extraction/checking of data and quality assessments. MS reviewed and edited the article. VM and AG conceived the idea for the review, made the final decisions regarding the inclusion/exclusion of all papers, and reviewed and edited the article.

### Details of ethics approval

Ethical approval was not required.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Characteristics of the studies included in the meta-analysis. ■

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