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Review

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Physical exercise in pregnancy: benefits, risks and prescription

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Abstract

Objectives: The aim of this article is to provide a comprehensive literature review, gathering the strongest evidence about the risks and benefits and the prescription of physical exercise during pregnancy.
Content: Regular physical exercise during pregnancy is associated with numerous benefits. In general women are not adequately advised on this matter. Along with their concerns regarding the potential associated risks, it contributes to the abandonment or refusal to start exercising during pregnancy. A systematic review was conducted in *MEDLINE* including articles considered to have the highest level of scientific evidence. Fifty-seven articles, including 32 meta-analysis, 9 systematic reviews and 16 randomized controlled trials were included in the final literature review.
Summary: Exercise can help preventing relevant pregnancy related disorders, such as gestational diabetes, excessive gestational weight gain, hypertensive disorders, urinary incontinence, fetal macrosomia, lumbopelvic pain, anxiety and prenatal depression. Exercise is not related with an increased risk of maternal or perinatal adverse outcomes. Compliance with current guidelines is sufficient to achieve the main benefits, and exercise type and intensity should be based on woman's previous fitness level.
Outlook: Exercise in pregnancy is safe for both mother and fetus, contributing to prevent pregnancy related disorders. Exercise type and intensity should be adapted to woman's previous fitness level, medical history and characteristics of the ongoing pregnancy.

Keywords: outcome; physical activity; physical exercise; pregnancy.

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Introduction

Physical exercise, defined as a planned, structured physical activity performed to improve one or more components of physical fitness is a key element of a healthy lifestyle, contributing to the prevention and treatment of several diseases [1]. Pregnancy is a great time to start exercising, since it is associated with an increased motivation to maintain or start a healthy lifestyle, and an increased frequency of medical appointments, which facilitates physical exercise monitoring [2].

Regular physical exercise during pregnancy is associated with numerous benefits, such as decreased incidence of gestational diabetes, hypertensive disorders, operative deliveries, excess weight gain and weight retention in the postpartum period, postpartum depression, among others [3–7].

The fact that pregnant women are not properly advised on this matter together with concerns regarding the potential risks associated with exercise contribute to the abandonment or refusal to start exercising during this period [8, 9].

Pregnancy is associated with physiological adaptions. The energy cost increases proportionally to maternal weight gain, affecting weight bearing activities (e.g. walking) but not weight supported (e.g. stationary cycling) [10]. A maternal-fetal temperature gradient is established, to promote fetal heat loss, raising concerns about the possibility of reversing this mechanism under strenuous exercise, endangering fetal well-being [11]. Resting heart rate is increased, but maximal heart rate is decreased, leading to a reduced heart rate reserve, reducing woman's capacity to adapt to exercise-related stress [12]. Measuring maternal heart rate is therefore a less precise way of estimating exercise intensity and to guide exercise prescription - it overestimates the intensity of lower work rates, underestimating the intensity of higher work rates [12]. After the 20th week, the cardiac output is affected by positional changes (specially on supine position), as the gravid uterus may obstruct the aorta and the inferior vena cava, potentially influencing the type of exercise women can do [13].

The aim of this review is to gather the strongest scientific evidence to date about physical exercise's risks, benefits and prescription, according to woman's individual characteristics, medical history and characteristics of the ongoing pregnancy.

Materials and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocols (PRISMA-P) recommendations were used to guide this review [14].

This review aimed to include studies focusing on the practice of physical exercise during the gestational period and their respective maternal and fetal outcomes. Meta-analyses, Systematic Reviews, Randomized Controlled Trials (RCTs) and Prospective Studies were considered. Case reports, case series and narrative reviews were excluded.

A search on MEDLINE was conducted using the following queries: "pregnancy AND (physical exercise OR physical activity) AND outcome". All studies identified were screened for these inclusion criteria: (1) published in English or Portuguese, (2) between January 1990 and December 2020, (3) with full-text available, (4) maternal and fetal outcomes related to physical exercise during pregnancy. Articles found by cross-referencing that met the inclusion criteria were also included. Studies focusing on long-term post-gestational follow-up or pre-gestational period were excluded.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework was used to assess the quality of evidence across studies for each considered outcome [15]. Evidence from randomized controlled trials was first rated as "high" quality of evidence, and was graded down if a risk of bias, indirectness, inconsistency, imprecision or risk of publication bias was detected. Evidence from all non-randomized interventions and observational studies was first rated as "low" quality of evidence. If there was no cause to downgrade, the studies could be upgraded if there was (1) a large magnitude of effect, (2) evidence of dose–response effect, (3) all residual confounding factors would decrease the magnitude of effect.

Results

The search strategy resulted in 266 articles. Two additional articles were added by cross-referencing. Two duplicates were identified, remaining 266 articles. After examining title and abstract to determine those that met the inclusion criteria, 136 articles were excluded. The remaining 134 articles were accessed and analyzed for eligibility, and 77 articles were further excluded, for the following reasons: long-term post-gestational follow-up (n = 9), focus on pre-gestational period (n = 5), and no relevant outcomes recorded (n = 63). Fifty-seven articles were finally included in this review. A PRISMA diagram of the search results is shown in Figure 1.

The review included 32 meta-analysis, nine systematic reviews and 16 RCTs. The main characteristics of each study are described in Supplementary Material Tables 1–12.

Benefits associated with exercise during pregnancy

A summary of the evidence concerning the evaluated outcomes is presented in Table 1.

Gestational weight gain, excessive gestational weight gain and postpartum weight retention

The Institute of Medicine has established recommendations for weight gain during pregnancy, according to women's weight prior to their pregnancy [63]. An excessive gestational weight gain (EGWG) is considered if these recommendations are exceeded. It is estimated that almost 50% of pregnant women exceed their goals, being previous overweight and obesity important risk factors [64]. Moreover, EGWG is associated with an increased risk of gestational diabetes, cesarean section, birth canal trauma, large-for-gestational-age infants and postpartum weight retention, [64].

Seven meta-analysis [16, 17, 20, 21, 26–28] and four systematic reviews [23, 35, 36, 38], analyzing various types of exercise interventions in women without contraindications to exercise, found a significantly reduced GWG in the exercise groups. Total GWG mean deviations (MD) between groups ranged from −1.61 kg (95% CI = −1.99 to −1.22, $p<0.01$) [28] to −0.61 kg (95% CI = −1.17 to −0.06, $p = 0.03$) [26]. Additionally, Wang et al. [16] found, in their subgroup analysis, that this effect was greater with exercise interventions conducted at least 3 times a week, 30–45 min per session and throughout the entire pregnancy. Chan et al. [35] added that a greater effect on the improvement of

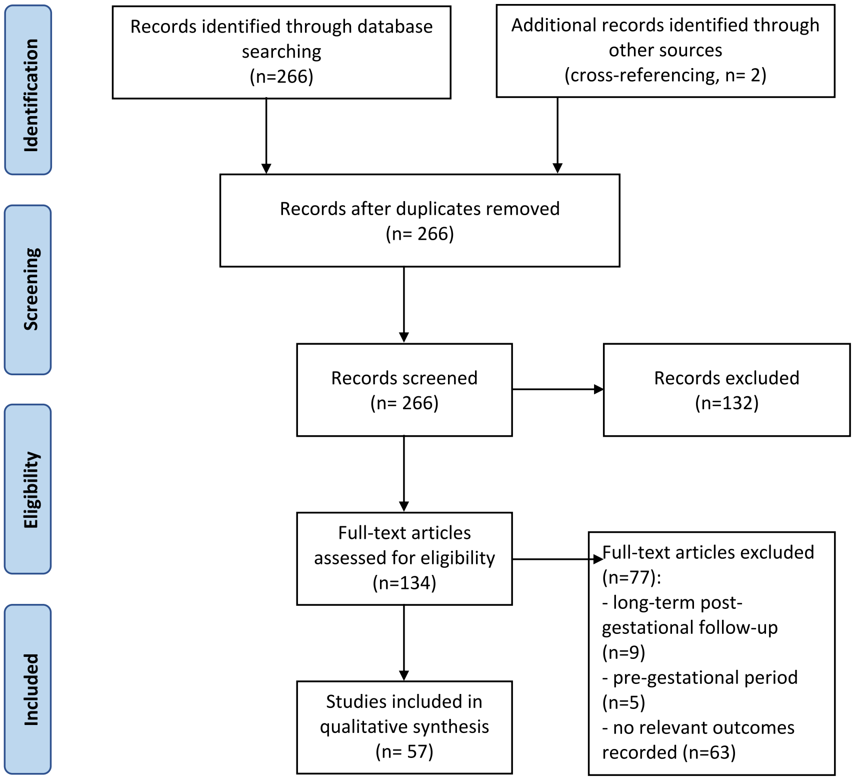

Figure 1: Flow-chart of the literature research (PRISMA-P).

pregnant women's level of physical activity was seen among supervised exercise classes.

This relationship was also sought among overweight and obese pregnant women [17, 25, 65], and all studies confirmed this hypothesis when exercise interventions were structured, either supervised or home-based (MD −1.14 kg, 95% CI = −1.67 to −0.62, $p<0.0001$ [17] and −0.91 kg, 95% CI = −1.76 to −0.06, $p = 0.035$ [25]). Exercise interventions that included only counseling and encouragement were not effective [65].

An identified limitation was the fact that all the included studies measured total body weight difference, instead of body fat. This is particularly important in exercise interventions that included muscle training/resistance exercises, since women may have increased their global muscle mass independently of the body weight variation.

EGWG was evaluated in four meta-analysis [20, 21, 23, 36], and three RCTs [30, 31, 33], with the majority [20, 23, 31, 33, 36] (n = 5) finding a significant better weight gain control in the exercise groups. The decrease in the odds of having EGWG with exercise varied between 18% (odds ratio (OR) = 0.82, 95% CI = 0.68 to 0.99 [21]) and 61% (OR = 0.39, 95% CI = 0.17 to 0.89 [31]). Nobles et al. [30], who did not find a significant correlation, prescribed an unsupervised exercise intervention, without indicating a specific type of exercise to be performed, which may have hampered the efficacy of the intervention. However, Da Silva et al. [33] included an individually supervised exercise intervention, and also did not find significant results.

On the other hand, other systematic reviews and meta-analysis did not find significant effects of exercise interventions on GWG [18, 19, 37], along with three RCTs [29, 32, 33]. These studies analyzed GWG and not EGWG. In fact, Bacchi et al. [31] found no significant difference in mean GWG, but found significantly reduced odds of EGWG in the intervention group (OR = 0.39, 95% CI = 0.17 to 0.89, $p = 0.02$). Also, most of the studies' populations included mainly previously healthy women – so, if only a small proportion of women gained more weight than expected, significant differences between groups could have been overlooked. A correlation between type of exercise, program duration and mean GWG results could not be drawn, since a great variety of exercise interventions were included in each review.

Considering postpartum weight retention (PPWR), a meta-analysis [20] related exercise during pregnancy with reduced PPWR (MD = −0.92 kg, 95% CI = −1.84 to 0.00, $p = 0.05$), together with two RCTs [29, 34]. All the studies included aerobic exercises and were performed for at least 20 weeks, finishing at the end of the third trimester.

Table 1: Benefits of exercise, summary of evidence.

Benefits of exercise	Studies	Summary of evidence	Level of evidence, grade
GWG, EGWG, PPWR	**Meta-analysis:** Wang [16]; Du [17]; Beetham [18]; Shieh [19]; Ruchat [20]; Da Silva [21]; Sanabria-Martínez [22]; Muktabhant [23]; Lamina [24]; Choi [25]; Streuling [26]; Wiebe [27]; Ming [28] **RCTs:** Brik [29]; Nobles [30]; Bacchi [31]; Ramírez-Vélez [32]; Da Silva [33]; Kong [34] **Systematic Reviews:** Chan [35]; Nascimento [36]; Schlüssel [37]; Perales [38]	Exercise has a beneficial impact in all weight-related variables.	**GWG:** Low to high **EGWG:** Very low to high **PPWR:** Low to moderate
GDM, GC	**Meta-analysis:** Du [17]; Yu [39]; Ming [28]; Mijatovic-Vukas [40]; Davenport [6]; Davenport [41]; Da Silva [21]; Harrison [42]; Sanabria-Martínez [22]; Russo [43]; Di Mascio [44]; Han [45] **RCTs:** Sklempe [46]; Da Silva [33]; Cordero [47] **Systematic Reviews:** Perales [38]; Schlüssel [37]; Nascimento [36]	Exercise reduces GDM risk and improves post-prandial glucose control.	**GDM:** Very low to high **GC:** Low to moderate
Macrosomia, LGA	**Meta-analysis:** Du [17]; Davenport [7]; Da Silva [21]; Pastorino [48]; Bennett [49]; Wiebe [27]; Muktabhant [23]; Han [45] **Systematic Reviews:** Perales [38];	Exercise is related to a lower risk of macrosomia and LGA infants.	**Macrosomia:** Very low to high **LGA:** Very low to high
CD, ID, VD, LD	**Meta-analysis:** Du [17]; Poyatos-León [50]; Davenport [5]; Di Mascio [44]; Wiebe [27]; Ming [28]; Muktabhant [23]; Han [45]**RCTs:** Ramírez-Vélez [32]; Sanda [51]; Barakat [52]; Agur [53] **Systematic Reviews:** Perales [38]	Exercise does not influence cesarean delivery, labor duration or instrumental delivery rates. Exercise improves the chance of vaginal delivery.	**CD:** Moderate to high **ID:** Moderate to high **VD:** Moderate to high **LD:** Low to high
GH, PE, BP	**Meta-analysis:** Du [17]; Davenport [6]; Meher [54]; Aune [55]; Di Mascio [44] **RCTs:** Haakstad [56]; Da Silva [33] **Systematic Reviews:** Schlüssel [37]	Exercise lowers GH and PE risk and maternal resting systolic BP.	**GH:** Very low to high **PE:** Very low to moderate **BP:** Low
LP	**Systematic Reviews:** Nascimento [36]; Chan [35]	Exercise improves LP intensity control.	Very low to low
UI	**Meta-analysis:** Davenport [57] **RCTs:** Reilly [58] **Systematic Reviews:** Perales [38]; Nascimento [36]	Exercise lowers UI prevalence.	Very low to moderate
PPD, PD, PA	**Meta-analysis:** Davenport [3] **RCTs:** Coll [59]; Haakstad [60]; Mohammadi [61] **Systematic Reviews:** Chan [35]; Nascimento [36]; Shivakumar [62]	Exercise improves PA and PD prevalence. Exercise does not influence PPD.	**PPD:** Low to high **PD:** Very low to moderate **PA:** Low to moderate

GWG, gestational weight gain; EGWG, excessive gestational weight gain; PPWR, postpartum weight retention; GDM, gestational diabetes mellitus; GC, glucose control; LGA, large for gestational age; CD, cesarean delivery; ID, instrumental delivery; VD, vaginal delivery; LD, labor duration; GH, gestational hypertension; PE, preeclampsia; BP, blood pressure; LP, lumbopelvic pain; UI, urinary incontinence; PPD, postpartum depression; PD, perinatal depression; PA, perinatal anxiety.

Gestational diabetes mellitus

Gestational diabetes mellitus (GDM) is considered the most common metabolic disorder during pregnancy [66]. Indeed, GDM is associated with many adverse outcomes, such as higher risk of preeclampsia, macrosomia and birth trauma, neonatal hypoglycemia, diabetes later in life, among others [66]. A known modifiable risk factor for developing GDM is obesity [67], along with a sedentary lifestyle [66], all possibly influenced by physical exercise.

Several meta-analysis [6, 17, 22, 28, 39, 40, 43, 44], two systematic reviews [21, 37] and one RCT [47] evidenced that exercise during pregnancy had a beneficial effect on GDM, reporting a risk reduction between 28% (RR = 0.72, 95% CI = 0.58 to 0.91) [43] and 59% (RR = 0.41, 95% CI = 0.24 to 0.68) [44]. This benefit was found across different populations - obese and overweight women (RR = 0.71, 95% CI = 0.57 to 0.89) [17] and previously healthy women [6, 21, 22, 28, 37, 39, 40, 43, 44, 47].

Davenport et al. [6] found a dose-dependent correlation between exercise and GDM prevention: to achieve a 25% reduction, it was necessary to perform 140 min per week of moderate-intensity exercise. Cordero et al. [47] reported that engaging in physical exercise 150–180min per week during pregnancy reduced the odds of developing GDM by 90% (OR = 0.103, 95% CI = 0.013 to 0.803, p = 0.009), comparing to standard care.

Furthermore, physical exercise can also play a role in disease control [36, 41, 42, 46]. A RCT [46] with pregnant women previously diagnosed with GDM showed that structured aerobic and resistance exercise lowered postprandial glucose at the end of pregnancy (4.66 ± 0.46 mmol/L exercise group (EG) vs 5.30 ± 0.47 mmol/L control group (CG), p<0.001), but no difference was found regarding fasting glucose. Harrison et al. [42] found that exercise interventions significantly lowered both postprandial levels (MD = −0.33 mmol/L, 95% CI = −0.49 to −0.17) and fasting blood glucose levels (MD = −0.31 mmol/L, 95% CI = −0.56 to −0.05), among women previously diagnosed with GDM. Accordingly, a meta-analysis [41] described that both acute and chronic exercise were able to reduce maternal glucose values, and the sensitivity analysis showed that this reduction was driven mainly by women previously diagnosed with diabetes (MD = −2.76 mmol/L, 95% CI = −3.18 to −2.34, p<0.00001). On the other hand, the insulin requirement was not significantly different between groups.

On the contrary, a systematic review from Perales et al. [38] found only a weak level of evidence between exercise interventions and a reduced incidence of GDM. Correspondingly, no significant difference between groups was found by Han et al. [45] (OR = 1.10, 95% CI = 0.66 to 1.84), Nascimento et al. [36] or by Da Silva et al. [33] (OR = 1.0, 95% CI = 0.6 to 1.9).

Regarding glucose control studies, a recognized limitation was the inability to detect the interference of insulin or other glucose sensitizing agents on the presented results. As for the studies focused on GDM risk, different applied diagnostic criteria for GDM is considered a constraint.

The great majority of the presented studies analyzed only previously healthy pregnant women. However, other populations such as overweight or obese women have a greater risk of developing GDM. Thus, it is possible that a diminished ability to detect significant differences between groups may have resulted from a selection bias.

Excessive fetal growth

Excessive fetal growth includes definitions such as macrosomia – a birth weight superior to 4000–4500 g, and large-for-gestational-age (LGA) – a birth weight equal or superior to the 90th percentile for a given gestational age [68]. Approximately 7.8% of all newborns in the United States are born with 4000 g or more [69]. An increased birth weight is associated with an increased likelihood of operative deliveries, shoulder dystocia, birth trauma and postpartum hemorrhage [68].

The exercise potential positive impact on excessive fetal growth was confirmed by five meta-analysis [7, 21, 27, 48, 49] and a systematic review [38]. Risk reduction regarding macrosomia varied between 4% (RR = 0.96, 95% CI = 0.94 to 0.98) [48] and 61% (RR = 0.41, 95% CI = 0.25 to 0.68) [49]. As for LGA infants, it was found a risk reduction between 19% (RR = 0.81, 95% CI = 0.69 to 0.96) [49] and 49% (RR = 0.51, 95% CI = 0.30 to 0.87) [21]. All studies included women without contraindications to exercise, and no specific subgroup analysis was made. Pastorino et al. [48] found a significant correlation only when exercise was performed during late pregnancy, rather than during early pregnancy, possibly indicating a greater contribution of exercise interventions for this outcome when carried out during the late second and third trimesters. This is in line with the physiological fetal weight gain in the second half of pregnancy.

Two meta-analysis [17, 45] and two systematic reviews [23, 38] found no significant difference in the odds of delivering a macrosomic infant between exercise and standard antenatal care groups. This was verified across different study populations, including overweight/obese women [17] and previously healthy women [23, 38, 45]. Bennett et al. [49] did not find significant differences between groups regarding LGA risk (RR = 1.13, 95% CI = 0.54 to 2.36), as opposed to macrosomia risk (RR = 0.41, 95% CI = 0.25 to 0.68). A correlation between type of exercise, program duration and macrosomia/LGA results could not be drawn, since a great variety of exercise interventions were included in each review.

Delivery mode and labor duration

Regarding cesarean delivery (CD), three meta-analysis [27, 44, 50] and one RCT [51] showed a significant reduction in the group who exercised during pregnancy. Sanda et al. [51] analyzed an exercise intervention of moderate-to-vigorous intensity, and found 67% reduced odds of CD (OR = 0.33, 95% CI = 0.11 to 0.97, p = 0.044). In Poyatos-León et al. [50] this effect was significant when exercise was performed during the second and third trimesters [50] (RR = 0.78, p = 0.105 vs RR = 0.66, p = 0.028) regardless of the type of exercise. This finding is in line with Pastorino et al. [48], who found a decreased risk of macrosomia when exercise was performed during the third trimester. However, four meta-analysis [5, 17, 28, 45], two systematic reviews [23, 38] and one RCT [32] did not find significant differences in CD rates. This was verified with different populations, namely obese and overweight women [17], previously healthy women [5, 23, 38, 45] and previously inactive women [32]. Types of exercise, frequency and session's duration were largely diverse across interventions. Thus, a correlation between different samples, interventions and CD outcomes could not be drawn.

Two meta-analysis [44, 50] and one RCT [51] evaluated the impact of exercise in vaginal delivery rates. All found an increase in vaginal births in the exercise groups (RR = 1.09, 95% CI = 1.04 to 1.15 [44], RR = 1.12, 95% CI = 1.01 to 1.24 [50] and OR = 2.69, 95% CI = 1.02 to 7.09 [51]).

Instrumental delivery (ID) had a lower prevalence in the exercise group of one meta-analysis [5]. A reduction of 24% on the odds of ID (OR = 0.76, 95% CI = 0.63 to 0.92, p = 0.004) was found among previously healthy pregnant women [5]. On the other hand, two RCTs [51, 53] and two meta-analysis [44, 50] did not find any significant differences in ID. In terms of delivery duration, evidence is not consensual. Sanda et al. [51], Perales et al. [38] and A-gur et al. [53] found no differences in labor duration; on the other hand, Barakat et al. [52] reported that the intervention group had a shorter first stage (409.15 ± 185.74 min (EG) vs 462.83 ± 208.37 min (CG), p = 0.01) and a shorter total duration of labor (450.74 ± 188.64min (EG) vs 507.19 ± 2.16.06min (CG), p = 0.01). Included populations were diverse (i.e. previously inactive women [50], women with antenatal bladder neck mobility [53], normal-weight women and previously healthy women [45, 51, 70]), however, none included overweight or obese women, conditions related to a slower labor progression and an increased need for ID [71], possibly underestimating the effect of exercise on these outcomes.

Hypertensive disorders of pregnancy

Hypertensive disorders of pregnancy include Gestational Hypertension (GH) and Preeclampsia (PE).[70] These disorders are relatively common during pregnancy - PE complicates 2–8% of pregnancies worldwide. Furthermore, hypertensive disorders are related to 16% of maternal deaths, as well as other adverse outcomes, such as inadequate fetal growth, preterm delivery and perinatal death [72].

A systematic review [37] and three meta-analysis [6, 44, 55] showed a significant risk reduction of GH and PE among previously healthy women who exercised during pregnancy. Davenport et al. [6] found a 39% reduced risk of developing GH (RR = 0.61, 95% CI = 0.43 to 0.85, p = 0.003) and 41% reduction of PE (RR = 0.59, 95% CI = 0.37 to 0.90, p = 0.03). Furthermore, a meta-regression analysis revealed that these benefits were achieved when exercise interventions were performed ≥3 days per week, at least 25 min per session, and with a higher compliance, which was found in supervised programs [6]. Additionally, a RCT investigated the effect of exercise during pregnancy on blood pressure [56], among previously inactive women, showing a significantly reduced systolic blood pressure (MD = 7.5 mmHg, p = 0.013).

Contrarily, a meta-analysis [17] and two systematic reviews [33, 54] found no significant differences on PE and GH risk between groups. Comparing the three studies, two considered a population with an increased risk of developing hypertensive disorders (i.e. women at risk of developing PE [54] and overweight/obese women [17]), which can sustain that exercise may be only effective in preventing GH and PE among women without a previously increased risk for these conditions. However, these findings need to be interpreted with caution, since in Meher et al. [54] the sample size was considered too small to draw reliable conclusions.

Lumbopelvic pain

Lumbopelvic pain (LP) is a prevalent condition among pregnant women, with more than 50% of them experiencing it [73].

Two systematic reviews [35, 36] found a beneficial effect of exercise during pregnancy on lumbopelvic pain. Chan et al. [35] reported a significant effect on pain intensity of low back and pelvic pain, but findings regarding pain prevalence were inconsistent. Nascimento et al. [36] also related exercise interventions with decreased lumbopelvic pain intensity, but not with lumbopelvic pain prevalence. Exercise interventions varied on type, frequency, intensity and duration, hindering a possible association of specific types of exercise interventions with these outcomes.

Urinary incontinence

Urinary incontinence (UI) is a prevalent pathology in the prenatal and postpartum period, affecting 18–75% of women in late gestation [74] and one-third of women after childbirth [75]. Literature is not consensual, but high-impact activities, due to intra-abdominal pressure increase, are described as potential risk factors for pelvic floor weakening [76]. Nevertheless, aerobic exercise during pregnancy has been correlated with the prevention of EGWG and LGA infants, known important risk factors for prenatal and postnatal UI.

UI benefited from exercise during pregnancy [36, 38, 57, 58]. Considering its prevention, in Davenport et al. [57], exercise reduced the odds of UI by 52% during pregnancy (OR = 0.48, 95% CI = 0.32 to 0.73, p = 0.0005) and by 39% in the postpartum period (OR = 0.61, 95% CI = 0.48 to 0.77, p<0.0001). However, exercise did not show a beneficial effect regarding UI treatment [57].

Most exercise interventions included pelvic floor muscle training (PFMT) [36, 57, 58]. Hence, PFMT appears to play an important role on UI prevention in pregnancy and postpartum period. On the other hand, a systematic review [38] described a strong level of evidence for the combination of aerobic plus resistance exercise programs, possibly indicating that exercise in general can have a beneficial effect on UI prevention. Studies' samples included previously healthy women, and one RCT [58] focused on pregnant women with pelvic floor weakness (women with antenatal bladder neck mobility). It would be also important to investigate the effect of exercise interventions on overweight and obese pregnant women. Indeed, since overweight is a modifiable risk factor for UI, perhaps exercise interventions could be effective in reducing its prevalence in this population.

Psychological outcomes: postpartum depression, perinatal depression and anxiety

Depression during pregnancy and in the postpartum period affects approximately 13% of women, and anxiety up to 39% [77, 78]. Pregnant women tend to report more negative feelings than non-pregnant individuals [79], evidencing pregnancy as a potential vulnerable period for women's psychological well-being.

Exercise during pregnancy was related to a significant beneficial effect on prenatal depression in a meta-analysis [3] and three systematic reviews [35, 36, 62]. In fact, Davenport et al. [3] reported a 67% reduction on the odds of prenatal depression (OR = 0.33, 95% CI = 0.21 to 0.53). Likewise, several studies [3, 35, 36, 62, 80] revealed that symptom severity was reduced with exercise. Haakstad et al. [60] found a significant difference only when results were analyzed per-protocol, pointing out that exercise compliance is an important aspect to achieve any benefit on psychological outcomes.

Concerning postpartum depression, a systematic review [36] found positive effects on depressive symptoms severity, but no strong evidence was found considering its prevalence. Still, two RCTs [59, 61] and one meta-analysis [3] found no significant differences on symptom severity [3, 59, 61] or prevalence [3, 59]. Exercise programs were only performed during the prenatal period, which may indicate that, for exercise to have a beneficial effect on postpartum depression, it should also be performed in the postpartum period.

Regarding anxiety symptoms, a significant reduction was shown in two systematic reviews [35, 62] and one RCT [60]. Haakstad et al. [60] added that feelings of sadness, hopelessness and anxiety had a significant improvement with exercise when women had complete exercise adherence (p = 0.01). On the other hand, Davenport et al. [3] found no evidence supporting the benefits of exercising on anxiety prevalence or symptom severity.

Risks associated with exercise during pregnancy

A summary of the evidence concerning the evaluated outcomes is presented in Table 2.

Preterm birth

Preterm birth (PTB) is a leading cause of perinatal morbidity and mortality, occurring in approximately 10% of all live births worldwide, and in about 6% of all live births in Europe [85]. Physical activity was thought to be related to an increased risk of PTB, as it could reduce placental circulation, and increase the release of catecholamines, which stimulate myometrial activity [86]. On the contrary, exercise may have a protective effect by

Table 2: Risks of exercise, summary of evidence.

Benefits of exercise	Studies	Summary of evidence	Level of evidence, grade
PTB	**Meta-analysis:** Du [17]; Yu [39]; Davenport [7]; Da Silva [21]; Di Mascio [44]; Beetham [18]; Muktabhant [23] **RCTs:** Ramírez-Vélez [32]; Da Silva [33] **Systematic Reviews:**; Nascimento [36]; Schlüssel [37]; Kahn [81]	Exercise does not increase PTB risk.	Very low to high
LBW, SGA	**Meta-analysis:** Beetham [18]; Davenport [7]; Bennett [49]; Di Mascio [44]; Du [17]; Da Siva [21]; Pastorino [48]; Wiebe [27]; Han [45] **RCTs:** Ramírez-Vélez [32] **Systematic Reviews:** Nascimento [36]; Schlüssel [37]; Mottola [82]	Exercise does not change LBW or SGA risks.	**LBW:** Very low to moderate **SGA:** Very low to high
Miscarriage, PM	**Meta-analysis:** Davenport [4] **Systematic Reviews:** Schlüssel [37]; Mottola [82]	Exercise does not influence PM or miscarriage risk.	**Miscarriage:** Very low to low **PM:** Very low to low
MCT, CA	**Meta-analysis:** Davenport [83] **Systematic Reviews:** Ravanelli [84]	Exercise does not rise MCT to dangerous values, nor affects CA risk.	**MCT:** Very low to moderate **CA:** Very low

PTB, preterm birth; LBW, low birth weight; SGA, small for gestational age; PM, perinatal mortality; MCT, maternal core temperature; CA, congenital anomalies.

preventing pregnancy complications such as PE, obesity or GDM [87], which in turn are related to an increased PTB risk.

The risk of PTB among women who exercised during pregnancy was shown not only not to be increased [7, 17, 23, 32, 33, 36, 39, 44] but also to be reduced [18, 21, 37, 81]. Da Silva et al. [21] found a 20% reduction in the odds of PTB (OR = 0.80, 95% CI = 0.70 to 0.91). Considering specific types of populations, PTB was not related to exercise among overweight and obese women [17], previously inactive women [32] or normal weight women [44].

Most studies evaluated this outcome among previously healthy women, with only observational studies considering a broader and less restricted population. Consequently, the level of evidence regarding populations with a higher PTB risk is low to moderate.

Inadequate fetal growth

Small-for-gestational-age (SGA) - a birth weight below the 10th percentile for the GA, and low birth weight (LBW) – a birth weight inferior to 2500 g [88], are important predictors of neonatal morbidity and mortality [89]. Substrate use during exercise, together with increased insulin sensitivity and redirection of blood flow to the working muscles, can possibly hamper the energy demands required by the fetus [90].

Seven studies, including meta-analysis [7, 18, 44, 49], systematic reviews [36, 37] and a RCT [32], evaluated the effect of exercise on the risk of delivering a LBW infant. In all articles, the incidence of LBW was not increased, regardless of the population, intervention type or gestational age.

Similarly, all the systematic reviews [82] and meta-analysis [7, 17, 18, 21, 27, 45, 48, 49] that examined the impact of exercise during pregnancy on the risk of delivering SGA infants found no significant differences. In particular, Wiebe et al. [27] performed a subgroup analysis considering women with different comorbidities. In all groups, including overweight and obese women (OR = 0.90, 95% CI = 0.31 to 2.63, p = 0.85 [27]) and women with chronic hypertension or a history of PE (OR = 0.75, 95% CI = 0.28 to 1.98, p = 0.56 [27]), exercise did not significantly increase the odds of SGAs.

An inadequate GWG may impair fetal growth, increasing the risk of SGA and LBW infants [91]. In this sense, Bennett et al. [49] included in their review only studies designed to reduce GWG. Although a small reduction in infants' birthweight was noticed, exercise did not increase the risk for SGA (RR = 0.38, 95% CI = 0.01 to 15.0) or LBW (RR = 0.88, 95% CI = 0.60 to 1.29).

Thus, the available evidence supports the safety of exercise during pregnancy regarding the risk of SGA and LBW infants, including low, moderate and vigorous intensity exercise.

Miscarriage and perinatal mortality

Miscarriage is a common adverse outcome, occurring in approximately 15% of all pregnancies [92]. Perinatal mortality (PM) rates in the United States are around six per 1,000 live births [93]. Obesity, hypertension and diabetes are known risk factors [93], conditions that can possibly be attenuated by regular exercise.

The risk of miscarriage in women who exercise during pregnancy was assessed by a meta-analysis [4] and a systematic review [37], and neither found a significant correlation (OR = 0.69, 95% CI = 0.40 to 1.22, p = 0.20) [4], suggesting that exercise is not associated with this outcome. However, in Davenport et al. [4], most of the evaluated studies included pregnancies after the eighth week of gestation, when the risk of miscarriage is smaller. Furthermore, amount, intensity or frequency of exercise did not seem to alter the odds of PM or miscarriage [4]. The maximum session duration registered was 60 min, at moderate intensity and, therefore, it is not possible to infer about the safety of more intense and prolonged exercise exposures.

Similarly, regarding PM, none of the analyzed studies [4, 82] found significantly increased odds associated with exercise.

Maternal hyperthermia

One systematic review [84] and one meta-analysis [83] evaluated the exercise effect on maternal core temperature. Ravanelli et al. [84] included trials with exercise performed in different conditions: land-based and water immersion exercise. In neither studies women exceeded the threshold of 39 °C (highest Tcore = 38.9 °C [84]), nor changed core temperature more than 1.5 °C (MD = 0.26 °C, 95% CI = 0.12 to 0.40 [83]). Thus, a safe zone was defined regarding exercise intensity and conditions: land-based exercise for up to 35 min (80–90% of maximum heart rate, 25 °C and 45% relative humidity), and water immersion exercise for up to 45 min (≤33.4 °C), irrespective of pregnancy stage.

Davenport et al. [83] also assessed the odds of congenital anomalies and found no significant differences between groups (OR = 1.52, 95% CI = 0.54 to 4.32). However, exercise was performed in most studies after 12 weeks gestation (as is well established the risk of developing congenital abnormalities is greater in the first trimester).

It is currently not possible to infer conclusions concerning exercise performed at different intensities, durations and environmental conditions other than those included in these trials. Accordingly, the safety of more vigorous exercise or exercise performed at more critical conditions remains unknown.

Prescription

Exercise prescription is addressed by several international guidelines [94–98]. Regarding its frequency and duration, it is advised to accumulate 150–300 min of exercise per week, with sessions in most days of the week (≥3 days) of at least 20–30 min [94–96].

Women's previous fitness level should always be considered to decide about exercise intensity. Although previously active pregnant women can be advised to exercise at moderate intensity, previously sedentary women should start their exercise program with light intensity exercise, followed by a more gradual progression [94]. Considering exercise at higher intensities, research is limited, but there is no evidence so far suggesting that vigorous exercise is harmful (in women with a previously high fitness level) [96].

Regarding exercise type, there are certain activities that were found to be safe in pregnancy, such as walking, stationary cycling, aerobic dancing, resistance exercises (using light weights, body weight, elastic bands), stretching exercises, swimming and water aerobics [94, 96]. Moreover, a variety of aerobic and resistance exercises should be performed for greater benefits [95]. Specific PFMT exercises should also be performed to prevent UI [36, 38, 57, 58]. Contact activities and sports with increased risk of trauma should be avoided [97]. Exercise in the supine position should be addressed carefully, avoiding long periods of training, especially after the first trimester [95, 96].

Additionally, all women should also be informed of the warning signs that should motivate them to stop: vaginal bleeding, abdominal pain, regular uterine contractions, amniotic fluid leakage, persistent excessive shortness of breath, dizziness, headache, severe chest pain, muscle weakness, calf pain or swelling [94–96].

Contraindications

Before recommending an exercise program, a thorough clinical evaluation should be conducted, to secure that there are no medical or obstetrical reasons to either avoid exercise or modify exercise routines [94, 97]. According to the 2019 Canadian Guidelines, absolute contraindications to exercise are: ruptured membranes, premature labor, unexplained persistent vaginal bleeding, placenta praevia after 28 weeks' gestation, PE, incompetent cervix, intrauterine growth restriction, high-order multiple pregnancy (e.g. triplets), uncontrolled type I diabetes, uncontrolled hypertension, uncontrolled thyroid disease and other serious cardiovascular, respiratory or systemic disorders [95]. Additionally, relative contraindications are: recurrent pregnancy loss, history of spontaneous PTB, twin pregnancy after the 28th week, GH or mild/moderate cardiovascular or respiratory disease, symptomatic anemia, malnutrition, eating disorders, and other significant medical conditions [95].

Discussion

Benefits

Exercise proved to have a beneficial impact in all weight-related variables - GWG (low to high quality level of evidence, 13 studies [16, 17, 20–24, 26–28, 35, 36, 38]), EGWG (low to high quality evidence, five studies [20, 23, 31, 33, 36]) and PPWR (low to moderate quality of evidence, three studies [20, 29, 34]). Similarly, women who exercised during pregnancy had a lower risk of GDM (very low to high quality evidence, 11 studies [6, 17, 21, 22, 28, 37, 39, 40, 43, 44, 47]). In fact, risk factors for developing GDM are maternal overweight and obesity, which can be improved with exercise. A lower risk of macrosomia (very low to high quality evidence, four studies [7, 38, 48, 49]) and LGA (low to high quality evidence, three studies [21, 27, 48]) was also found, possibly also related to the reduction of GDM risk. Both GH (very low to high quality evidence, three studies [6, 37, 44]) and PE (very low to high quality evidence, four studies [6, 37, 44, 55]) risks were lower in women who exercised during pregnancy.

Exercise did not influence cesarean delivery rates (moderate to high quality evidence, seven studies [5, 17, 23, 28, 32, 38, 45]), labor duration (low to high quality evidence, three studies [38, 51, 53]) or instrumental delivery rates (moderate to high quality evidence, four studies [44, 50, 51, 53]). However, a higher probability of vaginal delivery (moderate to high quality evidence, three studies [44, 50, 51]) was found in exercise groups. Heterogeneity among these findings may be related to the fact that operative deliveries are influenced by multiple variables (including maternal obesity that was not considered in many studies). Additionally, exercise can prevent fetal macrosomia, GDM and improve maternal cardiorespiratory capacity and fitness level, decreasing maternal exhaustion, but it does not influence aspects such as fetal breech presentation, uterine abnormalities, and obstetric emergencies such as cord prolapse, maternal request for a cesarean delivery or obstetrical protocols to treat labor dystocia.

Exercise showed a beneficial effect in UI prevalence (very low to moderate quality evidence, four studies [36, 38, 57, 58]). The fact that exercise lowered LGA, macrosomia and EGWG risks, could also have influenced this outcome. Exercise type had an important role, since most studies that presented significant results included PFMT in their intervention. Also, lumbopelvic pain intensity had a better control in women who exercised during pregnancy (very low to low quality of evidence, two studies [35, 36]), although pain prevalence was similar between groups. Among the included studies, pain intensity measurement tools varied plenty, hampering the establishment of firm conclusions. Anxiety and prenatal depression were reduced with exercise (very low to moderate quality of evidence, five studies [3, 35, 36, 60, 62]), although postpartum depression was not influenced by prenatal exercise (low to high quality of evidence, three studies [3, 59, 61]).

Overall, the level of quality of evidence was rated down mainly because of risk of bias and heterogeneity of the presented results in Supplementary Material Tables 1–12.

Risks

Two studies [83, 84] evaluated maternal core temperature changes with exercise, and concluded that it doesn't rise to dangerous values (very low to moderate quality evidence). Evidence did not relate exercise to an increased risk of PTB (very low to high quality evidence, 12 studies [7, 17, 18, 21, 23, 32, 33, 36, 37, 39, 44, 81]). More research is needed regarding women with increased risk for PTB (e.g. history of a previous PTB). Low-birth-weight risk (very low to high quality evidence, seven studies [7, 18, 32, 36, 37, 44, 49]) and SGA risk (very low to high quality evidence, nine studies [7, 17, 18, 21, 27, 45, 48, 49, 82]) were uniformly unaltered with exercise interventions across studies.

Overall, the level of quality of evidence was rated down mainly because of risk of bias, heterogeneity of results and indirectness of evidence in Supplementary Material Tables 1–12.

Prescription

Analyzing dose-response relationships of physical exercise and pregnancy outcomes, in general, greater health benefits are seen with more intense and frequent exercise sessions [6, 16, 47, 80], and most benefits can be achieved with compliance to current international guidelines

[94–96]. Interventions that consisted only in counseling were not as effective, probably due to an increased adherence to supervised and structured exercises.

Concerning exercise safety limits, the available evidence states that low, moderate and vigorous intensity physical exercise is safe. In studies evaluating miscarriage, the maximum registered session duration was 60 min, at moderate intensity, with no negative outcomes reported. Exercise for up to 35 min at moderate intensity, 25 °C and 45% relative humidity, and water immersion (≤33.4 °C) exercise for up to 45 min, are safe, irrespective of pregnancy stage. It is currently not possible to infer conclusions concerning exercise performed at different intensities, durations and environmental conditions other than those included in these trials.

Strengths and limitations

There are some limitations to this review. First, it has only considered studies in English and Portuguese, possibly inducing a publication bias. Mainly RCTs and systematic reviews were included, which may have limited its comprehensiveness. Secondly, the fact that several different types of exercise interventions were considered for each outcome may have influenced the significance of the results. Another important issue is that some articles included interventions not limited to exercise (such as diet and lifestyle counseling) and this also may have induced some bias. Finally, there is lack of strong evidence for some of the included outcomes, such as LP, PM, miscarriage and congenital anomalies (very low to low quality evidence, n = 3 studies).

The strengths of the current review include the synthesis of evidence from 15 countries and five different continents, and the application of the GRADE methodology to evaluate the quality of evidence. Additionally, the chosen study design of the included articles provided a strong level of evidence, since only RCTs, systematic reviews and meta-analysis were included.

This review provides an important insight to exercise prescription in clinical practice. On one hand, it reassures and increases the confidence in the prescription of exercise during pregnancy - exercise generally improves maternal and fetal outcomes, in the absence of significant harmful effects. On the other hand, based on international guidelines and dose-response analysis, it was possible to find an appropriate duration, frequency and intensity to be advised as a goal for most pregnant women. In addition, these results can help to improve women's motivation to comply with exercise programs.

In future studies, more attention should be paid to the impact of specific types of exercises, timing of initiation and total duration on pregnancy outcomes. Moreover, program compliance should be monitored more rigorously, and factors that may influence participants' retention and compliance should be accessed. Also, it would be important to access the effects of a sedentary lifestyle during pregnancy. There is a necessity to better define an upper-safe-limit of exercise intensity, frequency and duration, to better advise previously active women, namely professional athletes and exercise enthusiasts.

Conclusions

Exercise can help to prevent important pregnancy related disorders, such as GDM, GH and PE. Conditions that have an impact in maternal quality of life, such as anxiety, prenatal depression, LP and UI are also prevented and may be improved with exercise. Exercise was not found to be related with an increased risk of miscarriage, CA, PTB, PM, or inadequate fetal growth (SGA and LBW). Considering exercise prescription, most of the described benefits can be achieved with compliance to the current international guidelines. Exercise intensity should be adapted to women's previous fitness level. Specific types of exercise and their particular effect in each maternal and perinatal outcome as well as exercise in women with specific comorbidities need more extensive research.

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